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Singapore as a sustainable city: Past, present and the future

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Abstract

This paper outlines Singapore's major sustainability challenges and its policy response in the areas of land use, transportation, waste management, water, and energy. We review the current and past Concept Plans from the perspective of sustainable land use and provide an overview of transportation policy in Singapore. We also examine Singapore's policies to manage increasing wastes and review the four tap water management plan. Finally, we look at various initiatives by the government for sustainable use of energy. While Singapore has been successful in many ways in transforming itself into one of the most prosperous and sustainable cities in the world, there remain challenges to make the city even cleaner and greener for a better future. We discuss the opportunities that new technologies will bring about and the role that Singapore can play in building a sustainable city.

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1. Introduction

Singapore has achieved impressive economic growth over the last half a century. The GDP per capita was only around US$4,088 in constant 2010 USD in 1965 when Singapore became independent, but it reached US$58,248 in 2018, according to the World Development Indicators. As Singapore became more prosperous, it has increasingly become a destination that foreigners wish to migrate to. Correspondingly, the total population of Singapore almost tripled from around 1.9 million to 5.6 million between 1965 and 2017. During this massive economic transformation from a developing country to a country that is among the richest, Singapore faced various issues that challenged its sustainability and liveability. In this paper, we provide an overview of the major sustainability challenges Singapore has experienced and policies that have been adopted to address them, particularly in the areas of land use, transportation, waste management, water, and energy. We argue that Singapore has been successful in addressing these challenges owing to the sound long-term vision and planning as well as flexibility in the implementation of policies to tackle them. At the end of this paper, we provide some discussion on policy options, challenges, and opportunities for making Singapore more sustainable and liveable.

2. Coping with land scarcity

Land scarcity has been recognised as one of the most serious challenges by the leaders of Singapore since its independence. Therefore, efficient land use with sound planning has been among the most important policy objectives to enable sustainable growth in Singapore. Efficient land use was promoted by the government, empowered by the Land Acquisition Act of 1966 and subsequent amendments, which enabled the government to compulsorily acquire land from private landowners at below-market prices for public and certain other purposes (Phang, 2018; chapter 2). The government indeed aggressively acquired land to build public housing and transportation infrastructure. By 1985, the government became the biggest land owner by far, owning 76.2 per cent of Singapore (Tortajada and Biswas, 2017).

Singapore's push towards efficient land use has been supported by sound planning with a long-term vision, starting from the first Concept Plan developed in 1971. The Concept Plan 1971 laid the foundation for the growth of a young nation by advocating the development of a ring structure of satellite towns through the creation of new housing towns, industrial estates, recreational spaces, and an efficient transport infrastructure around a centrally located water body. The Concept Plan 1971 is considered instrumental in shaping the structure of Singapore and guiding its development over time (Urban Redevelopment Authority 2019). Since then, the Concept Plan was revised three times in 1991, 2001, and 2011 to respond to the changing needs. These revisions involved the whole government and long-term land use decisions were taken collectively in government (Ng, 2017).

The Concept Plan 1991 shifted the focus from meeting basic needs towards achieving more balanced and inclusive growth. The plan proposed decentralisation of commercial and industrial centres and creation of technological corridors, made up of academic institutions and business parks, to facilitate exchange of ideas and innovation. With the vision to become a thriving world class city in the 21st century, the Concept Plan 2001 proposed various housing locations and types to meet different lifestyles, increase green spaces, and explored opportunities to transform Singapore into a global financial hub. The latest review of the Concept Plan in 2011-2013 led to the release of the Land Use Plan 2030 by the Ministry of National Development, which outlines the strategies to provide a high quality living environment for all Singaporeans. They include providing good affordable homes with a full range of amenities, integrating greenery into the environment, providing greater mobility with enhanced transport connectivity, sustaining a vibrant economy with good jobs, and ensuring room for growth and a good living environment in future. Thus the gradual evolution of the Concept Plan through the years demonstrates the fact that Singapore has been able to keep pace with the needs of time and offer its residents a wide range of resources.

With the land use planning outlined in the Concept Plan, Singapore has approached the land scarcity issue through three types of approaches. First, Singapore has directly increased land supply through reclamation. Second, Singapore has promoted vertical urbanism to address the competing needs for land in housing, transport, and

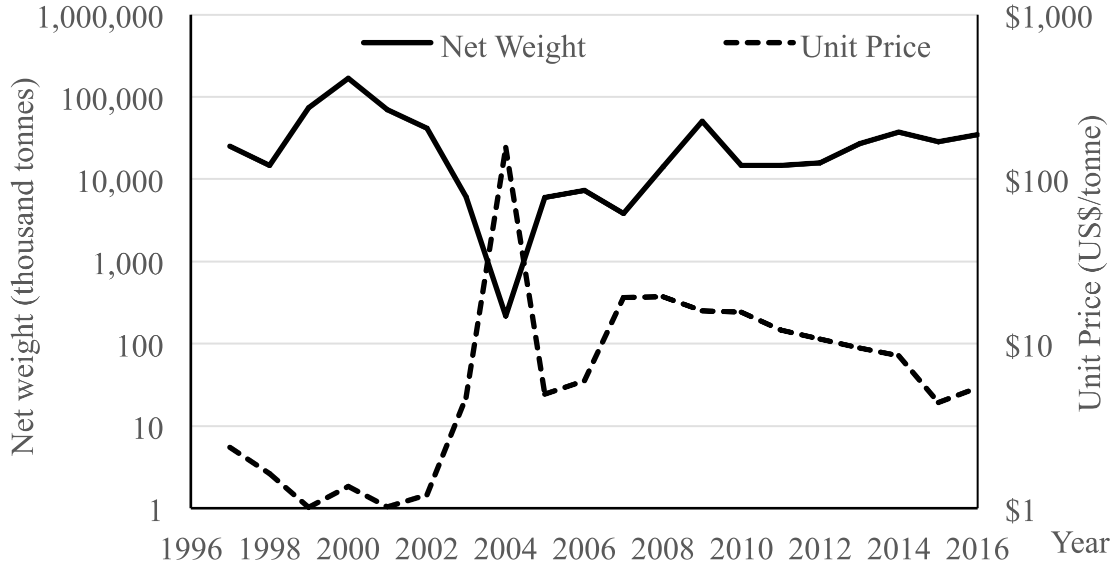

Figure 1: Net weight of sand import and average unit price in Singapore. Based on the United Nations COMTRADE statistics using HS 1996 classification and code 2505 ("natural sand except sand for mineral extraction").

commerce. Third, as the evolution of the Concept Plan above indicates, Singapore has increasingly shifted its focus of land policy towards sustainability and liveability by exploring opportunities to promote eco-friendly buildings and eco-smart lifestyles and to foster community spirit. Below, we study in detail each of these approaches.

2.1 Horizontal expansion through land reclamation

Land reclamation projects have been at the heart of Singapore's land policy to provide housing, commercial, and industrial space. Through land reclamation, Singapore has expanded its total land area from 580 square kilometres in 1965 to 721 square kilometres today. The government has a target to further expand the land area to 780 square kilometres by the end of 2030.

The first land reclamation in Singapore took place in present-day Boat Quay in 1822 when the British had colonised the island. Many of Singapore's notable buildings today, including those in the Marina Bay Financial Centre and the Changi Airport, have all been constructed on reclaimed land. Among the most prominent land reclamation projects is the East Coast Reclamation, popularly known as the Great Reclamation, which added a total area of 15.25 square kilometres along the southeastern part of the island, mostly for commercial and residential purposes. Jurong Island, which is home to many petrochemical firms today, was created by reclaiming the sea around seven islands and amalgamating them. Other notable reclamation projects include those in Telok Ayer, Kallang Basin, and Beach Road.

Most of the sand for reclamation used to be imported from the neighbouring countries of Malaysia and Indonesia. However, there was an official ban on sand exports by Malaysia in 1997 and by Indonesia in 2007, following which Singapore was compelled to look for alternative source countries such as Cambodia, Vietnam, the Philippines, and Myanmar. However, Vietnam banned sand exports to Singapore in 2009. In 2017, Cambodia too declared a complete ban on sand exports to Singapore (BBC 2017). Nevertheless, these bans do not appear to be fully enforced and Singapore continues to import from these countries (Banergee 2018). Indeed, Singapore has been accused of allowing illegal sand import. While Singapore denies such an allegation, there is a discrepancy between the quantity of sand imports reported by Singapore and the quantity of sand exports reported by the source countries. For example, Singapore reported 73.6 million tonnes in sand imports from Cambodia since 2007, but the Cambodian government reported that only 2.7 million tonnes left for Singapore (Siau 2017).

Besides the concerns for environmental degradation due to illegal sand exports from source countries, Singapore's massive land reclamation has also made neighbouring countries, such as Indonesia, wary that it may lead to a loss of its own sovereign territory (Subramanian 2017). Furthermore, land reclamation became more expensive. The average import price of sand skyrocketed from around US$ 1 per tonne in 1999 to over $150 per tonne in 2004. Even though the recent price trend is downward, the price remained well above US$5 (Figure 1). All these points raise the importance of reducing the dependency on imported sand for reclamation.

As a result, empoldering—a method of reclamation in which a dike is first built around the area to be reclaimed and then the water inside is drained—was considered, because it can significantly limit the potential damage to the surrounding coastal and marine ecosystem. Also, compared to the traditional method of infilling with sand, empoldering requires less sand and saves on upfront construction costs (Yeo 2016). The Housing Development Board (HDB)—a government organisation that provides public housing in Singapore—adopted empoldering for the ongoing reclamation of Pulau Tekong.

Though efforts to increase the land area through reclamation has clearly helped mitigate the space constraint that Singapore faces, horizontal expansion alone is unlikely to resolve all the land issues, because reclamation is already expensive and takes a long time to complete. Furthermore, land reclamation will continue to become more expensive, even if the import sand price remains stable. This is because the sites suitable for land reclamation become deeper and deeper into the sea as Singapore's land reclamation expands. We, therefore, turn to vertical urbanism as a complementary approach to address land scarcity in Singapore.

2.2. Growing taller: vertical urbanism in Singapore

Competing needs for land between housing, transport, and commercial uses necessitated Singapore to turn to the concept of vertical urbanism. Vertical growth is an apparent solution to the problems of land scarcity and urban sprawl, and it may lessen environmental damage (Wong 2004). Singapore has promoted vertical urbanism through various policies such as relaxed storey height limits and facilitation of collective sales (Phang, 2018; chapter 5), the latter of which would lead to increased supply of units. Through vertical urbanism, various needs for space can be simultaneously fulfilled and open space for greenery can be created. Tall buildings can also significantly lessen the volume of traffic and reduce carbon footprint, if suitable policies are in place.

Singapore's history of vertical urbanism will be incomplete without understanding the critical role that the HDB played in the housing market. The HDB was founded in 1960—when many people were living in unhygienic slums and crowded squatter settlements—and tasked to solve Singapore's housing crisis (Housing and Development Board 2017). The HDB buildings in early years were made of slab blocks with 10 storeys or fewer. However, in the 1970s and 1980s, as the HDBs' supply began to expand, a majority of the HDB buildings had more than 10 storeys. In the 1990s, 30-storey HDB complexes appeared, and the first 40-storey complex was completed in Toa Payoh in 2005. HDB buildings and private condominiums with 30 or even 40 storeys are now common in Singapore. The tallest HDB in Singapore currently is the 50-storey Pinnacle@Duxton in Duxton Plain completed in 2009 with 1848 units (Lee 2011). HDB buildings are clustered in a town and normally have essential facilities such as supermarkets, hawker centres, clinics, schools, and recreational facilities in their vicinity. Today, 81 per cent of Singaporeans live in a HDB unit, typically in a high-rise building, and about 90 per cent of them own the unit they occupy.

While constructing more such high-rise, high density residential buildings, it was essential for policymakers to understand the attitude of the residents towards vertical urbanism. Wong (2004) interviewed residents of newly constructed tall buildings and found certain pull and push factors that, respectively, attract and repel residents. According to the survey results, good view, fresher air, ventilation, and better quality of housing were taken as some of the benefits of vertical urbanism. On the other hand, perceived drawbacks included safety issues, long waiting time for lifts, lack of community interaction, high-rise littering, and high prices of high-floor units.

In recent decades, as the policy focus shifts towards sustainability and liveability, the possibility of exploiting the rooftops of high-rises as gardens has been explored. Greenery can be extended skywards, such that it is closer to individual homes in tall buildings and fosters interactions within the community. Rooftop greenery can be beneficial not only from an aesthetic viewpoint but also from the perspective of rainwater harvesting and energy conservation through the better insulation greenery provides. Various programs have been put in place to promote skyrise greenery in Singapore. For example, the Urban Redevelopment Authority (URA) launched the Landscaping for Urban Space and High-Rises (LUSH) in 2009 to incentivise developers to build sky terraces and roof gardens in new constructions. The Skyrise Greenery Incentive Scheme, which subsidises installation of skyrise greenery in existing buildings, was also initiated as part of the Singapore Blueprint 2009. However, one of the primary concerns for developers has been that rooftop greenery tends to be underutilised and people have a natural inclination to go to parks at the ground level (Yuen and Wong 2005).

While growing taller has been the primary focus of vertical urbanism in Singapore, Singapore also uses its underground space for various purposes—such as shops, carparks, rail network, roads, caverns, underground pedestrian networks, and utility tunnels. Underground space is relatively expensive to develop but it has some advantages over above-ground spaces such as insulation from scorching sun and torrential rain in the tropical climate. Deep underground space can be used for storage, transport, utility, and industrial facilities. In view of this, Singapore is indeed exploring greater use of its underground space (Urban Redevelopment Authority and ARUP 2014).

Though critics of vertical urbanism argue that it leads to social segregation and disrupts the horizontal dynamism of urban space (Hou 2012), in a land-constrained city like Singapore, vertical urbanism is among the most practical ways to provide residential and commercial space to cater to an increasing population.

2.3. Improving land use for more sustainable and liveable Singapore

As environmental awareness of Singaporeans rises and as they increasingly require more than just a shelter, the emphasis of land policy has shifted towards the construction of more eco-friendly buildings and promotion of an eco-smart lifestyle. One example is the Elevator Energy Regeneration System in the lifts of HDB buildings. These lifts recover energy from the movement of elevators to power other common services and have already been installed in 350 blocks in Punggol. There are plans to expand this provision further to new and existing HDB blocks (Cheng and Tong 2017). Another example is the use of LED lighting in common areas, which is more energy-efficient than the conventional lights. Other green measures include installation of solar panels in rooftops and centralised chutes as discussed below.

The government of Singapore has used a sound mix of normative messages and economic incentives over time to achieve desired economic and social outcomes. It has set an ambitious target of making 80 per cent of its buildings 'green' by 2030. Some of the first initiatives towards greener buildings were taken in mid 2000s. For example, the Building and Construction Authority (BCA) Green Mark Scheme was launched in 2005, and the first Green Building Masterplan, which stimulated industry stakeholders to adopt new green buildings, was unveiled in 2006. The second Green Building Masterplan, which was launched in 2009 in partnership with the Inter-Ministerial Committee on Sustainable Development, focused on incorporating the public and private sectors in the drive towards achieving greenery as well as improving green building technology, imposing minimum standards, and raising general awareness among the population (Building and Construction Authority 2009).

While the first two Green Building Masterplans focused on the roles of developers, designers, and builders to construct eco-friendly buildings through incentives such as the BCA Green Mark Scheme, the third Green Building Masterplan published in 2014 raised awareness among the occupants of these buildings about the adoption of eco-friendly ways of living. Under the third Masterplan, a \$50 million Green Mark Incentive Scheme for Existing Building and Premises was introduced to promote environmental friendly retrofits through co-funding. In 2018, the BCA further launched a new voluntary rating, Green Mark for Super Low Energy Building (the best-in-class energy performing Green Mark Building that achieves at least 40% energy saving based on prevailing code, or 60% energy saving above 2005 building codes) and Zero Energy Building (the best-in-class energy performing Green Mark Building with all of its energy consumption including plug load, supplied from renewable source).

While the Green Mark Scheme is mostly a voluntary scheme, any building on the land sold under the Government Land Sales Programme in selected strategic areas is required to meet the prescribed Green Mark Certification. A good example is Punggol Eco-Town, in which any building is required to achieve Green Mark Gold^{plus} rating. Punggol Eco-Town now boasts of a sustainable waterfront town of the 21st century and is an exemplary model using energy- and resource-efficient solutions, including solar photovoltaic (PV) system, elevator energy reservation system, smart grids, and effective water management solutions through rainwater harvesting.

The measures discussed so far have been taken to address the sustainability issues in areas of land use, but the push towards greener buildings and lifestyles has also risen from the concomitant issue of liveability. Singapore has worked towards realising the "garden city" vision put forward by then Prime Minister Lee Kuan Yew in 1967 to enhance the attractiveness and liveability of the city. For example, Singapore has introduced regulatory provisions to mandate land within developments to contribute to the overall greenery of the city and set aside planting verges along roads (Tan 2017b). Efforts have also been made to bring greenery and nature into the residential and commercial space to create a more liveable Singapore. Today, Singapore already tops the ranking of urban tree density (Tan 2017a). The government now aims to have 9 in 10 homes within 10 minutes' walk from a park and plans to build 400 kilometres of park connectors and 100 kilometres of waterways open to recreational activities by 2030 (National Parks 2017).

There has also been a concerted effort to bring more greenery into living spaces and create better public spaces for the community. One noteworthy ongoing project is Tengah, popularly known as the 'Forest Town', which will feature car-free city centre, walking and cycling paths along all roads, and greenery woven through the town, from a large central park to community farmways that run through housing estates (Heng 2016). Upon completion in about two decades, Tengah will have an estimated 42,000 new homes with public housing comprising a vast majority of 70 per cent (Cheng 2016). Besides, the URA is creating car-free zones on weekend and encouraging the provision of green spaces under the LUSH program, as mentioned earlier.

Creating an active and vibrant community to enhance liveability has also become a focal point in Singapore's policy dialogue. Initiatives have been taken to make better use of public spaces—including playgrounds, hawker centres, void decks, and parks—for the civil community, where people can come together to exchange new ideas or just sit and relax. For example, the URA launched the 'Pick a Bench, Pick a Place' project in 2014, in which the public was invited to vote for their favourite bench design and location for the bench to be installed. In this project, 42 benches were installed across 15 locations in Singapore, and these benches provide the community with resting place and serve as focal points for community interactions (Urban Redevelopment Authority 2014). Ongoing efforts to raise liveability also include research and development (R&D) programs. One prime example is the Land and Liveability National Innovation Challenge, a multi-agency effort that seeks to leverage research and development to come up with innovative solutions to increase Singapore's land capacity for its long-term development needs and to provide options for future generations (National Research Foundation 2018).

3. Building an efficient transportation system

Land-use policies work hand in hand with transportation policies, because where to live, where to work, and where to play can depend much on whether there is a good transportation system. A good transportation system is also crucial for the sustainable growth of a city as congestion undermines the smooth movement of goods and people within the city and reduces its attractiveness and the welfare of its residents. Therefore, the presence of an efficient transportation system is vital for both liveability and sustainability of a city. Indeed, building a good transportation system has always been of great importance in Singapore's public policy. Singapore has managed to pre-empt congestion and ensure smooth traffic flow through careful long-term planning and flexible implementation of policies to address unexpected issues.

While Singapore already had a road network with a total of 800 kilometres of road length in the 1960s (Centre for Liveable Cities and Land Transport Authority 2013), opening of new HDB towns and increasing population and industrial activities necessitated the construction of more roads. Therefore, Singapore has continued to add and improve roads, and there is a total of 3,500 kilometres of road in Singapore as of 2017 (Land Transport Authority 2018). Besides this sizable growth in the total road length, Singapore opened 11 expressways with a total length of 164 kilometres since 1965, when there was no expressway. In 2012, roads constituted 12 per cent of the total land area and adding roads further will be expensive in land-scarce Singapore. Indeed, just increasing the supply of roads has never been and will not be a fundamental solution to the challenges of meeting the increasing transportation demand in Singapore.

Singapore has taken a two-pronged approach to address transportation issues. One approach is to strengthen the push factors from private vehicle transportation to manage congestion by making the usage and ownership of private vehicles more expensive. The other approach is to address pull factors into alternative modes of transportation by improving the public transportation system. In this section, we review both approaches and explore future opportunities and challenges in Singapore's transportation system.

3.1. Past and present policies to manage traffic congestion

While roads have been built across the island, demand-side management has played a critical role in the transportation policy of land-scarce Singapore. To address urban traffic congestion, the government has implemented, broadly speaking, two types of policies to manage demand. One type of policies is to disincentivise the use of cars during peak hours by imposing a charge. The other type of policies attempts to reduce car ownership.

One of the first policies aimed at reducing the use of cars, the Area Licensing Scheme (ALS), was implemented in 1975, when a rapid increase in car ownership due to increasing incomes was leading to a major traffic congestion in the Central Business District. The ALS was the first comprehensive road pricing scheme ever implemented in the world (Rodriguez 1976). Under the ALS, drivers of all vehicles—excluding exempted vehicles such as buses, taxis, motorcycles, commercial vehicles, police and military vehicles, ambulances, fire engines, and high occupancy vehicles (HOVs) with at least four passengers—had to pay an entry fee to enter the restricted zone (RZ) during the peak hours between 7.30 am and 9.30 am, except for Sundays and public holidays. The payment was made through the purchase of a paper license—priced initially at S$3 per day or S$60 per month—and it had to be displayed on the vehicle's windscreen. To support the ALS, the government also implemented complementary measures such as the hike of parking rates in the RZ and construction of roads that circumvent the RZ.

The ALS was generally deemed successful in curbing urban congestion and encouraging people to travel in public transport. For example, the share of public transportation users increased from 33 per cent in the pre-ALS period to 69 per cent in the post-ALS period (Phang and Toh 2004). The average speed of traffic in the Central Business District during the peak hours was 19 kilometres per hour in 1975, but by May 1991, it had increased to 36 kilometres per hour (Phang and Toh 1997). This figure compares favourably to the average downtown peak hour vehicular speed of 10 and 18 kilometres per hour in New York and London, respectively (Menon et al. 1993). Not only did the implementation of ALS improve the speed of traffic, but it also helped reduce air pollution in the CBD and earned the government a savings of at least US$ 500 million on road repairs and investment in infrastructure (Holland and Watson 1982).

Following the success of the ALS, a Road Pricing Scheme (RPS) was introduced in 1995. The way the RPS worked was similar to the ALS; under the RPS, the vehicles passing through the East Coast Parkway during the morning peak hours between 7.30 am and 8.30 am on weekdays, excepting the exempted vehicles, had to purchase a RPS license—priced at S$0.5 for motorcyclists and S$1 for other vehicles. As with the ALS, the RPS was also deemed effective in reducing congestion and increasing travel speed along the expressway.

However, these measures were not without problems. In fact, there is an important challenge inherent in demand management measures like the ALS and RPS. People often respond to a new policy and adjust their behaviour, which may undermine the effectiveness of the policy or create an unanticipated problem. For example, the government initially encouraged people to carpool through the exemption of HOVs and subsequently even set up special pick-up points outside the RZ for carpooling. However, this turned out to be a loophole of the ALS and eventually the HOV exemption was abolished in 1989 (Menon and Loh 2006). Another example is the adjustment of travel time and route by drivers to avoid the payment. The adjustment is desirable on its own from the perspective of reducing congestion that the ALS is targeted to reduce. However, it led to a transfer of congestion to a new time and location. For these reasons and to cope with changing traffic conditions, the ALS had to be adjusted several times by varying the entry fee and the period of chargeable peak hours (Lim 2014).

Inadequate understanding of the behavioral response can also lead to inefficient use of resources. When the ALS was first implemented, its impact was too large and, as a result, roads were underutilised. The traffic volume during the restricted hours fell by 43 per cent, even though the target was to reduce it by 25 to 30 per cent (Phang and Toh 2004). Another example is the Park & Ride scheme launched in 1975 to support the ALS. Under this scheme, motorists could park their vehicles in one of 15 fringe car parks outside the RZ and continue their journey using shuttle buses (Muthu 1975). However, this scheme completely failed as car parks were empty and the shuttle buses were underutilised. Motorists who decided to switch to buses did so from home and not from the fringe car park (Menon and Loh 2006).

Furthermore, the implementation of the ALS and RPS was inefficient and prone to errors, because they required dedicated license sale booths and visual monitoring for manual implementation. To address this issue, the government explored Electronic Road Pricing (ERP) and replaced the manual versions of the ALS and RPS with the ERP in April 1998 (Chin 2005). In the ERP system, when a car passes under an on-site ERP gantry, the gantry communicates with the car's in-vehicle unit (IU) and deducts the ERP charge—which depends on the vehicle type, location of the gantry, time of the day, and day of the week—from the stored-value smartcard called CashCard inserted in the IU. The ERP gantries are also equipped with an enforcement camera system, which takes a picture of the offending cars, such as cars with no IU, no CashCard inserted in the IU, or insufficient balance in the CashCard.

Once an IU is installed, the ERP system is easy to use; drivers only need to insert a CashCard into the IU. Therefore, the installation of IUs was critical for successful implementation of the ERP system. The government started publicity campaign more than a year prior to the launch of the ERP system and from September 1997, the government started the IU-fitting program, which gave away IUs at no cost to vehicle owners if the IU is fitted during a particular period (installation costs S$150 otherwise). This program was implemented over a period of 10 months, so that there was no last-minute rush to fit the IUs. While the fitting of IUs was voluntary, more than 98 per cent of registered vehicles were fitted with IUs at the end of the IU-fitting program.

The ERP system has been increasingly used across the city-state to control congestion, and there are 77 ERP gantries as of 2015 (Diao 2018). The ERP system not only removed the need for manual enforcement but also allowed policymakers to implement the charges more flexibly, which in turn mitigated the undesirable side effects of ALS and RPS. For example, by adopting shoulder-charging, in which the charges change gradually around the peak hours, the incentive for the drivers to wait just outside the chargeable areas was substantially diminished.

More importantly, in the initial years after its introduction, the ERP system successfully reduced traffic in the expressways by 15 per cent and increased the average speed of motorists from 35 kilometres per hour to 55 kilometres per hour during the hours of operation of the ERP (Menon and Guttikunda 2010). However, in spite of several benefits of the ERP, some people had concerns about the pay-as-you-use system. Drivers needed to pay a flat fee for multiple entry under the ALS, but under the ERP system, they have to pay a charge every time they pass a gantry during its operating hours. In addition to the regular ERP charge, there is also a penalty of S$10, if they pass through an operational gantry without a properly inserted CashCard or sufficient value in the CashCard (Land Transport Authority 2019a). There has also been some unease about the lack of privacy that this system entails, because the commuter's travel and location patterns are recorded.

However, the diffusion of the IUs and CashCard also provides additional convenience to drivers as they can make payments without getting off the car. For example, many car parks in Singapore today adopt the Electronic Parking System (EPS), which operates like the ERP system. In EPS car parks, the parking charges are automatically calculated and deducted from the CashCard upon exit. For example, of the 2,108 car parking lots available in the HDBs, around 88 per cent of them use the EPS (Housing and Development Board 2019).

While the ERP system provides greater flexibility and efficiency than the ALS and RPS, it requires heavy physical infrastructure such as overhead gantries and signage. Furthermore, the ERP charges that a driver incurs depend only on whether and when the car passes through the ERP gantries and not on how long the car stays on congested roads. To address these issues, the Land Transport Authority (LTA) of Singapore is currently testing the next generation of the ERP system. The new system dispenses with the physical gantries by using satellites and charges motorists for the distance they travel on congested road (Tan 2016a).

The measures discussed above were primarily intended to reduce the *usage* of cars. Singapore also implemented various policies to restrain the *ownership* of cars as well. Until 1990s, car ownership was restricted primarily by price policies, which included an import tax, a lump sum registration fee, an additional registration fee (ARF), and an annual road tax, based on vehicle capacity. These taxes and fees were increased substantially over time with an increasing car population. Between 1968 and 1990, the import tax rate increased from 30 per cent to 45 per cent, the registration fee from S$15 to S$1,000, and the ARF from 15 per cent to 175 per cent of the market value of the vehicle. The annual road tax has also increased from 10 cents to 70 cents or more per cc, depending on the engine of the car (Chia and Phang 2001).

The government was, however, also concerned that a high ARF would discourage existing car owners from replacing their cars, or potential new car owners from buying new vehicles. Thus, when the ARF was increased from 55 per cent to 100 per cent in 1975, the government introduced the *preferential* additional registration fee (PARF), which provided a discount on the ARF when the car owner scraps a car within 10 years of age upon registering a new car. The amount of PARF was determined by the open market value of the car and engine capacity, but the scrap car prices were determined only by the engine capacity. As a result, the scrap car price was higher than the original purchase price of an inferior car in the same category, and many car owners enjoyed low or even negative cost of ownership (Chia and Phang 2001). Furthermore, despite the rapid increase in the cost of owning cars, car ownership increased quite rapidly as the income levels went up. Between 1975 and 1989, the car fleet in Singapore grew by 80 per cent from 142,000 to 257,000, even though the population growth during this period was only about 30 per cent (Poon 2016).

Against this backdrop, the government decided to depart from price policies and adopted a Vehicle Quota System (VQS) in 1990. Under the VQS, a buyer of a new car must purchase a Certificate of Entitlement (COE). COEs may be obtained in a public tender separated into different categories by the engine capacity and purpose of the car, and successful individual bidders pay the lowest successful bid price in a given category.

The VQS has clearly succeeded in containing the growth of car population in Singapore as the number of COEs to be issued can be chosen by the government. As of 2017, Singapore's total automobile population stands at 962,000, which translates into a linear density of 274 motor vehicles per kilometer. While this is among the highest in the world, this figure has changed little over the last decade. Further, the number of motor vehicles per thousand people actually declined slightly during the same period (Figure 2).

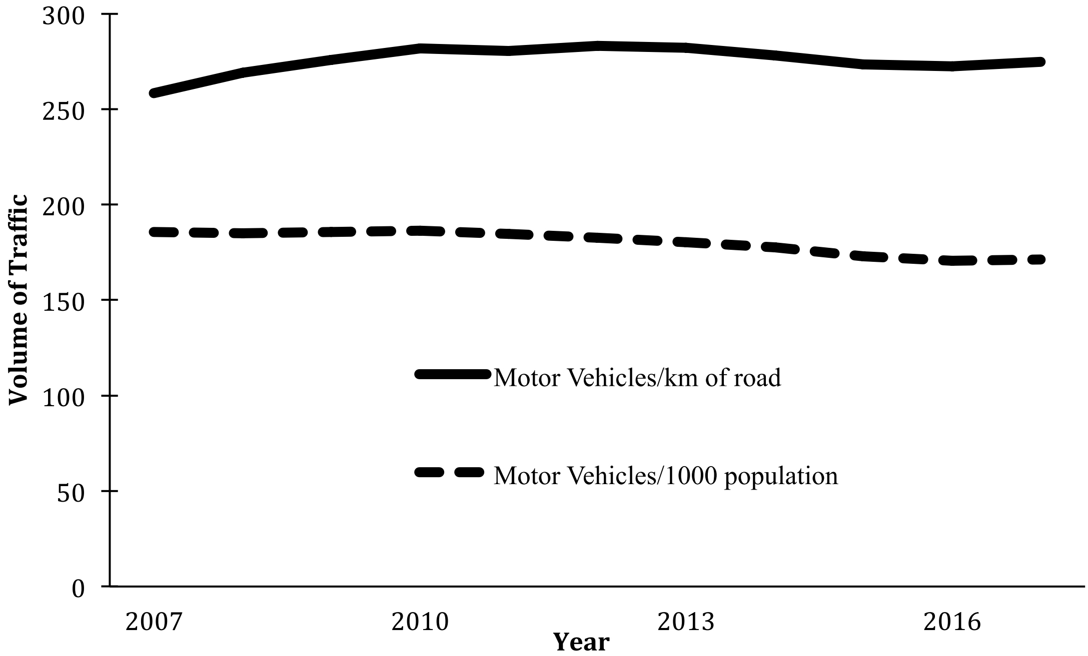

Figure 2: Trend in the Volume of Traffic, 2007-2017 (Source: 2017 Annual Vehicle Statistics).

One consequence of using a quantity-based regulation like the VQS is that the prices may become volatile. Indeed, the COE prices have fluctuated substantially depending on the supply of COEs and economic environment at the time of bidding. For example, the COE price for Category A (small cars up to 1,600cc and 97kW) had gone up from an all-time low of S$2 on November 19, 2008 to a historical high of S$92,100 on January 9, 2013. The price difference between the two periods denotes several times the pre-tax price of many small cars. Such a large fluctuation can, therefore, potentially penalise people who happen to be in dire need of cars at the time of high COE prices, which, for example, may include families with small children, elderly people, and disabled members.

Because of the various taxes and fees, owning a car in Singapore has been very expensive. For example, a Honda Civic was reported to cost around S$149,000 in 1997, of which the government would collect around S$100,000 in taxes and fees (Phang and

Toh, 1997). Thus, to allow more people to own a car without increasing the fear of congestion, the Weekend Car (WEC) scheme was implemented in 1991. Under the WEC scheme, the car owners were required to obtain a COE for the new category created for weekend cars under the VQS. While they were restricted to drive only during the off-peak hours (7pm to 7am on weekdays, after 3pm on Saturdays, and all day on Sundays and public holidays), they could enjoy reduced annual road tax and tax rebates on the registration fee, import duty, and COE premium, up to S$15,000. If the owners of the weekend cars wanted to use their cars on weekdays, they were required to purchase a S$20 coupon for each day.

This policy, however, suffered from a loophole, as one could purchase a weekend car and use it like a normal car (Leong 1994). In particular, the WEC scheme favored big (and expensive) cars and owners of such cars could use up the savings from the purchase of weekend cars to buy a sizeable number of daily coupons. In July 1994, the discount on the COE premiums for weekend cars relative to normal cars was so large that the up-front combined savings from this discount and tax rebates combined were more than sufficient to finance 10 years of S$20 daily coupons (Phang et al. 1996). To address this loophole, the WEC scheme was replaced by the Off-Peak Car (OPC) scheme, in which car owners received an upfront rebate of S$17,000 and discount on annual road tax. The OPC was further revised in 2010 to the Revised Off-Peak Car scheme to encourage drivers to join the scheme. Nevertheless, both the number and proportion of off-peak vehicles (cars and station wagons) registered reduced from 50,040 (8 per cent of 595,185 vehicles) in 2010 to 30,469 (5 per cent of 602,311 vehicles) (Tang 2016).

Singapore's two types of measures, one to reduce the usage and the other to reduce the ownership of cars, were overall successful as Singapore managed to maintain healthy traffic flow and contain the growth of vehicle population, particularly in comparison to the experiences of other cities. However, some policies did not work in the way they were expected and adjustments were needed. Singapore's experience demonstrates the difficulty of fully anticipating behavioural responses and the importance of calibrating the policies swiftly as needed.

3.2. Investing in public transportation system for liveability and sustainability

While the policies to manage traffic congestion have been successful, they may potentially come at a high welfare cost if they simply result in reduced mobility of people. Hence, it is important to improve the pull factor by making the public transportation system accessible and attractive to all residents.

At the time of Singapore's independence in 1965, buses were practically the only mode of public transportation. However, the bus transportation system was inadequate and inefficient. There were 11 bus companies, which included the government-owned Singapore Traction Company (STC) and 10 Chinese companies, and there was no planning or coordination among them to build a bus system to serve the public. The lack of integration often resulted in long and inconvenient journeys with multiple transfers (Lew and Choi 2016) and the low demand areas were not covered (Looi and Choi 2016). Badly maintained buses broke down regularly all over town and there were more buses in for repairs than there were on the roads (Sharp 2005). Buses also did not run on time, partly because workers often went on strikes and demanded a higher pay and better working condition (Centre for Liveable Cities and Land Transport Authority 2013). The bus fleet in Singapore was small relative to the demand and these issues exacerbated the overcrowding of buses.

Furthermore, corrupt practices were also prevalent. For example, many conductors pocketed passengers' fares or resold the paper tickets if they could and their bosses were no better. It was generally accepted that the bus company owners were little more than gangsters, or else in the grip of gangster protectors. As such, a sizeable number of bus companies was making losses. For example, the total accumulated losses for STC was S$5.7 million between 1964 and 1969 (Sharp 2005).

The problems with the bus transportation system were well recognised even before 1960s. Following the Great STC Strike in 1955 that lasted 142 days, the Report of the Commission of Inquiry into the Public Passenger Transport System of Singapore—also known as the Hawkins Report—called for the consolidation of 11 companies and a single licensing authority. The latter was realised as formation of the Omnibus Services Licensing Authority (OSLA), but it lacked power to effectively regulate the STC. For example, the OSLA could not withdraw any of the STC's routes, even if the STC was inefficiently managed (Looi and Choi, 2016).

It was not until the early 1970s that a drastic reorganisation of the bus services finally took place. The first turning point was the publication of the White Paper on the *Reorganisation of the Motor Transport Service of Singapore* in 1970 (Government of Singapore 1970), which described the bus services at that time as follows:

> *No survey needs to be conducted to establish the fact that there is an inadequate number of buses in service for the public. The large crowds waiting patiently over long spells at bus stops and the existence of thousands of 'Pirate Taxis' for more than 15 years, are plainly visible.*[4]

The White Paper called for, among others, the empowerment of OSLA, eradication of pirate taxis, creation of more job opportunities with increased bus fleet, reorganisation of the STC, and amalgamation of bus companies to improve public bus services. The White Paper lead to the commissioning of *A Study of the Public Bus Transport System of Singapore*, also known as Wilson report, which provides specific recommendations and implementation plans (Wilson, 1970). What the White Paper and Wilson report called for were implemented through early 1970s, even though the road to rationalisation of the bus system was full of ups and downs (Looi and Choi 2016).

While we are not aware of any rigorous evaluation of the impact of reorganisation of bus services on the environment, the pollution problem was well recognised in the White Paper and it is likely that replacement of old buses and improved maintenance have contributed to the reduction of pollution from buses. Old private buses and privately-owned taxis were running all over the place, full of black smoke as Mr Tan Gee Paw, a former Permanent Secretary of the Ministry of Environment, recalls (Centre for Liveable Cities 2016).

[4] Pirate taxis are the private cars operating as taxis without licenses. There were some 6,000 pirate taxis, even though only 3,800 taxi licenses were issued by 1970. While these pirate taxies had poor service standards and irregular fare structures and were a cause of road safety issues, their services complemented inadequate bus transport services then (Looi and Choi 2016).

Because the buses have limited capacity to transport people and are subject to delay due to traffic congestion, the possibility of building a Mass Rapid Transit (MRT) rail transport system, which can potentially transport hundreds of people at once without being affected by traffic congestion, was debated throughout 1970s. After much deliberation and taking into account potential costs and benefits of the MRT system, the government gave the green light to the construction of MRT in 1982 and the first two lines opened five years later in 1987.

Since early 1990s, efforts have been made to integrate the bus and MRT networks. The bus routes have been revised to complement, rather than compete against, the MRT lines. Fare collection system was also integrated across different public transport operators using store-valued magnetic strip tickets, which enabled cashless payment. These tickets were later replaced by contactless smartcards called EZ-Link cards. The integrated payment system enabled distance-based charging—in which fares are calculated by the travel distance regardless of the number of transfers—and the EZ-Link cards are accepted as a mode of payment in many shops across Singapore. Most new MRT stations are underground such that commuters do not need to be exposed to hot and humid weather in Singapore. As of 2018, there are five MRT lines and three Light Rail Transit lines and an additional three lines are being planned or constructed. With the completion of these three lines and planned extensions of existing lines, the government expects that 8 out of 10 households will be within a 10-minute walk from a train station by 2030 (Chew 2016). Through the expansion of network, the MRT system has increasingly become an integral part of the public transport system in Singapore.

As Singapore built up a better functioning and more sophisticated public transportation system, the focus of Singapore's transport policy has also shifted from just building physical infrastructure towards better user experience of public transport. To achieve better service standards and operational efficiency, measures have been taken to increase competition and contestability. For example, additional bus and MRT companies were allowed to enter these previously monopolised markets.

From 2016, the government has progressively implemented the Bus Contracting Model (BCM), where the LTA owns the bus infrastructure—including buses, depots, and bus management systems—and specifies the requirement for the bus services to be bid competitively. Under the BCM, the contracted bus operators are paid the fees to operate the services, while fare revenues are retained by the government (Land Transport Authority 2014). Since 2016, the operation of the MRT lines has also shifted in steps towards a somewhat similar model under the New Rail Financing Framework—in which the operating assets are held by the LTA and operators pay for the license to operate. Both the MRT and bus services appear to have made notable improvements in the quality of service in recent years. For example, the reliability of the MRT network as measured by the Mean Kilometre Between Failure has dramatically improved from 93,000 train-km in 2014 to 680,000 train-km in 2018 (Tan 2019).

With various measures and policies implemented by the government and public transportation operators, the public transportation system in Singapore has become more attractive to the general public. For example, the share of residents aged 15 and older, who take either the MRT, bus, or combination of both, to work has gone up from 50.7 per cent to 58.7 per cent in a decade's time according to the General Household Survey conducted in 2015 (Lee 2016). Indeed, boasting of one of the best public transportation systems in the world, Singapore ranks first in the overarching urban mobility ranking of 24 global cities (McKinsey & Company 2018) and eighth out of 100 cities around the world in the Sustainable Cities Mobility Index 2017 (Arcadis 2017).

In sum, Singapore has enjoyed remarkable success in raising the standards of public transportation system from a chaotic state in 1960s to a world-class standard today. The affordable, reliable, and efficient transportation system in Singapore positively contributes to its liveability today.

3.3 Transport policies and technologies to move forward

As we have seen in the previous two sections, Singapore has implemented a number of measures to discourage the ownership and usage of cars and to encourage the use of public transportation by making it more attractive. Singapore has also taken measures to improve the environment for pedestrians and cyclists by, for example, building sheltered walkways, pedestrian overhead bridges, and designated bike paths. The rules about bicycles and personal mobility device—where users are allowed to use them and how fast they can move with them—have also been introduced for the safety of pedestrians and sustainable coexistence of different modes of transport. These measures and policies would help promote active mobility and achieve a "car-lite" society.

Singapore has also implemented measures to make the city more sustainable. For example, Singapore has implemented progressively more stringent emission and noise standards for vehicles and quality standards for automotive fuels. Financial incentives have also been introduced to encourage people to buy cleaner cars or to replace older and more polluting vehicles with cleaner ones. Despite these efforts, it remains imperative for Singapore to further improve environmental performance indicators to build a sustainable city, particularly given that the total population is projected to increase to 6.2 million by 2030 from 5.6 million as of 2018 (World Bank's population estimates and projections), which would further increase the strain on the environment.

In particular, transport sector can play an important role in reducing air pollution in Singapore. This is important, because air quality in Singapore needs substantial improvement to achieve the Air Quality Guidelines (AQG) by the World Health Organization (WHO), which provides a guidance in reducing the health impacts of air pollution. In 2017, nitrogen dioxide (NO_2) and carbon monoxide (CO) were the only pollutants that were within the WHO AQG. Sulphur dioxide (SO_2), fine particulate matters with a diameter of 2.5 μm or less ($PM_{2.5}$), and coarse particulate matters with a diameter of 10 μm or less (PM_{10}) were within the WHO Interim Targets, which are less stringent than the WHO AQG and used in high pollution areas to progress towards the WHO AQG level. The level of ozone (O_3) even exceeded the WHO Interim Target. In Singapore's own Pollutant Standards Index which uses the measurements of six pollutants mentioned above (i.e., NO_2, CO, SO_2, $PM_{2.5}$, PM_{10}, and O_3), only less than 10 per cent of the days had 'good' air quality and almost all the remaining days had 'moderate' air quality both in 2016 and 2017 (National Environment Agency 2017). Because vehicles contribute directly or indirectly to the ambient concentration of these pollutants,[5] it is imperative that the emissions from the transportation sector be reduced to improve the air quality of Singapore.[6]

$PM_{2.5}$ is a particularly good example. In 2017, the annual average level of $PM_{2.5}$ was 14 μg/m^3, well above the WHO's recommended limit of 10 μg/m^3. The government aims to reduce $PM_{2.5}$ to 12 μg/m^3 by 2020 and eventually to 10 μg/m^3. Since vehicles account for about half of the $PM_{2.5}$ in Singapore (National Environment Agency 2017), reducing the use of vehicles, particularly the more polluting ones, would be an important way to lower the level of $PM_{2.5}$ pollution.

The LTA has adopted various measures over time to help reduce air pollution through less carbon emission from cars, and at the same time raise consumer awareness about the fuel efficiency of new cars and its potential impact on the environment. Under the Carbon Emissions-Based Vehicle Scheme, car owners, who had registered their cars from 2013 onwards, were required to pay a surcharge or enjoyed a rebate on the car registration fee, depending upon the emission levels of carbon dioxide. This scheme was replaced by the Revised Carbon Emission-Based Scheme in 2015 and the level of carbon emission to enjoy the rebate was lowered. The scheme was further revised in 2018 and the emission levels of four other pollutants including hydrocarbons, carbon monoxide, nitrogen oxide, and particulate matter were also taken into account under the Vehicular Emissions Scheme. In addition, under the Fuel Economy Labelling Scheme introduced in 2012, a vehicular emissions label must be displayed in the showroom to make it easy for consumers of cars or light goods vehicles to compare the vehicle's fuel economy and emissions of major pollutants. Thus, economic incentives have been at the core of Singapore's policy to reduce air pollution from the transportation sector.

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[5] This does not mean that vehicles are an important source of emissions for all these pollutants. For example, vehicles only account for 0.1 per cent of SO_2 emissions, whereas refineries account for over 90 per cent in 2017 (National Environment Agency 2017).

[6] Transboundary pollution can also be an important source of air pollution in Singapore. In particular, forest fires in Indonesia and Malaysia have created haze, which became a major public concern from time to time, particularly in 1997 and 2013 (See, for example, Quah (2002) and Forsyth (2014)). Singapore has taken some steps domestically such as the enactment of Transboundary Haze Pollution Act (Lee et al., 2016) to address this issue. However, detailed discussion of transboundary pollution is out of the scope of this paper. We shall briefly discuss the impact of climate change at the end of this paper.

Besides air pollution, noise pollution in Singapore also needs to be addressed for a better living condition of the city. A study by researchers from the National University of Singapore found that the outdoor sound level throughout the day in Singapore is about 69.4 decibels (Ng and Xi 2017), which is still within the WHO's threshold noise limit of 70 decibels but exceeds the recommendation of 67 decibels by the National Environment Agency (NEA). The main contributors to noise pollution in the city are the MRT and the vehicular traffic in the expressway. Noise barriers, which are able to reduce noise from passing trains by at least 5 decibels, have been built along the MRT tracks since 2013 to alleviate the situation.

Going forward, technology will play a critical role in making Singapore's transport system cleaner and more convenient, and various initiatives are already in place. One notable example is the development and testing of Autonomous Vehicle (AV) technology. With the endorsement of the LTA since 2015, Singapore is currently ranked second (only behind the Netherlands) in terms of the readiness for AVs (*The Straits Times*, 2019). Autonomous scheduled buses and on-demand shuttles are set to go on board in Punggol, Tengah, and Jurong Innovation Districts from the early 2020s. Electric car sharing is on the rise recently, and the number of electric cars is expected to grow to 1,000 with access to 500 charging stations across the island by 2020 (Abdullah 2018).

The public transportation system can also improve with the use of new technology. Automated vehicle inspection system and automatic track inspection system have been used to inspect, respectively, trains cars and tracks in some MRT lines in recent years. The use of drone technology is also being explored as an option to capture images and videos of problems within the tunnel (Kor, 2018). These technologies will enable more efficient maintenance of the MRT system.

Technology can also make the public transportation system more convenient and accessible to all. For example, new crowd monitoring systems are in place to inform the commuters of relatively emptier cabins. Another example is the use of the Common Fleet Management System, through which commuters can learn about the expected arrival time of a bus and bus drivers can monitor deviation from the scheduled headway (Sim 2014). At four MRT stations, new hands-free payment, which uses bluetooth-enabled mobile device or a radio-frequency identification test card, is being tested with the involvement of people with disabilities (Paramanantham 2018). These technologies will contribute to the improvement of the efficiency, accessibility, and inclusiveness of the MRT system.

The government of Singapore is also investing heavily in research and development of the transport sector and has taken a host of initiatives. The LTA has allotted S$25 million for mobility-related research and technology trials over the next five years that would shape the future of transport in Singapore (Tan 2018c). Together with Singapore University of Technology and Design, LTA set up a transport research centre that will foster collaborative research in key areas such as cybersecurity, automation and robotics, and data analytics, behavioural studies and user-centric design in transport solutions (*Channel News Asia* 2017b).

As described in the Land Transport Master Plan 2040, Singapore envisions a transport network that is convenient, well-connected, fast, and more inclusive and creates a safer, healthier and more liveable environment (Land Transport Authority 2019b). Singapore aims to achieve 20-Minute Towns and a 45-Minute City—where one can reach the nearest neighbourhood centre within 20 minutes and one's workplace within 45 minutes during peak periods by combining different modes of transport such as walk, cycle, bus, and MRT. Singapore also aims to make transport more accessible and inclusive by creating, for example, more wheelchair-accessible facilities, priority queues and cabins, resting points, and accessible overhead bridges. Singapore also envisions a land transport system that creates a safer, healthier, and more liveable environment by adopting, for example, more stringent emission and noise standards for vehicles and quality standards for automotive fuels.

4. Tackling the challenge of increasing waste in Singapore

As Singapore becomes more affluent, its residents consume more goods and services. Not surprisingly, the massive rise in the standards of living has been accompanied by a rapid increase in the production of wastes. Between 1970 and 2017, the amount of solid waste disposed of in Singapore increased from 1,260 tons a day to 8,443 tons a day, at an average rate of 4.1 per cent per annum (National Environment Agency 2017). This is lower than but comparable to the annual growth rate of 4.7 per cent in real GDP per capita, computed from the World Development Indicators.

4.1. A brief history of waste management in Singapore

Table 1: Summary of incineration plants in Singapore in operation as of December, 2018.

Name of the plant	Tuas Incineration Plant[a]	Senoko Waste-to-Energy Plant[b,c]	Tuas South Incineration Plant[d]	Keppel Seghers Tuas Waste-to-Energy Plant[b,c]
Year of completion	1986	1992	2000	2009
Site area (ha)	6.3	7.5	10.5	1.6
Capacity (tonne/day)	1,700	2100	3,000	800
No. incinerators	5	6	6	2
Generation capacity (MW)	30	36	80	22
Disposal fee (S$/tonne)	77	81	77	77

[a] https://www.nea.gov.sg/docs/default-source/our-services/tip-brochure.pdf

[b] http://www.keppelseghers.com/en/download.ashx?id=8667

[c] http://nea.websparks.sg/docs/default-source/our-services/kstp-brochure.pdf

[d] https://www.nea.gov.sg/docs/default-source/our-services/waste-management/tsip-brochure_printed-2018.pdf

In the early stages of development, wastes were separated to recover the recyclable and reusable products in Singapore. This was done due to economic viability rather than environmental reasons (Bai and Sutanto 2002). The remaining wastes were mostly landfilled. However, Singapore has limited area for landfill and the need to contain the volume of wastes for landfill had become increasingly apparent by the late 1970s. Following the opening of the first incinerator in 1979,[7] Singapore steadily increased the incineration capacity (Table 1), because incineration can reduce the volume of wastes by up to 90 per cent.

Today, wastes that are not recycled are mostly incinerated by the four incineration plants that are in operation. The heat produced from incineration is used to generate electricity. Some of the generated electricity is used for the operation of the incineration plant, and the excess is exported to the national grid. These four plants generate about two per cent of Singapore's total electricity demand (Energy Market Authority, 2018b). Besides energy, ferrous and non-ferrous metals are also recovered in a metal recovery facility from incineration bottom ash generated by the incineration plants. The remaining

[7] The Ulu Pandan Incineration Plant. This plant operated until 2009.

ashes are then moved to the Tuas Marine Transfer Stations and shipped to Semakau Landfill, which is located off the main island. The Semakau Landfill is currently Singapore's only landfill facility covering an area of 350 hectares.

The Semakau Landfill had an initial landfill capacity of 11.4 million m^3 when it commenced in 1999, and its capacity has increased by 16.7 million m^3 when its Phase II development was completed in 2015. It is expected to meet Singapore's solid waste disposal needs up to 2035 (Sidik 2015). However, increasing incineration and landfill capacities do not fundamentally address the issue of ever-increasing production of wastes. Therefore, the Singapore government has increased the efforts to systematically manage wastes, particularly since the 1990s. For example, the Waste Minimisation Unit was set up in 1991 by the Ministry of Environment and upgraded to form the Waste Minimisation Department (WMD) in 1992 with the functions to develop, plan, promote, and implement waste minimisation and recycling programs and schemes in Singapore (Seik 1997).

The Singapore Green Labelling Scheme (SGLS) was also launched in 1992 to endorse industrial and consumer products that have less undesirable effects on the environment, and is administered by the Singapore Environment Council. Products that use recycled materials or produce less waste are eligible to apply for the label. The green labels like SGLS enable potential buyers of greener products to readily identify them and possibly nudge them to purchase. The SGLS has expanded substantially in product coverage with over 3,000 certified unique products and is the region's most established eco-labelling scheme today (Singapore Green Labelling Scheme 2019).

4.2. Catching up with neighbours in waste management

Despite various policies implemented to date, Singapore has not been particularly successful in containing the amount of wastes produced. For example, the amount of municipal solid wastes generated in Singapore was around 700 kilogram per capita in 2000, up from around 550 kilogram per capita in 1985. This figure is substantially higher than the corresponding figure of 400 kilogram per capita or lower in 2000 in Japan, Korea, and Taiwan (Lu, et al. 2006). These countries have stabilised or lowered their waste generation since 1985.

More recently, Singapore has also increased efforts to promote the 3Rs—Reduce, Reuse, and Recycle. Singapore has steadily made progress in increasing the rate of recycling with the share of wastes recycled standing at 61 per cent in 2016, up from 47 per cent in 2003 (National Environment Agency 2016). The most notable increase in the rate of recycling was witnessed in paper/cardboard, horticultural wastes, wood, and scrapped tyres.

However, there has been a wide variation in the rate of recycling across different kinds of wastes. For example, the recycling rates for construction debris, ferrous and non-ferrous metals, and used slag have always been very high (90 per cent or above) at least since 2003, such that the increase in the rate of recycling was at best modest in recent years. These types of wastes are mostly industrial and tend to be generated in large quantities from a relatively small number of locations or firms. This, in turn, makes recycling comparatively easy because the economic benefits obtained from recycling relative to the costs of material collection and recovery tend to be high. Further, it is relatively easy to regulate a small number of firms that generate certain specific types of wastes.

On the other hand, for some other items such as food, ash/sludge, textile/leather, plastics, and glasses, the recycling rates remained low (20 per cent or below) between 2003 and 2016. With the notable exception of ash/sludge, a sizable fraction of these wastes comes from a large number of small waste producers such as households and small businesses (as opposed to large factories and plants). This tends to drive up the costs of material collection and recovery relative to the value of these wastes when recycled. Further, the costs of monitoring and enforcement tend to be high when there are many producers of wastes. Of course, the costs discussed above are not the only important factors that would significantly affect the recycling rate. For example, the technology for storage and processing of collected materials as well as the economic benefits of reclaimed materials also play an important role (Butlin 1977). In fact, households today still sell paper wastes and some other unwanted items of value to rag-and-bone men, locally known as *karung guni* men. Nevertheless, the difficulty associated with collecting and recovering materials from a large number of small sources like households is likely to remain as an important challenge for recycling.

This, of course, does not imply that recycling of household wastes is impossible or makes no economic sense from the societal perspective, even in the presence of relatively large costs of material collection and recovery. This is because the total *private* cost, or the sum of costs paid collectively by households, of disposing household wastes is not the same as the corresponding *social* cost. Consider the cost of refuse collection for households as an example. The private cost, or the cost that households pay for refuse collection, is determined by the type and location of residence and not by the volume of household wastes in Singapore. Therefore, even if households marginally increase the amount of wastes, the private marginal cost, or the cost that the household bears for disposing the incremental amount of waste, is zero. On the other hand, the social marginal cost, or the cost of disposing the incremental amount of waste for the society, is clearly positive. Similarly, the social net benefit of recycling may be positive even when the private net benefit for recycling is negative.

Furthermore, recycling wastes may be inconvenient in comparison to simply throwing them away. This may be true everywhere, because it is easier to dump everything together than to separate different types of wastes. Nevertheless, Singapore's housing situation arguably makes it too easy to throw away wastes instead of recycling. That is, in a typical housing unit in private apartments and publicly provided HDB flats, there is a single rubbish chute from which households can throw away most of their wastes. At the bottom of the chute, there is normally a large waste collection container, which is transferred to the garbage collection truck. The rubbish chute provides the convenience of being able to dispose wastes anytime without going out of the unit. In contrast, recycling typically requires households to bring their wastes to a designated bin outside their units. Moreover, the chute also enables households to dispose their wastes without being observed by others. Therefore, it provides anonymity and creates no peer pressure for source separation for recycling. This means that the private marginal net benefitt of recycling may be substantially lower than the corresponding social marginal net benefit.

This gap between private and social marginal costs would explain why the recycling rate for household wastes remains low at only 21 per cent in 2016 in contrast to the corresponding rate of 76 per cent for industrial wastes. It is also notable that the household recycling rates in other Asian territories such as Taiwan and South Korea are around 40-50 per cent (Wee 2017), even though international comparisons require a caution because of various methodological difficulties associated with the measurement of recycling rates.

4.3. Exploring better waste management practices

The government is well aware of the issue of waste management and a number of measures have been put in place over the last few years. In 2014, the government announced that all new public housing projects will be fitted with recycling chutes and every HDB block be provided with a recycling bin. From 2018, new non-landed private developments are required to have dual chutes and existing private condominiums one recycling bin per block (Boh 2017; Tan 2018a). Another example of modern and efficient waste management is automated waste collection through the Pneumatic Waste Conveyance System, which has already been introduced in new HDB housing areas, such as Tampines North, Punggol North, and Bidadari. In this system, wastes are sent to a central location through an underground network of concealed pipes. Further, new technologies are being tested and implemented to enable cleaner and more efficient refuse collection. For example, in Punggol's Northshore District, a Smart Pneumatic Waste Conveyance System is installed to monitor the waste disposal pattern and reduce the resources needed for refuse collection (Yeo 2015). These measures have been taken to improve the infrastructure for recycling, facilitate the participation of households in recycling, and increase the domestic recycling rate.

Besides recycling infrastructure, the government also plans to expand the overall waste management infrastructure. A new plant, TuasOne Waste-to-Energy Plant, has been under construction using the Public Private Partnership scheme, making use of the design-build-own-operate model. The plant was designed to have a contracted incineration capacity of 3,600 tons per day exclusively to the National Environmental Agency for a period of 25 years from 2019 to 2044 and a generation capacity of 120 MW

(Hyflux 2015). The plant can use the electricity for its operation and export the excess electricity to the grid.[8]

The NEA is also planning the development of an Integrated Waste Management Facility (IWMF) to meet Singapore's long-term waste management needs. The IWMF will be co-located with the Tuas Water Reclamation Plant (TWRP) to maximise their synergies and to optimise land use footprint. The IWMF will be equipped with several state-of-the-art solid waste treatment technologies that will enable it to effectively handle multiple waste streams—including incinerable wastes, recyclables, source segregated food waste, and dewatered sewage sludge from the TWRP—and optimise resource and energy recovery while minimizing environmental impact. The IWMF is expected to complete in 2027 and will have a capacity to incinerate 5,800 tons of waste per day (Boh 2016). The improved waste management infrastructure through these and other efforts will help Singapore cope with increasing wastes.

In the long run, however, further promotion of the 3Rs will be needed for Singapore to move towards a zero waste nation, which is one of the focus areas of the Sustainable Singapore Blueprint (Ministry of the Environment and Water Resources 2017). For example, work places have been required to report waste data and submit waste reduction plan from 2014 (National Environment Agency 2017). Since 2016, the Singapore Exchange (SGX) introduced sustainability reporting for all publicly listed companies on a "comply or explain" basis (Tan 2016b). In a national push to effectively manage waste, companies will have to report the packaging materials used in their products and their package waste reduction plans by the end of 2020 to the NEA (Wong 2018). These measures will make firms conscious of the environmental impact that they create.

In contrast to the policies for industrial wastes, few measures have been taken to promote source reduction and recycling of household wastes. For most recyclable

[8] There is some uncertainty about the fate of the TuasOne project at the time of writing, because Hyflux, which implements the projects together with the Mitsubishi Heavy Industries through a project company, became insolvent and has been in the midst of debt restructuring (Leong, 2018). Even if debt restructuring is successful, the completion of the project has already been delayed to early 2020 due to lack of funding (Leong, 2019).

household wastes, there is currently no price-based system such as deposit-refund system or recycling subsidies,[9] except that public waste collectors have implemented cash-for-trash programs under which households can exchange some recyclable items for cash in some HDB neighbourhoods. There are also no economic incentives for households to reduce other household wastes either, because the refuse collection fee depends on the type of the household's residential unit but not on the amount of waste that the household generates, as noted earlier.

This is in stark contrast to Japan, Korea, Taiwan, and some other countries in Europe and elsewhere. These countries have a strict source separation policy and a unit pricing system (UPS) in which households' payment for waste collection and disposal services varies according to the volume or weight of the waste collected. In a typical implementation of a UPS, households have to i) pay a fixed fee for the collection of a fixed amount of waste in a fixed time interval (and pay an extra amount in excess of that amount), or ii) purchase designated trash bags or stickers for their wastes to be collected. Under the UPS, households have an incentive to reduce wastes and increase recycling, provided that the policy is effectively implemented. However, it would require the adoption of some technologies to effectively implement a similar policy (Hong 1999) in places with a single rubbish chute to be able to identify and punish the violators of the rules of a UPS. Such technologies may include a combination of Radio-Frequency Identification (RFID), censors or cameras, and tag. Even if the technical problem of monitoring is resolved, implementing a pay-as-you-throw policy may be politically difficult as it is likely to be unpopular. For example, in a recent survey of 100 readers of *The Straits Times*, 69 opposed this idea (Teh 2019).

In Japan, Korea, Taiwan, and various other high-income countries, the burden of recycling has shifted from municipalities or households to the producers and importers through an Extended Producer Responsibility approach for some domestic electric and electronic items such as refrigerators, washing machines, personal computers, and televisions. Singapore will also follow this model and the Ministry of Environment and Water Resources will implement a mandatory e-waste management system by 2021

[9] See Palmer et al. (1997) for the property of these policies.

(*Channel News Asia*, 2018). Incentives or taxes will also be used to prod manufacturers and importers to meet specific recycling targets (Boh 2018).

The incentive policies discussed above may work if they are appropriately implemented. Nevertheless, economic incentives alone would be insufficient for two reasons. First, in a study of 10 OECD countries, non-economic motivations are very important in explaining household recycling behavior (Halvorsen 2012). A strong moral commitment, a high expectation about the effectiveness of recycling to improve environmental quality, and a positive attitude towards environmental policies in general are found to be among the most important factors influencing the recycling rate. Second, even if non-economic motivations were not very important, it would be impractical to manage everything through incentives. Consider food waste as an example. It is an important problem in the island state with 810 million kilogram of food wasted in 2017, half of which is from households. However, it will be difficult to regulate domestic food waste by economic incentives alone as it will be too costly to monitor. Therefore, it will be critical to advance the understanding of the 3Rs and foster broad environmental consciousness.

There are grassroots-level initiatives to this end. For example, the Clean Plate Campaign has been running a campaign in schools and more recently in hawker centres to raise awareness of the environmental and societal impact of food wastes (Liew 2018). Zero Waste SG, an environmental group, provides a variety of information on the 3Rs and runs campaigns to encourage recycling and to reduce the consumption of single-use plastic disposables by bringing reusable alternatives (Zero Waste Singapore 2018).

The government is also stepping up the efforts in this direction. The Ministry of Environment and Water Resources designated 2019 as the Year Towards Zero Waste (MEWR 2019). The aim is to raise the awareness of waste issues and build a strong 3R culture. Singapore has set itself a target of achieving a recycling rate of 70 per cent by 2030. Both the domestic and industrial sector have to play a pivotal role in meeting this goal. The domestic [non-domestic] recycling rates are expected to go up from 22 [74] per cent in 2018 to 30 [81] per cent in 2030. Among other objectives, this initiative will also aim to raise awareness about reducing e-waste and packaging waste, including the use of plastics. These efforts may change, if slowly, the environmental attitude and behaviour of the residents of Singapore and lead to a reduction in the waste generated and disposed.

5. Meeting water needs of the residents

With its tropical climate, Singapore has abundant rainfall with the annual average of 2,340 millimetres, well above the global average of 990 millimetres. However, there is limited scope for capturing and storing the rainwater, because of the limited land space. Nevertheless, Singapore provides a great success story in both demand- and supply-side water management.

As a country highly dependent on import of water from Malaysia—which has become a political issue from time to time—since its independence in 1965, diversifying water sources has been imperative to Singapore. Meeting the water demand is likely to continue to pose an important challenge, as the population is projected to increase substantially over the next decade and as the problem of water scarcity in Singapore is projected to be among the severest in the world, because of the depletion of surface water in the coming decades (Luo et al. 2015). Nevertheless, Singapore has an ambitious goal of achieving self-sufficiency in water resource by 2061 through local catchment, water reclamation, and desalination of seawater.

We first review the supply-side policies, which use the four national taps of imported water, water from local catchment, reclaimed water, and desalinised water. These policies have been promoted by the Public Utilities Board (PUB)—Singapore's National Water Agency, which is responsible for the collection, production, distribution, and reclamation of water. We then evaluate the demand management policies through water pricing and water conservation programs.

5.1. Managing water supply through the four national taps

Water imported from Malaysia has been an important source of water for Singapore since its independence. The two water agreements, collectively known as the Johor Water Agreements, have allowed Singapore to import raw water at 3 sen (S$0.01 by the market exchange rate) per thousand gallons and Malaysia to buy treated water at 50 sen (S$0.17) per thousand gallons up to a certain limit. The first agreement signed in 1961, the Tebrau and Scudai Water Agreement, already expired in 2011, and the second agreement signed in 1962, the Johor River Water Agreement, will expire in 2061. The price of water under these agreements has been a source of contention between the two countries. For example, Malaysia's Prime Minister Mahathir Mohamad has reportedly criticised the 1962 agreement as 'too costly' and 'ridiculous' (Naidu 2018).

To reduce reliance on imported water from Malaysia, there has been a concerted effort to achieve self-sufficiency in water supply by harnessing alternative sources. One important alternative 'national tap' is the rainwater in Singapore. Singapore is indeed one of the few countries where rainwater is systematically collected, treated, and used for the purpose of drinking. The rainwater collected through an extensive system of drains, rivers, and canals is passed on to one of the 17 reservoirs.[10] The water is then treated to make it potable. With the completion of the Marina, Punggol, and Serangoon reservoirs in 2011, Singapore's water catchment area now comprises of two-thirds of Singapore's land surface area (Public Utilities Board 2018a). The system for rainwater collection is strictly separated from the sewage system to prevent the pollution of drinking water (Tan 2017c).

Another important tap is the reclaimed water called NEWater. NEWater is produced in water reclamation plants, which collect and treat used water by microfiltration, reverse osmosis, and ultraviolet disinfection to make it potable. NEWater has been available since 2003 and scientifically tested to be well within the WHO's safety requirements and is, in fact, cleaner than other water sources in Singapore. Nevertheless, there is some skepticism about NEWater among the public, and only 74 per cent of the people approve of NEWater as suitable for drinking according to a survey (Timm and Brian 2018). Currently, NEWater is widely used in industrial and commercial sectors, including wafer fabrication plants where the required water quality is more stringent than that for drinking water. NEWater produced in five existing water reclamation plants supplies 40 per cent of Singapore's current water demand today. It is expected to meet 55 per cent of the water needs by 2060.

[10] The system for collecting rainwater, particularly stormwater, is also important for flood management. See, for example, Public Utilities Board (2014).

Finally, as a country surrounded by the sea, Singapore has huge potential to transform sea water into potable water. Currently, desalinated water produced from three desalination plants meets 30 per cent of Singapore's water demand (Public Utilities Board 2019). Despite the population growth and projected increase in water demand, desalinated water is still expected to meet 30 per cent of water demand in 2060. Thus, NEWater and desalinated water combined are expected to meet 85 per cent of Singapore's water requirement by 2060.

The increased reliance on local catchment, reclaimed water, and desalinised water would reduce the dependence on imported water from Malaysia and help achieve sustainable water supply. Nevertheless, the reliance on reclaimed and desalinised water implies increased energy consumption per unit of water supplied, because both reclaimed and desalinised water currently use reverse osmosis for their production, which is energy-intensive. Therefore, it is important to find more energy-efficient ways to reclaim or desalinise water. Indeed, ongoing research explores alternatives such as electrodeionisation and biomimicry.

5.2. Managing water demand through prices and conservation programs

To ensure a sustainable supply of water, adequate demand management policies must complement the supply-side policies so that no drop of water is wasted. Broadly speaking, the PUB has implemented the following three types of policies to manage demand: water pricing, mandatory water-efficiency labelling, and water conservation programs. Below, we review each type of policies.

Among these types of policies, pricing policy is arguably the most important policy instrument to signal the scarcity of the resource and to give the end users of water a right incentive to conserve water. The water price in Singapore takes into account the entire national water system's costs and consists of water tariff, water conservation tax, and waterborne fee. Water tariff reflects the cost of collection, treatment, and distribution of water, whereas water conservation tax is levied to create awareness among Singaporeans about the scarcity value of water and to encourage water conservation. Waterborne fee is collected to defray the cost of treatment of used water and maintain the used water network (Public Utilities Board 2018b). Each of these three price components depends on the type of water (e.g., potable water, industrial water, and NEWater) and, for households, whether the cutoff level of 40 m^3 per month—above which higher rates apply—is exceeded. For households with monthly consumption below the 40 m^3 threshold, water tariff, water conservation tax, and waterborne fee are respectively S$1.21/$m^3$, S$0.61/m^3, and S$0.92/$m^3$, as of March 2019.

Water prices in Singapore were increased for the first time since 2000 in two steps—in July 2017 and July 2018—to accommodate the rising costs of producing high quality recycled and desalinated water. Even though the price increment was implemented over two years, there was an overall prince increase of 30 per cent. Because water is a necessity and has no close substitute, a substantial increase in water price can have a severe negative impact on poor households. For this reason, price measures to conserve water are often controversial around the world. Singapore mitigated this issue by increasing the U-save rebates, which can be used to offset the utility bills, so that there is no increase in water bill on average for one and two-room HDB households after the rebates. Nevertheless, in a poll of over 1,100 citizens conducted after announcement of the water price hike, 43 per cent of those polled disagreed that it was reasonable to increase water prices to fund higher costs of production and encourage conservation. Only 32 per cent agreed while the rest were neutral (*The Straits Times* 2017).

The second policy instrument is the mandatory water efficiency labelling. In 2009, the mandatory Water Efficiency Labelling Scheme (WELS) was introduced. The label carries different number of ticks depending on water efficiency, such that consumers can easily distinguish between water-efficient and water-inefficient appliances and fittings. The most water-efficient ones carry three or four ticks, depending on the type of appliance or fitting, whereas the least water-efficient ones carry no tick. The WELS was first applied to taps, low-capacity flushing cisterns, and urinals (Teo 2009), and it has been expanded to dishwashers and washing machines. Mandated water-efficiency levels have increased over time such that taps with 0-ticks have been phased out. From April 2019, the PUB will mandate the sales, supply, and installation of minimum 2-tick water fittings in all new and existing premises undergoing renovation.

The third policy instrument is water conservation program. Through various educational programs and advertisements, the PUB has tried to raise awareness about the importance of and the effective ways for water conservation. For example, households are encouraged to adopt good practices that are effective in reducing water consumption, such as repairing leaks, reusing rinse water, washing utensils in a filled sink instead of under a running tap, reducing shower time, and being cognizant of the monthly water bills. The PUB also helped households reduce water usage, for example, by replacing old water closets with more efficient ones and by installing smart shower devices to provide real-time information.

PUB introduced a redesigned utilities bill in a joint initiative with the SP Services, EMA, and City Gas from August 2016 to raise the awareness of consumers about their water, electricity, and gas usage (Goy 2016). Unlike the old design, which only provided the consumers with their consumption compared with the national average, the new design allows consumers to view their consumption relative to the residents living in the same block and in a similar kind of housing. The new design also provides personalised tips to improve water and energy efficiency. With these initiatives, Singapore's per capita household water consumption declined from 165 litres per day in 2003 to 143 litres per day in 2017 (Public Utilities Board 2018c). This presents a more promising picture than other major cities in the region such as Hong Kong, Taipei, and Tokyo, where per capita household water consumption was above 200 litres per day in 2016.

Singapore's success in containing water consumption owes to the households' efforts to engage in water conservation practices. According to Mr Masagos Zulkifli, Minister of Environment and Water Resources, the mandatory WELS has made households more aware of water efficient products, thus helping them reduce consumption. In 2017, automated meters installed in 500 households in Punggol helped households keep track of their daily water usage through the use of a mobile application (Tan 2018b). Hence, improved technology has an instrumental role to play in further reducing household water consumption in Singapore. In the light of such encouraging results, the government has revised the target for per capita household water consumption for 2030 from 140 litres per day to 130 litres per day (Yusof 2018).

The PUB also implemented water conservation programs targeted at workplaces. In 2007, the PUB launched the Water Efficiency Fund to encourage organisations to study the best water management practices. This can be done by hiring researchers and water experts who engage in active research within the organisation. If the organisation successfully reduces water consumption by at least 10 per cent, the PUB will co-fund the project.

Since 2015, organisations that have water consumption of at least 60,000 cubic metres in the previous year are required to submit a Water Efficiency Management Plan. These organisations are strongly encouraged to implement water efficiency measures identified in the plan. To recognise the top water-efficiency performers, the Water Efficiency Awards, which evolved from the Water Efficient Building Certification, was introduced in 2017. This award is given to top performers in each of the following categories: office, retail, hotel, wafer fabrication, refinery, school, and estate.

5.3. Addressing future water challenges for a liveable and sustainable Singapore

Since water is a scarce resource in Singapore, the management of water supply and demand is of primary importance for the sustainable use of water. Besides, water ways and reservoirs may also serve as a place for recreation and contribute to the liveability of the city. In 2006, the PUB launched the Active, Beautiful, Clean Waters (ABC Waters) Programme to revamp the blue spaces. More than 100 locations across the island have been identified as potential ABC Waters sites. As of December 2017, 36 sites had been made accessible to the public, and this project is expected to complete by 2030. In addition to providing amenity, the ABC Water sites would also promote the appreciation of reservoirs and water ways.

The water scarcity that Singapore faces may also create an opportunity. The PUB and Economic Development Board jointly lead the initiative of uniting government organisations, private companies, and research institutions to transform Singapore into a thriving global hub for research and development for water solutions. If successful, the water solutions developed in Singapore would make Singapore more liveable and sustainable, and, at the same time, better prepared for and resilient to the perils of the

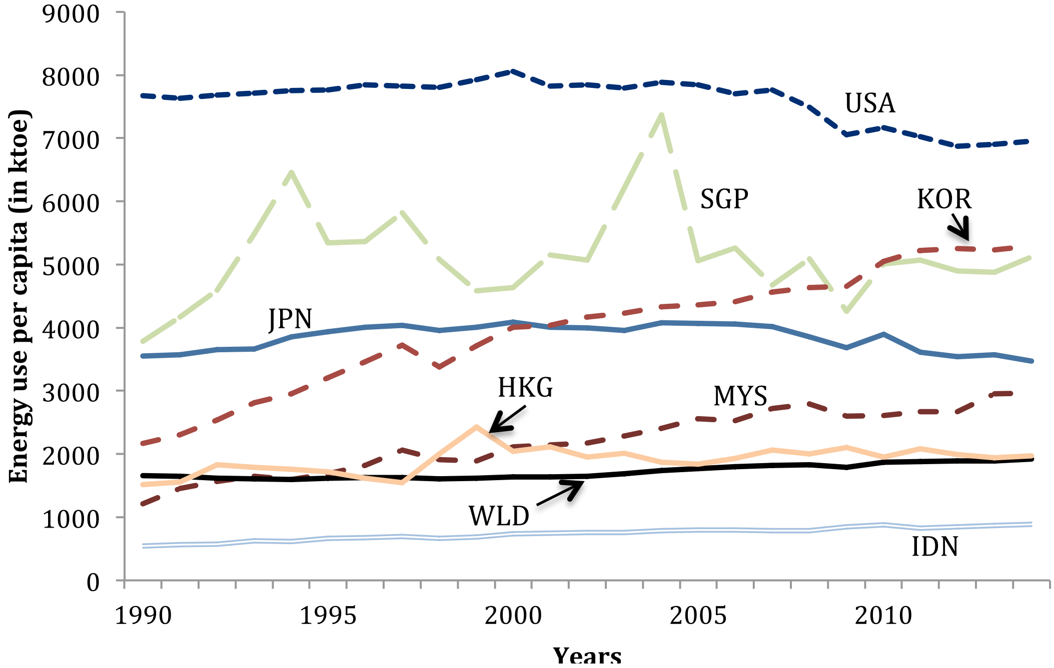

Figure 3 Cross-country comparison of energy use per capita (Source: World Development Indicators)

future uncertainty about water. The new technologies, knowledge, and experiences generated in Singapore may also be useful to other cities around the globe, which in turn might bring about new jobs and business opportunities to Singapore.

6. Addressing Singapore's increasing energy demand

In light of rapid industrialization and an ever growing population, Singapore's energy consumption has increased by 38 per cent from 10,700 kilotonne of oil equivalent (ktoe) in 2009 to 14,700 ktoe in 2017. Today, the energy consumption per capita in the island state is among the highest in Asia. It is much higher than other high income countries such as Hong Kong and Japan as well as the neighbouring countries of Malaysia and Indonesia, with the exception of South Korea. The situation is more apparent when one compares Singapore's per capita energy consumption to the world average (Figure 3).

Though per capita energy consumption is high in Singapore, its energy efficiency is among the highest in the world. Singapore's GDP per unit of energy use (constant 2011 PPP $ per ktoe) is not only the highest in South East Asia but also higher than some other developed economies around the globe such as Germany, Japan, and the US according to the World Development Indicators. Singapore's energy consumption depends, directly or indirectly, on fossil fuels such as petroleum and natural gas. In 2016, petroleum products and natural gas accounted for 61 per cent and 9 per cent of energy consumption (Energy Market Authority 2018b). Electricity, most of which is generated by burning fossil fuels, accounts for an overwhelming majority of the rest of energy consumption, and this pattern has not changed much over the past decade.

To satisfy the large energy demand for its residents and businesses, Singapore imports fuels and fuel products from other countries. In 2017, 189.3 million tonnes of oil equivalent (Mtoe) of energy was imported, out of which 58.0 Mtoe was crude oil, 120.5 Mtoe petroleum products, 9.9 Mtoe natural gas, and 0.9 Mtoe pete and coal (Energy Market Authority 2018b). The main sources of crude oil are mostly in the Middle East such as the United Arab Emirates, Qatar, Saudi Arabia, and Kuwait, whereas petroleum is imported predominantly from Asia, including China, India, and Malaysia.[11] It should be noted, however, that not all of the imported energy is consumed within Singapore. Singapore is the undisputed oil hub in Asia and exports 102.6 Mtoe of energy mostly as petroleum products to destinations such as Malaysia, Indonesia, and China.

Natural gas is also an important source of energy. Besides industrial demands and domestic and commercial demands for cooking and heating, natural gas also contributes to about 95 per cent of electricity generation. Singapore has been highly dependent on Indonesia and Malaysia for import of natural gas. Therefore, to reduce dependence on the two neighbouring economies, Singapore began importing liquefied natural gas from other countries such as the United States of America, Australia, Norway, Russia, Qatar, and Brunei (Soh, 2016).

While diversification of import sources is likely to make Singapore less vulnerable to external shocks and ensure a secure and reliable supply of energy, it is critical to reduce the dependency on fossil fuels and to harness renewable sources such as solar and wind energy to enhance the sustainability of energy use in Singapore.

[11] Based on the import value reported by Singapore in the UN COMTRADE data in 2017, using as reported HS codes 2709 for crude oil and 2710 for petroleum.

Since modern technologies invariably rely on electricity, its consumption deserves a special attention. The composition of electricity consumption across different sectors has been steady in Singapore. As of 2017, industry-related activities (manufacturing, construction, and utilities) consume the largest fraction of electricity (21,516 GWh) followed by commerce and service (17,804 GWh), household (7,295 GWh), and transportation (2,751 GWh) sectors. Within the household sector, the average annual household electricity consumption in private housing is 7,936 kWh, which is far more than that in public housing (4,333 kWh). Thus, there is arguably a case for advocating reduction in electricity consumption in private housing.

In the remainder of this section, we first discuss changes in Singapore's electricity market in an effort to make it more efficient. We then explore opportunities for Singapore to harness alternative sources of energy and reduce the use of fossil fuels. We also evaluate some of the energy conservation and emission reduction policies adopted by the government to make energy use of the city-state more sustainable.

6.1. Singapore's electricity market and its evolution over time

Singapore's experience with electricity dates back to the early 20th century. With the opening of the Mackenzie Road Power Station in 1905, electricity was provided only to limited areas in the central part of Singapore. In 1927, St James Power Station began generating electricity with a 2 MW steam turbo-alternator set, and the consumer base also increased. For example, between 1920 and 1930, the number of consumers connected to mains electricity went up from 1,452 to 13,100. Both the consumer base and generation capacity have continued to grow over time with a notable exception of the period around the Second World War. After the war, the first 25 MW generator in Pasir Panjang was placed in service in 1952. By 1960, combined generation capacity of Pasir Panjang and St James Power Stations reached 188MW (Public Utilities Board 1985).

In 1965, the then Prime Minister Lee Kuan Yew opened a new power plant in Pasir Panjang to further increase the generation capacity. Subsequently, Jurong, Senoko, and Pulau Serava power stations opened in the 1970s and 80s. Singapore also entered into a deal with Malaysia in 1986 where it could share electricity with its neighbouring

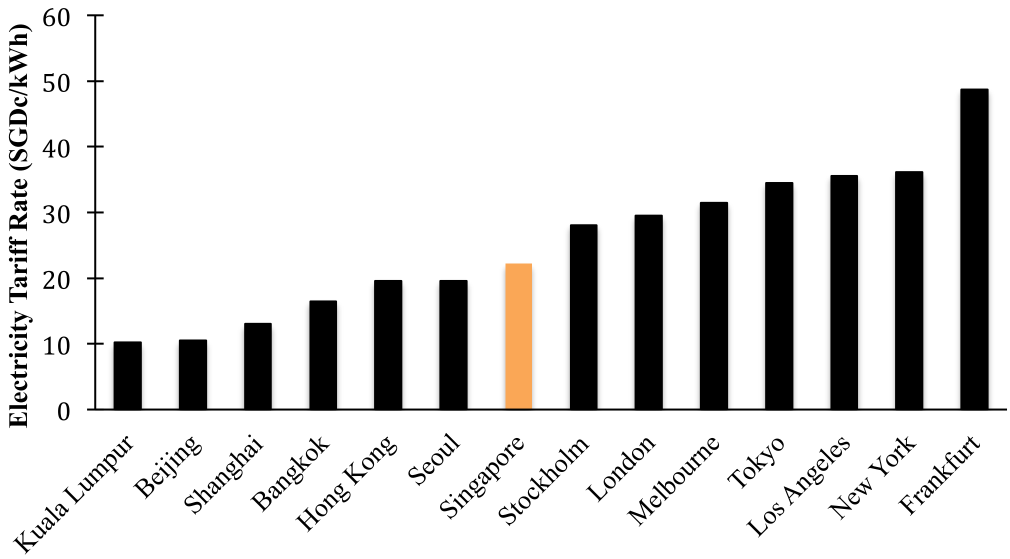

Figure 4: Comparison of electricity tariff rates across cities around the world based on electricity prices in 2017 (Source: the Lantau Group cited in https://www.ema.gov.sg/statistic.aspx?sta_sid=20190319gX6WhmRypOKm).

country during power outages. In 1995, PUB's electricity and piped gas undertakings were corporatised to liberalise the market and allow competition. Opening up the market not only resulted in increased efficiency but also complemented PUB's investments in infrastructural needs of the energy sector and was a major precursor to Singapore's eventual privatisation of the energy sector. In 1998, the Singapore Electricity Pool was formed to allow competitive price bidding among the power generation companies. In 2001, two major developments related to the energy sector took place; (i) electricity generation was separated from transmission and distribution functions, and (ii) the Energy Market Authority (EMA) was set up to further monitor the liberalisation process and to ensure a dependable and safe energy supply. About 250 business consumers with an electricity demand of more than 2 Megawatt (MW) were allowed to choose their own suppliers. In 2003, the National Electricity Market of Singapore (NEMS) opened up for trading and retailers could now buy electricity in bulk from the wholesale market to supply to consumers. In 2006, large consumers whose average monthly electricity consumption was 10,000 kWh and above became eligible to switch to a retailer of their choice.

Since the start of the NEMS, generation companies have been obliged to place bids every half an hour to sell electricity in the wholesale market. The SP Group (SP Services) and retailers buy electricity in bulk from the wholesale electricity market, following which the SP Group, through its member SP PowerGrid, transmits the electricity generated to its consumers. An analysis of NEMS by Chang (2007) suggests that the NEMS is quite competitive, even though the generation market is highly concentrated.

Until 2017, households and small business consumers could buy electricity only from SP Services at the regulated tariff. From 2018, the Open Electricity Market has been rolled out in phases and these relatively small entities now have the right to buy electricity from a retailer of their choice (non-contestable consumers) or directly from the wholesale market (contestable consumer). By building up the generation capacity, which is over 13,614.4 MW in 2018 (Energy Market Authority, 2018b), and by liberalising the electricity market, Singapore managed to provide electricity at an affordable price through increased capacity and competition. The prevailing tariff rate for electricity in Singapore is 25.52 cents per kWh (Energy Market Authority 2019), which is higher than some cities in other Southeast Asian countries but considerably lower than many other cities in Europe and the United States (Figure 4).

The brief history of Singapore's electricity sector we discussed above offers a great story of transforming a primitive market into one that was liberalised in an orderly fashion through a well-planned process. The gradual liberalisation of the electricity sector has made energy sector become more competitive and efficient without disrupting the steady supply to households and businesses. Furthermore, the introduction of the Open Electricity Market provided consumers with an alternative, giving them an opportunity to use electricity—a necessity in a liveable city—at a more affordable rate. Further, the Open Electricity Market allows the consumers to choose "greener" options. For example, ES Power offers "100% Carbon Neutral Electricity" options,[12] whereas Sunseap offers

[12] https://oem.espower.com.sg/. Accessed on 8 April 2019.

100% solar energy option.[13] Therefore, the Open Electricity Market can also support the choice that Singaporeans make for sustainable use of energy.

6.2. Harnessing renewable sources of energy

As we have seen above, Singapore primarily depends on import of fossil fuels to meet its energy demand. Though a large amount of energy can be generated by burning fossil fuels, it entails emissions of various air pollutants and contributes to global warming through the emission of carbon dioxide. Further, fossil fuels are non-renewable. Therefore, it is imperative that Singapore harnesses alternative, renewable sources of energy to meet the energy demand of its residents and businesses sustainably.

Currently, Singapore's use of renewable energy is mostly limited to solar power, with its contribution to electricity generation being less than 1 per cent. With an average annual solar irradiance of 1,580 kWh/m^2/year, Singapore has tremendous potential to expand the use of solar PV generation since it receives 50 per cent more solar radiation than temperate countries (Energy Market Authority 2018a). Thus, even though solar energy is largely untapped at the moment, it can potentially help Singapore attain a number of important objectives. First, solar energy is renewable and solar PV generation entails virtually no emission of carbon dioxide once the solar panels are installed. Therefore, the use of solar energy significantly improves the environmental sustainability of the city-state. Second, by reducing the reliance on import of fossil fuels, Singapore will become less vulnerable to the fluctuations in oil and gas markets. Third, the solar energy can help fulfil peak demand of electricity since the maximum output of solar energy occurs during the afternoon, which coincides with the time of peak energy use.

Despite these potential benefits, Singapore's ability to scale up the installation of solar panels is constrained by its land area. In spite of this problem, there has been considerable increase in solar PV from 25.7 MW in 2014 to 112.3 MW in 2017. Further, the number of grid-connected solar PV installations increased noticeably from 637 in 2014 to 2117 in 2017. The EMA aims to further raise the adoption of solar power to 1

[13] https://www.sunseap.com/. Accessed on 8 April 2019

gigawatt-peak (GWp) in the next decade, which will help Singapore achieve the target of reducing emissions intensity by 36 per cent from the 2005 level (Energy Market Authority 2018a).

While geothermal and hydropower are not viable modes of electricity generation in Singapore, tidal and wind generation have been explored. Even though the potential of these sources to generate power is limited in Singapore, they can complement solar power, as they are able to generate power at night or under the cloud.

Singapore's first tidal turbine system, planned and constructed by the Energy Research Institute of Nanyang Technological University, was built off Sentosa in 2013. Though the majority of the sea space in Singapore is used for anchorage, ports, and shipping lanes, there are plans to construct around 150 to 200 tidal turbine systems over 15 years, which would generate 200 MW of power (Ee 2013). In 2017, Singapore's first long-span wind turbine was installed at Semakau Landfill, and it can generate sufficient energy to power around 45 four-room HDB units per year (*Channel News Asia* 2017a). The power generated from the wind turbine is connected to a hybrid microgrid, which can consolidate power generated from other sources such as solar, tidal, diesel, and power-to-gas technologies and collectively supply enough power for 1,000 four-room flats (Wong 2016). In the first phase of the project, a microgrid facility with more than 4,500 m^2 of photovoltaic cells and a large-scale energy storage system was installed.

While the technologies discussed above are still needed to be tested and calibrated, energy generated from solar, wind, and tidal power and combined through microgrid may have the potential to enable Singapore to reduce dependency on import of fossil fuels and make its electricity supply more sustainable.

6.3. Promoting energy efficiency

The Singaporean government has taken several policies to increase the awareness of and promote the practice of energy conservation among households. One example is the Project Carbon Zero, a competition held in 2009 among primary- and secondary-school students, and its objective was to see whether children could nudge their parents to change their energy consumption patterns. The energy consumption of the participating households was monitored over the baseline period (January-April) and then during the competition period (May-August). If the average energy consumption in the competition period was less than that in the baseline period by more than 10 per cent, children were awarded with a certificate and a S$10 book voucher. There were also rewards for the participating schools and the best performing students. Agarwal et al. (2017) found that households within 2 kilometres of the participating schools consumed 1.8 per cent less electricity at the block level than those residing outside the 2-kilometre school zone. This indicates that children can act as an agent of change in household behaviour. He and Kua (2013) showed that a combined use of leaflets and stickers used under the Eco-living Program—implemented in the Hong Kah North Residential Council in the southwestern part of the city—resulted in a 15.8 per cent decrease in electricity consumption between October 2010 and July 2011. Besides these programs, the NEA has rolled out the Save Energy Save Money initiative to encourage households to cultivate energy-saving habits, such as switching off appliances at the power socket, switching off the heater after use, using more energy-efficient appliances, and using fan instead of air conditioner (National Environment Agency 2018a).

To help consumers make informed decision, the Mandatory Energy Labelling Scheme (MELS) was introduced in 2008 for regulated goods (air-conditioner, refrigerators, clothes dryers, televisions, and lamps). Similar to the WELS, appliances are given different numbers of ticks according to their energy efficiency under the MELS. The Minimum Energy Performance Standards (MEPS) implemented in 2011 has complemented the MELS by prohibiting the sales of appliance models that did not meet the minimum specified energy efficiency level. The increase in energy efficiency through the implementation of the MELS and MEPS not only contributes to the sustainable use of energy but also reduces the households' monthly electricity bills.

Guidelines for energy efficient practices are in place not only for households but also for energy intensive companies. Since 2013, energy intensive companies are required under the Energy Conservation Act to register with the NEA and implement mandatory energy management practices. Upon registration, companies must i) appoint an energy manager, ii) monitor and report energy use and greenhouse gas emissions annually, and iii) submit energy efficiency improvement plans annually (National Environment Agency 2018b).

Both private and public sector entities have also been encouraged to improve energy efficiency through various programs. For example, the Energy Efficiency National Partnership, a voluntary program implemented in 2010 and targeted towards businesses consuming a large amount of energy, helps these businesses increase their long-term competitiveness through learning network activities, provision of energy-efficiency related resources, and incentives and recognition (National Environment Agency 2019). The NEA also provides the Energy Efficiency Fund to help businesses become more energy efficient. Under the Public Sector Taking the Lead in Environmental Sustainability initiative, public sector agencies have been encouraged to implement environmental sustainability measures that encompass energy efficiency, water efficiency, and recycling (National Environment Agency 2018c).

Overall, Singapore appears to have taken some steps towards more sustainable energy use. Consumers in Singapore now have an opportunity to make greener choice for electricity supply with the liberalisation of electricity market. Various policies have been put in place to promote efficient use of energy in household, private, and public sectors. Nevertheless, given that Singapore has among the highest energy consumption per capita in the world and the use of renewable energy remains very limited, there remains a large room for improvement. To ensure its environmental sustainability, Singapore will have to improve energy efficiency, use more renewable sources, and reduce its carbon footprint.

7. Moving forward

Singapore has achieved a truly remarkable transformation since its independence in 1965. At the time of independence, Singapore's public policy primarily focused on meeting the pressing needs of the time. However, policymakers in Singapore also had a long-term perspective. The presence of good planning, which is particularly apparent in land use, transportation, and water policies, helped Singapore achieve sustained economic growth for five decades with little interruptions in between. Further, even though Singapore's policies have been primarily directed towards the promotion of economic growth, some considerations have always been paid to the living environment (Quah and Soh, 2014). As Singapore's standard of living goes up, the emphasis of public policies has shifted towards the enhancement of the city-state's sustainability and liveability, particularly over the past decade. We have provided an overview of some of the important policies and their historical backgrounds. In this section, we draw some lessons from these policies and discuss the challenges and opportunities that may lie ahead of us.

7.1. Incentives vs normative messages for sustainable policies

Singapore has implemented various measures to provide relevant information to the consumers through labelling and certification such as the Green Mark Scheme, WELS, and MELS, which can be expected to help people make informed choices. Another important feature of Singapore's policies is the extensive use of economic incentives. As we have seen, various incentive policies have been used in land use, transportation, water, waste management, and energy policies. Among all, the extensive use of road pricing is unique to Singapore and particularly noteworthy. Singapore's policy is also notable in its flexibility. The Singaporean government quickly tweaks its policies as needed. This is important for the success of policy, because the behavioural response is generally difficult to anticipate perfectly. Therefore, even when there are some loopholes in the policy, Singapore tended to plug them swiftly.

While economic incentives can be a powerful policy instrument, incentives alone may not be sufficient. If incentive policies are not implemented appropriately, they may convey a wrong signal to the public. To make this point, take as an example a randomised field experiment involving child-care centre in Israel by Gneezy and Rustichini (2000). They studied the impact of the introduction of fine for parents picking up their children from child-care centre after closing time. They found that the parents in the treatment group—who are subjected to the fine—were actually more likely to pick up their children late than those in the control group—who did not face the fine. Further, the number of late-coming parents in the treatment group did not reduce even after the fine was removed. One plausible explanation is that the social norm may change with the introduction of the fine. That is, parents may feel more justified in picking up their children late as they now pay for the service provided by the caregivers who do not have to work for free. Further, the new social norm seems to persist even after the fine was removed.

While Gneezy and Rustichini (2000) offer a cautionary tale of economic incentives, its relevance to sustainability policies in Singapore is unclear. Nevertheless, we argue that providing a clear normative message is potentially helpful. In a randomised experiment conducted with 1,000 HDB households in Ang Mo Kio in 2016, households that received normative messages about water usage, which either appeal to the social norms by highlighting how the household compares with others in the neighbourhood or to the moral by highlighting the importance of doing right. In this study, households that received normative messages significantly reduced water usage. Further, adding economic incentives to conserve water had no additional impacts on water conservation efforts (Leong and Goette 2019).

This, of course, does not mean that normative message would always work or be more effective than economic incentives. For example, in a randomised study of households in the Kansai region of Japan, Ito et al. (2018) found that the economic incentives, which charge a high electricity tariff during the critical peak-demand hours, significantly reduced electricity demand during the treatment hours. Further, the economic incentives also appear to have induced treatment households to adopt more energy-saving behaviour, such that their energy consumption outside the peak-demand hours was also lower than the control households, and the treatment impact was lasting. On the other hand, moral suasion treatment, which provides consumers with a message describing the need for energy conservation during the critical peak-demand hours, reduced the energy consumption only marginally and insignificantly and its impact was short-lived.

The discussion above, therefore, suggests the importance of exploring both economic incentives and normative messages to raise the sustainability of the city-state, since they can potentially complement each other. Rather than looking at normative messages and economic incentives as substitutes for each other, the Singaporean government should exploit the complementarities available in these two kinds of policy design. Fully exploring both options is also important because the details of implementation is likely to matter. For example, economic incentives can be implemented under the names of prices, taxes, fees, tariffs, fines, charges, and so on. In terms of the monetary transaction, they may mean the same thing, but the message that they convey can be very different. Similarly, how well normative messages work depends on how well these messages are crafted as well as how they are conveyed. Indeed, Singapore also implemented various programs to send normative message to households and businesses in addition to economic incentives. Experimental economics approach can elucidate how people respond to different types of policies and help policy-makers find a best mix of economic incentives and normative messages (See, for example, Lee and Tan (2019)).

7.2. Important areas of challenge

While there are many elements of success in Singapore's sustainability policy, all areas we reviewed in this paper—land use, transportation, water, waste, and energy—are likely to continue to pose important challenges in the coming decades. In particular, two issues stand out as the areas that need more work. First, Singapore would need to make more efforts to contain the emission of wastes to bring it down to the level of other Asian cities. To this end, it would be important to take more measures to raise the awareness of the importance of 3Rs and make it easier to participate in recycling. For example, unlike some other cities, it is hard to come across recycling bins for recyclables such as plastic bottles and cans in the streets and the public spaces of Singapore. Cutting the trouble of travelling for recycling by adding the necessary infrastructure would be a first step to facilitate the participation of the public in recycling.

Second, Singapore's heavy reliance on import of fossil fuels will need to be addressed. As with water, Singapore's dependence on import of fossil fuels is a potential source of vulnerability and goes against the sustainable use of energy. For these reasons, it is imperative that Singapore further pushes for energy efficiency and use of renewables. Particularly for energy efficiency, the efforts by the private sector are indispensable, because the industrial-related and commerce and services-related sectors account for, respectively, about 65.7 and 11.5 per cent of the total final energy consumption in 2016 (Energy Market Authority 2018b).

It is important to note that the push for energy efficiency or better environmental performance in general does not necessarily harm the businesses. Clearly, efficient use of resources, including energy and water, makes business sense. Furthermore, better corporate image can be attained by improving the environmental performance. Therefore, energy efficiency and better environmental performance do not need to come at a sacrifice of business.

To highlight this point, we compiled a dataset for the companies underlying the STI Index, which tracks the performance of the top 30 companies listed on SGX using published sustainability reports and other sources. We then looked at the relationship between the average yearly changes in market capitalization and changes in environmental performance indicators such as electricity usage, water usage, and carbon dioxide emissions between 2013 and 2017. Because the sustainability report is not mandatory and 'comply or explain' policy was only introduced in 2016, we only have data for 11-13 companies, depending on the environmental performance indicator. Therefore, our analysis is limited by the data availability.

Subject to this caveat, when the company becomes larger in terms of the market capitalization, electricity usage, water usage, and carbon dioxide emissions tend to increase during the observation period. Figure 5, for example, shows that there is a positive correlation (ρ=0.33) between the change in market capitalisation and change in carbon dioxide emissions. We also found that the change in market capitalization is positively correlated with the change in water usage (ρ=0.42) and electricity usage (ρ=0.10).

This result is not surprising. Nevertheless, there are companies that have achieved growth in market capitalization and improved the environmental performance between 2013 and 2017. In particular, City Development (C09), a property and hotel conglomerate engaged in real estate development, is worth highlighting. It has reduced water usage, electricity usage, and carbon emissions by 9 per cent, 5 per cent, and 8 per cent annually during our observation period, while achieving an average annual increase of nearly 7 per cent in market capitalization. Besides these achievements, the City Development has won a number of environmental awards over the last decade and achieved the ISO 140001 certification for all functions at headquarters in 2008.

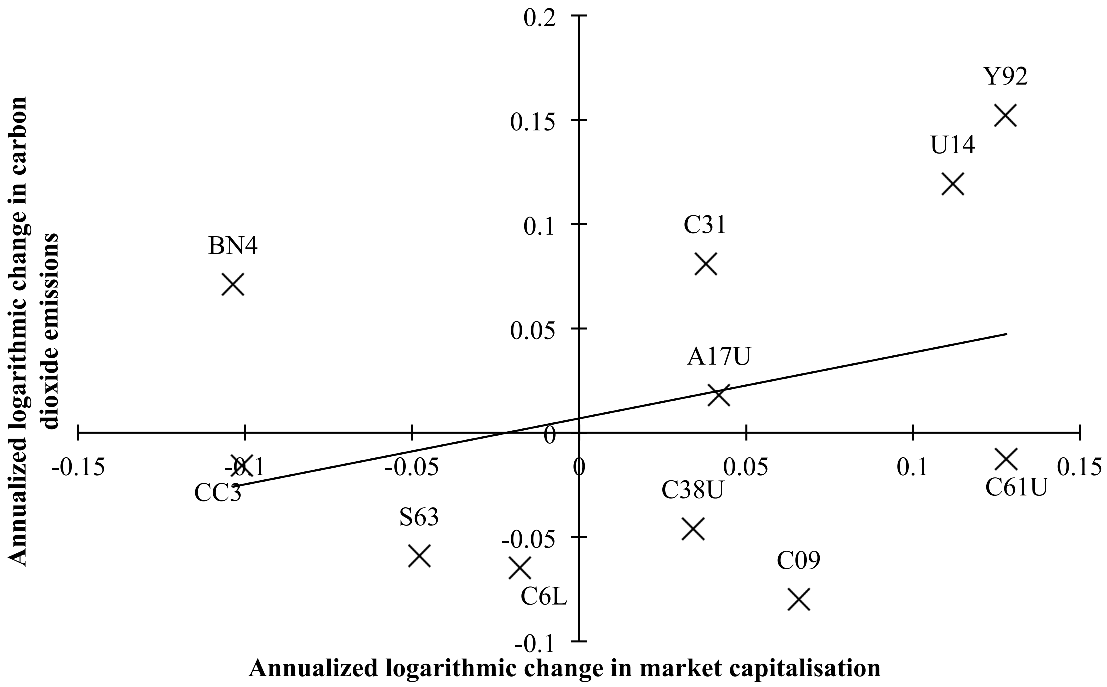

Figure 5. Changes in market capitalisation and changes in carbon emissions for companies in STI Index.

Clearly, these achievements cannot be attributed to a factor that is specific to the real estate sector, because other major real estate and property companies such as CapitaLand (C31), Ascendas Real Estate Investment Trust (A17U) and UOL Group (U14) have expended more energy, water, and electricity at the time of their growth in market capitalization. Instead, we argue that the City Development's environmental achievements can be attributed to its commitment to "Environment, Social and Governance" since 1995 when it established CSR-centric vision and adopted business model of "Conserving as we Construct."

Obviously, the case of City Development is simply an anecdote and it remains to be seen whether other businesses can simultaneously achieve the growth in business and improvement in environmental performance. Nevertheless, there are other success stories of doing well by doing good elsewhere (e.g., Laszlo (2008)). Thus, policies to encourage such business models would be conducive to Singapore's journey towards a sustainable and liveable city. For example, the government can implement standard market instruments such as emissions taxes, tradable permits, and subsidies for emissions reduction. In fact, Singapore just implemented a carbon tax in 2019 for large emitters—mainly from the petroleum refining, chemical, and semiconductor sectors—at the rate of $5 per tonne of emissions. This will go up to between $10 and $15 per tonne of emissions by 2030, but there is a scope for increasing the coverage of emitters and tax rates. Besides market instruments, the government can also implement policies to promote the sharing and transfer of new knowledge, management, and technologies across firms.

7.3. Potential opportunities for Singapore

Singapore has great potential to lead the world in transforming a city to become more sustainable and liveable and in creating a great place to live, work, and play. Singapore has been dubbed as a place where "East Meets West" and its culture is a confluence of various Asian and European cultures, which has allowed the country to take advantage of the strengths of both. As a young nation with an effective government and a good pool of talent, Singapore continues to be well positioned to test and adopt new ideas, technologies, and policies to tackle new challenges. In particular, Singapore can fruitfully take advantage of automation and artificial intelligence (AI) to optimise the allocation of resources to make the city simultaneously more liveable and sustainable.[14]

Transportation is a good example. Private cars that are used for commuting are typically driven only a few hours a day at most. During the rest of the day, they simply occupy parking lots. Therefore, this leads to an inefficient use of space and cars. While public transportation does not suffer from this issue, it can only serve the routes that have sufficient ridership. Therefore, if self-driving cars can be rented out to end-users during their idle time, both space and cars can be used more efficiently. Further, if the rides

[14] Singapore ranks 1st together with Australia and Sweden in Technological Readiness Ranking for 2018-22 (Economist Intelligence Unit 2018)

among end-users can be shared, energy can be more efficiently used to move people. These possibilities would also help reduce the need to own a car.

When the technology matures and precision of driving improves, the efficiency of road transportation may improve. In a situation where pedestrians are separated from motor vehicles, all cars on the roads are AVs, and they can communicate with each other in an orderly manner, vehicles would take the optimal route and even traffic lights may become unnecessary. In such a situation, AVs would be able to drive faster and at the same time safer than now. Since Singapore is small and densely populated, the time may come when it makes economic sense to build roads on which electric vehicles can be recharged while driving (Sweden already has an electrified road. Wireless charging is also technologically feasible). This in turn makes it easier to put smaller and lighter cars on the road as they do not need a high-capacity battery. Further, with the advancement of drone technology, air space can be used for transportation of goods (and possibly people), which in turn can potentially mitigate the space constraint on the ground.

Together with the accumulation of data, AI can often outperform human experts in prediction. This, in turn, allows us to facilitate efficient use of resources. For example, inventory, which does not produce anything on its own, can be managed efficiently with the help of AI. AI can also enable better demand prediction and supply chain management, which will enable firms to integrate retail sales and logistics better. As a result, the time, energy, and cost needed to deliver goods from producers to consumers can be saved. The potential gains from automation and AI discussed above are admittedly speculative and there are safety, legal, and other issues to be addressed. Nevertheless, these gains are not unimaginable and, if realised, may bring about a significant positive impact on a space- and resource-constrained country like Singapore.[15]

The space constraint Singapore faces also creates an opportunity to explore offshore technologies. For example, an offshore floating solar panel system, which will

[15] While the discussion on the demographic challenges of Singapore is beyond the scope of this paper, it is worth noting that Singapore's total fertility rate was 1.14 in 2018, among the lowest in the world. The use of automation and AI can both be spurred by and help mitigate the issue of ageing society (for a related discussion, see Acemoglu and Restrepo (2018)).

be able to generate 6,388 MWh of renewable energy annually, is already being built (Tan, 2018d). Lim (2017a, 2017b) even argues for building nuclear power plants on floating platforms. Even though the scalability of these ideas within Singapore's water may be limited given Singapore's busy maritime environment, new types of offshore technologies can simultaneously address Singapore's energy issue and add to Singapore's competitive advantage.

While this paper has focused on domestic issues, Singapore will not be able to escape form the challenges of climate change. Indeed, Singapore has become increasing wary of this fact as can be seen from the 2019 National Day speech by Prime Minister Lee Hsien Loong (Prime Minister's Office 2019). With about 30 per cent of the island less than 5 metre above the mean sea level (Chang 2019), Singapore is particularly vulnerable to the sea level rise, which is estimated to rise by 1 metre by 2100.

To cope with such serious long-term threats, Singapore is exploring options such as building polders or connecting islands to create freshwater reservoirs. This can be viewed as an opportunity to improve the island's infrastructure and potentially make Singapore a model of resilient city that other cities could follow. Obviously, such options are costly. Prime Minister Lee Hsien Loong estimates that it will cost $100 billion or more over 100 years to protect the country against rising sea levels. Despite the high cost and long time horizon involved, Singapore is apparently confident in dealing with the challenge of climate change. As Prime Minister Lee Hsien Loong puts it in his speech (Prime Minister's Office 2019), "In Singapore, for long-term problems, we can make long-term solutions. Not everywhere, but in Singapore, yes, we can."

In conclusion, Singapore is likely to continue to face challenges in land, transportation, water, waste, and energy issues in the future because of its inherent constraints of small size and little resources. Nevertheless, Singapore has an excellent record of accomplishment of addressing these challenges and great potential to become an exemplar city of sustainability and liveability.

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