CHAPTER 16

Towards Greater Sustainability and Liveability in an Urban Age

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Introduction

From the bustling agoras and marketplaces of a bygone era to the pulsating business districts of our modern times, cities have long been recognised as the economic engines of nations. Much of this economic growth is, and will continue to be, contingent on city-to-city trade, commerce, and investment activities. Over the past 50 years, a digital revolution has created a borderless platform enabling cities separated by long distances to network and conduct business in real-time while also demonstrating their economic might in front of a captive global audience. Furthermore, the expansive scale and extensive reach of today's digital world make it possible for information and ideas to flow across societies and cultures. The most dynamic and vibrant cities, therefore, are not only economic epicentres but also innovation hubs for knowledge and enterprise. In short, globalisation and urbanisation are parallel megatrends at the forefront of world development in the 21st century—and both phenomena have equally significant impacts on the sustainability and liveability of planet Earth. These impacts are further amplified by the rapidly expanding global population that may reach almost 10 billion by 2050 (UN, 2015a).

Today, urban areas accommodate more than half of the world's population with one in every eight urban dwellers living in a megacity exceeding 10 million inhabitants. In 1950 there were only two megacities on the planet, compared to 20 and 28 megacities in 2000 and 2014, respectively. By 2030, it is projected that there will be 41 megacities in the world (UN, 2014a). For Asia, this growth amounts to 44 million new inhabitants moving into the cities every year or, in other words, an increase of 120,000 people per day (Roberts and Kanaley, 2006). Linked to this simultaneous expansion of population and urbanisation are critical environmental challenges that implicate not only the development of cities in Asia but also, and ultimately, their liveability. With a focus on the Asian region and, in particular, Singapore, this chapter examines the impact of globalisation and urbanisation in Asia,

identifies Singapore's early initiatives towards sustainability, discusses the key sustainability issues of the 21st century, and explores homegrown innovations for long-term urban resilience and liveability in our own city-state.

Asian Cities in a Global Urban Age and the Urgency of Sustainability Planning

As the most populous continent with a current population of 4.3 billion people, Asia accounts for 60% of the world's 7.3 billion inhabitants (UN, 2015b). In 2010, the global rate of urbanisation tipped the scale for the first time in human history, thus marking the prevalence and propulsion of cities. Today, Asia represents 53% of the world's urban population; by 2050, it is projected that Asia and Africa will constitute close to 90% of the world's urban population (UN, 2014a). Between 2000 and 2010, 29,000 square kilometres of land in the 'East Asia region'[1] was converted for urban use (WBG, 2015)—that is, developed for roads, housing, industry, and supporting infrastructure to accommodate a burgeoning urban population. This 2.4% average annual rate in the expansion of urban land within a decade suggests that more, rather than less, urbanisation in Asia is likely to occur in the near future. For the most part, the rate of urban population growth in Asia is driven by unprecedented levels of rural-to-urban migration as migrants relocate to urban centres with the hopes of accessing better opportunities in employment, healthcare, education, and living conditions. China, for example, is actively ramping up urbanisation, driven largely by government-led investment, in order to meet the target of a 70% nation-wide urban population by 2025 (Johnson, 2013).

In both advanced and emerging cities of Asia, wealth creation through the sale and development of land has helped to boost construction and real estate activities and, thus, public investment capital and economic progress (Lin, 2010). Meanwhile, the aspirations and consumption practices of a rising urban middle class have placed greater pressures and demands on cities. From the desire for home and car ownership to the preference for branded and imported goods, the sophisticated and discerning tastes of the professional working class in Asia have a significant impact on urban development and, in turn, the environment. Car-oriented suburban growth, luxury single-family housing, gated communities, internationalised retail and entertainment precincts, and 'iconic' mega projects are some of the prevalent urbanisation trends shaping the physical landscape of Asian cities. These trends have also added challenges in terms of social inequality, creating in some cities a wide income gap made visible by

[1]The World Bank defines East Asia as comprising of Brunei Darussalam, Cambodia, China, Indonesia, Japan, the Democratic People's Republic of Korea, the Republic of Korea, the Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, and Vietnam (see World Bank Group, 2015, p. 7).

spatial segregation with the urban poor often left out of adequate and affordable housing, that is, relegated to the urban periphery or informal slum settlements.

This urban economic divide coupled with a lack of proper planning can have long-term, adverse impacts on the environment. In Asia, cities consume 80% of the region's energy and generate 75% of carbon dioxide emissions (ADB, 2015). Indeed, rapid and poorly-managed urbanisation are factors that can intensify climate change risks and place urban populations in potentially vulnerable situations. Jakarta, Manila, Mumbai, Wuhan, and New Delhi—which are among the fastest growing cities in Asia—have the lowest sustainability ranking (outperforming only Nairobi) in a list of 50 world cities, according to the 2015 Sustainable Cities Index developed by Arcadis (2015). Furthermore, a widening urban economic divide creates inequality in terms of who is able to access information and resources that promote awareness about sustainability issues. The unrestrained urban expansion in Asia, therefore, presents a real urgency to re-examine the methods of growth vis-à-vis sustainability and liveability.

Today, 16 of the 28 megacities worldwide are located in Asia with Tokyo (38 million), Delhi (25 million), and Shanghai (23 million) topping the list in terms of urban population (UN, 2014b). As might be expected, the Asian continent has the highest overall population density at 135 persons per square kilometre of total surface area (persons/km^2), compared to Africa (37 persons/km^2), Europe (32 persons/km^2), Latin America and Caribbean (30 persons/km^2), North America (16 persons/km^2), and Oceania (4 persons/km^2) (UN, 2014b). It is commonly agreed that the form and growth of a city can have an impact on sustainability, yet there are conflicting viewpoints regarding high-density and compact development as the best (or only) way forward towards achieving a sustainable urban future (Dempsey and Jenks, 2010; Heng and Malone-Lee, 2010; Heng and Zhang, 2010; Neuman, 2005). In this respect, some of Asia's highly-dense, modern, and economically developed cities could offer insightful lessons to advance our understanding of sustainable urban development. While cities may present many problems, they are also centres for innovation and influence where concerted efforts can make a positive global impact towards sustainability.

Singapore, as we shall illustrate in the following section, ventured on a sustainability journey decades before the seminal 1987 Brundtland Commission Report elevated sustainability at the apex of a worldwide environmental agenda. As an island-state with a miniscule land area in a developing region, Singapore's scarce supply of land and natural resources have made it necessary for the country to plan strategically and long-term for sustainable growth and, ultimately, survival.

Singapore's Quest for Sustainability and Liveability: The Early Years

Singapore is ranked the 10th most sustainable city in the world by Arcadis (2015) and rated as the most liveable city in Asia for international assignees to the region by

ECA International (2015). Employing methods and indicators that can differ widely from index to index, such surveys require critical reading. Nevertheless, the reports effectively draw attention to the cities which they feature, such as Singapore's efforts in the areas of environmental sustainability and urban liveability; these efforts pre-date the recent surge of concerns on climate change and quality of life issues. The vision for a sustainable and liveable city has always been at the forefront of Singapore's growth agenda since the earliest beginnings of the Republic's independence.

In 1965, Singapore was in a fragile state of affairs having emerged from almost 150 years of colonial rule to then be removed from the Federation Government of Malaysia and with an uncertain-looking future. The political leaders and state government of the newly-formed Republic embarked on their first of several arduous and urgent tasks—to alleviate Singapore from poverty by raising living standards and increasing social mobility through housing and job creation. The path to Singapore's transformation from a Third World to First World nation required thinking about sustainability from the very start and in every aspect of development: economic, social, and environmental. As an island with a small territorial size, Singapore's first sustainability challenge was the utilisation of land. In order to ensure that the limited land supply can accommodate long-term population growth and support the needs of future generations, strategic planning and careful management are the key strengths in Singapore's management of this precious resource. Four specific policy areas have been particularly foundational and instrumental in contributing to Singapore's sustainability and liveability goals.

Firstly, Singapore's public housing programme has enhanced urban liveability and promoted social sustainability (see also Chapter 14 by Tan Ern Ser for the impact of public housing on community development). In terms of social equity, the home ownership rate in Singapore is among the highest in the world at 90.3% as of 2014 (DOS, 2015). Public housing appeared in colonial Singapore during the 1930s under the administration of the Singapore Improvement Trust (SIT). The SIT was replaced by the Housing & Development Board (HDB) in 1960, after which building efforts were ramped up to provide proper and adequate housing to what was then a largely poor population. In the first Five-Year Plan (1960–1965) the HDB completed nearly 55,000 public housing units (HDB, 2014/15), exceeding the SIT's total of some 23,000 units during its 32 years of existence (Liu, 1985). Over the decades, public housing has accommodated generations of families with initiatives and incentives enabling grandparents, parents, and children to live within close proximities. Singapore's public housing adopted a 'new town' development model comprising high-rise blocks spatially arranged into self-sufficient neighbourhoods served by a central commercial core. Public housing, therefore, has facilitated urban density by accommodating greater numbers of people in a compact and land-efficient manner; in this way, reducing travel distances by enabling residents to work, live, and play

within proximity to their homes. At the same time, urban density and compactness make more viable the integration of an efficient and effective public transportation system, thus reducing reliance on private vehicles as the dominant means of daily commuting.

Secondly, the 'Garden City' and 'Clean Rivers' campaigns, launched in 1967 and 1977, respectively, demonstrate the early attention given to environment and water issues. The population boom after the Second World War outpaced planning projections outlined by the 1958 Master Plan, resulting in unfettered urban growth, congestion, and unregulated practices such as unscrupulous littering and improper waste disposal. The 'Garden City' initiative aimed to not only improve the aesthetic image of the streetscape but also counteract the environmental impact of urbanisation. Some of the pragmatic advantages of tree plantings in Singapore's hot tropical climate include: provision of shade, minimisation of heat island effect, reduction of traffic noise, containment of dust pollutants, and concealing otherwise imposing concrete structures such as retaining walls. The tree-planting programme was first initiated in 1963 by the then Prime Minister Lee Kuan Yew. In 1967, Singapore's greening efforts were formalised through an official declaration of the 'Garden City' vision and establishment of a Trees and Parks Unit within the Public Works Department. By 1970, new trees and shrubs in excess of 55,000 and 340,000, respectively, had been planted (PWD, 1971, p. 27). Today, greening efforts continue in Singapore with new emphasis on community gardens, recreational greenways, and biodiversity; thus, giving Singapore the renewed moniker of 'City in a Garden'. The 'Clean Rivers' 10-year programme for the revival of the Singapore River included resettlement of households and industrial enterprises. Here, earlier decades of indiscriminate sewage dumping by households and cottage industries in unsewered premises along the river banks made the waterways a toxic breeding ground for disease. The Singapore River clean-up was the impetus that led to a comprehensive, island-wide modern sanitation network and treatment system which was implemented completely in 1997 (CLC & CSC, 2014, p. 147). Although the project timelines for both the 'Garden City' and 'Clean Rivers' initiatives were short-lived, the vision was long-term with the aim to not only improve public health and living standards but also better the image of Singapore within and beyond our shores.

Thirdly, prior to the 1967 State and City Planning (SCP) study, transport planning was virtually non-existent, much less integrated with land use planning (see Chapter 8 by Mohinder Singh). The 1971 Concept Plan concretised the outcomes of the 1967 SCP study with a comprehensive plan in which land was safeguarded for road networks and mass rapid transit (MRT) lines to meet Singapore's physical development demands in the long-term. Besides infrastructure planning, strategic transportation policies are also crucial in the management of traffic given the pace of growth and development in Singapore. Perpetual traffic congestion not only hinders

businesses, services, and day-to-day activities that rely on transportation but also, as a result, increases fuel consumption and generates air pollution at the expense of liveability. In 1975, Singapore became the first mover in the world to implement a congestion pricing scheme, the Area Licensing Scheme (ALS). With advancements in technology, the current Electronic Road Pricing (ERP) came into being in 1998. The Vehicle Quota System (VQS), introduced in 1990, is another road use management mechanism which regulates the vehicle population. Transport infrastructure provision and policy have long been key pillars in reinforcing the goals of urban liveability and sustainability; and, at the same time, illuminating Singapore's innovation capabilities for sustainable planning on the world stage.

Finally, at the macro level, comprehensive and long-term planning has played a significant, overarching role in guiding Singapore's sustainability future in terms of resource management, infrastructure provision, and land use distribution for population and economic growth. In 1971, Singapore's first Concept Plan was adopted. Three key strategic thrusts of the 1971 Concept Plan are, today, ingrained features in Singapore's physical landscape: (1) a concentration of developments in a 'ring and line' pattern encircling the Central Catchment Area along which are nodes of high-density satellite towns, and another line of developments along the southern coast from the eastern to western extremes; (2) an integrated transportation network comprising a system of expressways, MRT lines, and gateways such as Changi Airport; and (3) the nurturing of the Central Area into a significant financial centre and tourism magnet for locals and visitors alike. The Concept Plan, reviewed every 10 years, enables a small island-state like Singapore to re-examine the needs of the nation and plan ahead to ensure development is sustainable for future generations.

Within Asia, Singapore has long been viewed as a trailblazer for environmental sustainability—serving as inspiration for other Asian cities. Many of the initiatives and policies which the city-state carried out in the 1960s and 1970s were relatively uncharted for their time, that is, a time before 'green' became trendy. Arriving at such critical crossroads required courageous visions, strong political will, and committed government support. In the mid-1970s, for instance, Singapore took a stance on upholding strict pollution standards when Japanese firm, Sumitomo, established a petrochemical plant on Pulau Ayer Merbau (today reclaimed as part of Jurong Island) (CLC & CSC, 2014, p. 10; Ng, 2012, p. 63–64; CLC, 2010, p. 75). At a time when the young island-state was vying for foreign direct investments, the government's uncompromising perseverance towards environmental sustainability was an exceptional manoeuvre but one that was viewed as a necessary development strategy for economic growth, rather than a deterrent against it. Sound environmental policies were considered to be equally vital in attracting and retaining investors, businesses, and professionals.

Singapore's early efforts and solutions in sustainability were motivated by and primarily addressed domestic environmental concerns. Today, place-specific environmental problems are no longer confined within national borders as can be observed by the seasonal transboundary haze pollution affecting Southeast Asia. Thus, the infrastructures, resources, technologies, and expertise that Singapore has developed and accumulated over the decades will need to be re-calibrated in order to better understand and confront future sustainability threats concerning human society at a global scale. The next section discusses the major sustainability issues of the 21st century and, turning to the challenges ahead, explores current strides in the domains of government and research to advance knowledge, produce cutting-edge technologies, and formulate new targets for a more sustainable and liveable urban future in Singapore.

Environmental Resilience and Responsibility: Towards a Sustainable Urban Future in Singapore

The two megatrends of the 21st century, which we described earlier as being globalisation and urbanisation, are implicating sustainable development in critical ways that are multi-dimensional and interconnected. At the forefront of the sustainability challenge is energy and climate change. Urbanisation is a resource-intensive process, involving vast amounts of energy to construct buildings, develop infrastructure, and drive industrial output in order to achieve higher standards of development and economic competitiveness. As cities expand to accommodate physical and population growth, their energy demands increase, simultaneously compounded by the day-to-day production and consumption patterns of urban dwellers. In 2013, global CO_2 emissions peaked at a new high of 35.3 billion tonnes (Gt) CO_2 (PBL NEAA, 2014) and, in the following year of 2014, the Earth's average surface temperature was recorded as the highest since the earliest readings in 1880 (NOAA NCEI, 2015). Climate change is increasingly being reported as the cause of extreme weather events over recent years, ranging from floods and storms to droughts and heat waves. Cities, today, are therefore more vulnerable to the heightened frequency and intensity of such natural disasters. The threat of rising sea levels, for example, is a scenario that an island-state like Singapore will need to consider in its capability planning for climate change adaptation.

Another pressing sustainability issue of our times is urban waste and water pollution. Rapid urban migration adds stresses and strains to the carrying capacity of cities, particularly in cities with the lack of resources to cope with rising population numbers. Currently, there are almost 830 million people living in slum conditions where potable water and adequate sanitation are scarce (UN, 2012). Here, a shortfall in the proper technology and infrastructure to handle the disposal and treatment of

waste can create serious problems related to environmental contamination and public health arising from unscrupulous dumping of waste and clandestine landfills. At the other end of the spectrum, member nations in the Organisation for Economic Co-operation and Development (OECD) produce approximately 1.75 million tonnes of waste per day, making the developed world the largest generators of waste (Hoornweg *et al.*, 2013). In Singapore, the amount of waste generated and disposed has increased over the decades from 1,260 tonnes per day in 1970 to 8,338 tonnes per day in 2014 (NEA, 2015), thus placing greater demands on the existing waste management system which is further compounded by our land constraints.

Against this backdrop of climate change and environmental pollution, the reliable and adequate production of food is a contentious issue with global demand and supply implications. At the same time, modern agricultural practices and contemporary food consumption habits are increasingly acknowledged as unsustainable, contributing to the exacerbation of food insecurity. Given that only one quarter of the land on Earth is suitable for cultivation (UNEP, 2012, p. 18) and almost 10 billion people are estimated to inhabit our planet by the year 2050 (UN, 2015a), the impetus for a more sustainable approach to food production and consumption will require concerted efforts at a global scale. Cities, in particular and as a start, can make a significant impact on improving the state of the world's food system through advancements in urban horticulture. Singapore relies on imports to meet the food demands of the island's growing population, though the country's global emissions output is currently less than 0.2%. Nevertheless, when environmental calamities and/or uncertainties heighten, this food supply chain would be affected if not disrupted completely. Therefore, apart from shrinking our carbon footprint related to food transport, we also need to consider innovations in self-sufficiency for food security.

The environmental issues affecting the planet today will have dire consequences in the foreseeable future, if the status quo remains. In order to counteract anthropogenic environmental degradation, more and more cities are now exploring two parallel strands of action: resilience and responsibility. Resilience—the ability to adapt and recover in times of adversity and disorder—can be fostered through preparedness. Preparedness, in turn, requires a multi-faceted framework of mechanisms, methods, and data to manage and minimise risks that might threaten the viability of cities. Resilience without accountability, however, is inadequate in driving sustainability. International environmental treaties—for example, the United Nations Framework Convention on Climate Change and its Kyoto Protocol—promote participation and, hence, incite nations to take responsibility in combatting climate change. In this regard, we will now examine six sustainability programmes representing the diverse perspectives and roles of the government and research sectors in Singapore; these programmes collectively aim to enhance our nation's resilience to environmental change while upholding an ethos of responsible urban development.

More significantly, at the crux of these programmes, a triangular relationship is forged between the spheres of design/planning, technology, and behaviour. In short, it is through forward-thinking design/planning, ingenious technology, and responsible behaviour that we can derive more effective solutions to the sustainability problem.

Government Sector

The government sector plays a significant role in promoting sustainability through public policy development, legislation, and setting of national targets; in this way, steering economies, industries, and citizens towards a cohesive agenda or vision with clear sustainability principles. As the key authority that decides how public funds are channelled, the government is a catalyst and provider of sustainability innovation. Such innovation includes infrastructure and technology development for improving environmental performance in areas of, for example, transportation, energy, buildings, and housing. In relation to housing, the HDB formed a Committee of Environment Sustainability in 2005 which involved government agencies, academia, and the private sector in formulating long-term strategies towards sustainable towns and estates (SPH, 2007). HDB's first eco-precinct, Treelodge@Punggol, is illustrative of such an initiative in this direction (see Chapter 7 by Cheong Koon Hean). By leading through example, the government helps to drive behavioural change towards greater sustainability-consciousness within civil society and the private sector. In Singapore, the government has developed several concurrent national-level agendas, three of which are highlighted below. The *Sustainable Singapore Blueprint*, *Smart Nation Programme*, and *National Climate Change Strategy* aim to advance sustainability through environmental goal setting and responsible urban development practices.

Sustainable Singapore Blueprint

The Sustainable Singapore Blueprint is a targets-based mandate developed with feedback from public dialogues, focus group discussions, and surveys; the document sets out environmental goals and initiatives with an immediate timeframe of 10 to 20 years. First launched in 2009, the Sustainability Singapore Blueprint is now in its second run with the 2015 edition led by the Ministry of the Environment and Water Resources and the Ministry of National Development. The 2015 Sustainable Singapore Blueprint presents a national vision towards higher standards of sustainability and liveability revolving around a desired five-pronged outcome: (1) 'eco-smart' housing districts; (2) 'car-lite' environment; (3) zero waste nation; (4) leading green economy; and (5) community stewardship. Identifying key environmental indicators and their levels in the year 2013, the 2015 Sustainable Singapore Blueprint maps out 2030 targets for these indicators

that include: increasing the amount of skyrise greenery from 61 ha to 200 ha; extending the length of cycling paths from 230 km to 700 km; doubling the rail network from 180 km to 360 km; increasing the proportion of buildings with BCA Green Mark Certified rating from 21.9% to 80%; and reducing flood prone areas from 36 ha to 23 ha.

Smart Nation Programme

The Smart Nation Programme is a national-level initiative involving government agencies across various sectors from information communication and technologies to transportation and housing. Premised on the 'smart city' concept—where digital technologies are leveraged to enhance the delivery and efficiency of urban services while reducing costs (environmental and economic) and catalysing user participation in the process—Singapore's 'smart nation' vision entails significant cooperation and collaboration between government, industry, business, and citizens. Of interest to note is how the Smart Nation Programme dovetails with the Sustainable Singapore Blueprint, as both agendas are essentially committed to improving the future of sustainability and liveability in Singapore. Two thrusts of the Smart Nation Programme, in particular, address the built environment through their focus on the development of big data and technology-driven innovations towards improving the future capabilities of transportation (Smart Mobility) and housing (Smart Living). The Smart Mobility 2030 plan, jointly developed by the Land Transport Authority and Intelligent Transportation Society Singapore, provides strategies for big data analytics and intelligent transportation system (ITS) applications towards a more integrated, interactive, and sustainable land transport ecosystem. Concurrently, under the Smart Living banner, the HDB has developed a 'Smart HDB Town Framework' that integrates smart technologies in the realms of town planning, environmental monitoring, estate management, and dwelling infrastructure. In 2015, Yuhua was the first live-in public housing estate where Smart technologies were trialled in 10 households for six months (HDB, 2015). The Smart home devices included an 'Elderly Monitoring System' and 'Utilities Management System' to alert of anomalies in elderly movements and utilities consumption, respectively. This demonstration project is currently being expanded to 3,200 households in Yuhua estate (CNA, 2016). Smart technology applications will also be test-bedded in the recently launched Punggol Northshore pre-sale Build-to-Order development, which will feature: a smart car park management system; a smart pneumatic waste conveyance system; sensor-controlled smart lighting in common areas; and a home energy management system.

National Climate Change Strategy

The Inter-Ministerial Committee on Climate Change (IMCCC), a whole-of-government effort on climate change policies, was established in 2007 and is today

provided with coordination support by the National Climate Change Secretariat, formed in 2010 under the Prime Minister's Office. The National Climate Change Strategy document, developed by the IMCCC shortly after the 2011 United Nations Climate Change Conference in Durban, seeks to address how Singapore can reduce long-term emissions and enhance energy efficiency while ensuring continued growth and progress. The vision articulated by the National Climate Change Strategy is for Singapore "to be a climate resilient global city that is well positioned for green growth" (NCCS, 2012, p. 12). Achieving this vision, as the document posits, involves a four-pillar approach in addressing climate change. Firstly, Singapore has set the bold target of reducing emissions by 16% below 2020 business-as-usual (BAU) levels.[2] Currently, Singapore has begun implementing policies and measures to reduce emissions by 7% to 11% from the 2020 BAU levels (Ibid, p. 11 & 40). Secondly, in order to enhance Singapore's adaptation measures to climate change, various government agencies alongside the research sector are attempting to bridge knowledge gaps and develop cutting-edge studies on topics such as coastal protection, water conservation, biodiversity and greenery, public health, and urban infrastructure. Thirdly, efforts in curbing climate change could generate economic opportunities for green growth. By tapping on these opportunities, Singapore not only creates an avenue across sectors for financing and trading but also fosters research and innovation in sustainability. Lastly, implementing and achieving sustainability policies and targets require local as well as global partnerships between committed stakeholders, ranging from civil society and government to the corporate sector and international community of nations and organisations.

Research Sector

Enhancing our proficiency in sustainability issues through scientific and applied research in areas such as climate change, land development, and changing demographic trends is an integral component of a comprehensive, national sustainability roadmap. The introduction of new tools and methods, test-bedding of real and hypothetical scenarios, and development of technical expertise are some of the ways through which the research sector can help better enable the government to formulate policies, regulations, and initiatives on sustainability. In 1991, Singapore established the National Science and Technology Board which launched a $2 billion, publicly-funded, inaugural five-year National Technology Plan (see Chapter 3 by Philip Yeo). A total of

[2]More recently, in the lead up to the 2020 Paris Climate Change Conference, Singapore has submitted to the UNFCCC Secretariat its intended nationally determined contribution (INDC) to achieve a 36% reduction in its 2005 emissions intensity by 2030. The INDC also states Singapore's intention to stabilise its emissions levels with the aim to peak emissions by around 2030 (see IISD, 2016).

$40 billion over a 25-year span has since been allocated for research and development (R&D) activities to support industry needs (Lin, 2016).

Today, the National Research Foundation, a department within the Prime Minister's Office and secretariat to the Research, Innovation and Enterprise Council, is tasked with setting the national direction for R&D—a direction that includes a renewed focus on sustainability projects under the NRF 'National Innovation Challenge', and developing the R&D capabilities of universities and institutes. Although national- and university-level research centres and institutes focusing in one way or another on sustainability research abound, the following sections describe three research centres located at the National University of Singapore (NUS): *Campus for Research Excellence and Technological Enterprise*, *NUS Environmental Research Institute*, and *SDE Centre for Sustainable Asian Cities* in order to highlight the mission and the kind of research programmes undertaken at research centres at the national, university, and faculty level respectively.

Campus for Research Excellence and Technological Enterprise

Launched in 2006, the Campus for Research Excellence and Technological Enterprise (CREATE) is an initiative under the National Research Foundation to help catalyse new innovations and develop their economic growth potential. Co-located with the NUS University Town, CREATE serves as a hub for international research collaborations and inter-disciplinary research activities. With a focus on four key research areas—environment systems, energy systems, human systems, and urban systems—CREATE research centres are positioned to address climate change through the advancement of scientific knowledge and development of cutting-edge mitigation and adaptation technologies. Some of the novel work conducted at CREATE include R&D in: energy storage systems, electric vehicle technologies, building energy efficiency, water and energy management, and renewable energy. In this way, CREATE not only contributes to but can also leverage on a flourishing R&D ecosystem comprising university research institutes, corporate laboratories, technology incubators, and start-up venture capitalists—all located within geographical proximity to foster partnerships, promote cross-fertilisation of knowledge, and facilitate technology transfer. The future of sustainability planning will indeed be dependent on the capability of cities to harness opportunities derived from technology and innovation.

NUS Environmental Research Institute

As a university-level research institute at NUS with a focus on environmental research, the NUS Environmental Research Institute (NERI) is mandated to coordinate multidisciplinary research and education initiatives involving strategic partners (in higher

education, government, and industry—locally and globally) on key environmental issues affecting sustainability in Singapore and elsewhere within Asia. One such partnership is the 'Energy and Environment Sustainability Solutions for Megacities' (E2S2), a five-year research collaboration between Shanghai Jiao Tong University (SJTU) and NUS which was initiated in 2012 through funding by NRF. Taking the two cities of Shanghai and Singapore as case study sites, E2S2 aims to develop and test-bed urban sensing, modelling, and assessment systems so as to better understand as well as address the complex challenges of future cities. This ongoing NUS-SJTU research collaboration recently spun-off a joint research centre at the NUS Research Institute (NUSRI@Suzhou) located at the Singapore Suzhou Industrial Park. The joint research centre is intended to strengthen the R&D capabilities of the NUS-SJTU partnership, while also exploring opportunities for collaborative research, commercialisation, and human resource training in the areas of environment and water. NERI is also equipped with a state-of-the-art laboratory and an in-house research team, enabling the institute to conduct and publish scientific research along four distinct tracks: (i) environmental surveillance and treatment; (ii) environmental and human health; (iii) green chemistry and sustainable energy; and (iv) impacts of climate change on the environment.

SDE Centre for Sustainable Asian Cities

Established in 2009, the Centre for Sustainable Asian Cities (CSAC) is a research centre at the School of Design and Environment (SDE), National University of Singapore, dedicated to the production of cutting-edge knowledge on sustainability issues and solutions with a focus on high-density urban environments in Asia. Working closely with the Ministry of National Development, CSAC complements the efforts at the national level to develop appropriate solutions and best practices for a more sustainable and liveable Singapore. Research conducted at CSAC ranges from studies of high density thresholds, urban metabolism, and urban spaces to that of urban climatic mapping, urban greenery, and the application of green plot ratio. Given the rapid rate of urbanisation in Asia and the enormous challenge faced by Asian cities in balancing urban growth and sustainability, CSAC has created an assessment framework for sustainable development and cities. This framework comprises four key thrusts that can each be readily evaluated by a set of relevant indicators from the slate of 13 themes including economy, environment, resources, people, and governance, etc. These themes are de-constructed to reveal a 'dashboard' of dimensions and key indicators for monitoring urban sustainability (Figure 1). Such a tool would be useful for city mayors, policy makers, and planners in charting their development trajectory vis-à-vis sustainable growth (see also http://www.sde.nus.edu.sg/csac/booklet%20small.pdf).

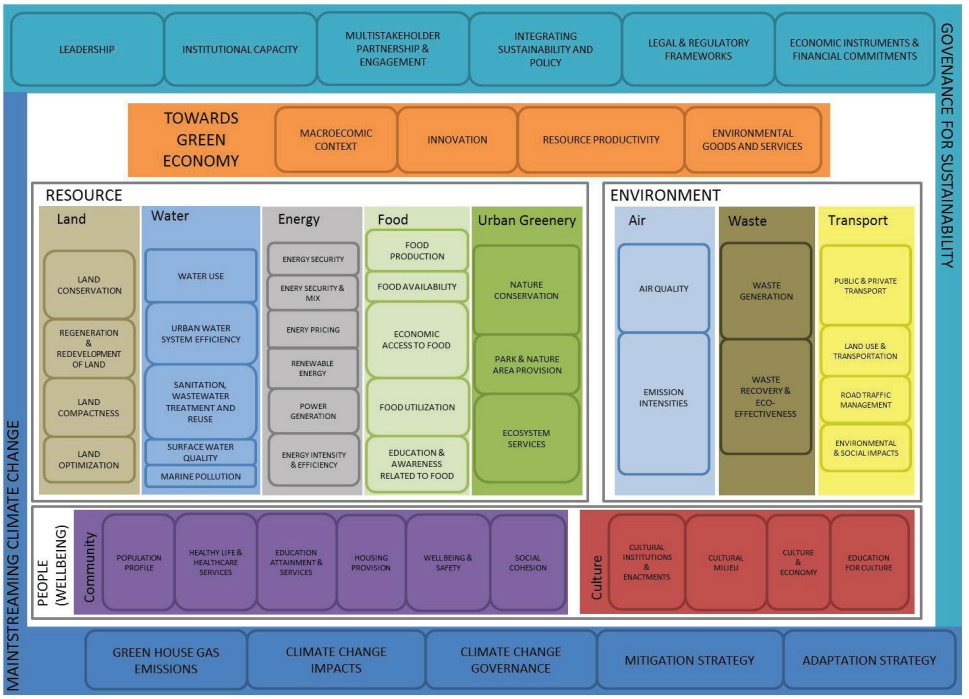

Figure 1. Dashboard for city sustainability developed by C.K. Heng and L.C. Malone-Lee.
Source: **CSAC, NUS.**

Conclusion

The 21st century represents not only the ascent of a global and digital era but also an era of rapid urbanisation. On the one hand, rapid world population growth has exacerbated (if not created) challenges for the future of sustainability and liveability on the planet. On the other hand, cities can play vital roles as innovation hubs for test-bedding and developing capabilities in design/planning, technology, and behavioural trends towards more effective sustainability solutions. For Asian cities, sustainable urban growth is and will continue to be a pressing issue as 660 million people are estimated to migrate into the cities in the next 15 years; thus, adding to the urban population and intensifying demands on resources and infrastructure. At the same time, it is also within Asia's most advanced cities where high-density urban development has long been practiced and where novel innovations in sustainability planning and building are often test-bedded.

Singapore's urban development, for example, was guided at the very early beginnings of independence by visions and policies that were not only pragmatic but also long-range and sustainable in order to safeguard standards of liveability for future generations. In the ensuing decades, however, Singapore and other urban

areas worldwide will need to enhance their resilience to climate change while also shouldering greater responsibilities to reduce their carbon footprints. As a nation with limited land and natural resources, Singapore's greatest contribution towards global efforts on sustainability is in demonstrating the significance of setting bold targets and, more importantly, achieving the targets through: strong leadership and coordination; thoughtful long-term planning; support of R&D initiatives to drive innovation in design/planning and technology; and cultivation of conscientious behaviour among citizens, government, and the private sector. Indeed, the challenges of creating a sustainable urban future are immense and complex; yet, the opportunities have never been greater for cities to drive forward a sound sustainability agenda into the next wave of urbanisation.

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