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Resource Urbanisms

Asia's divergent city models of
Kuwait, Abu Dhabi, Singapore and Hong Kong

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Kuwait (Photography: Alexandra Gomes)
Hong Kong (Photography: Nic Tinworth)

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Acronyms

CBD	Central Business District
CSB	Central Statistical Bureau (Kuwait)
DoT	Department of Transport (Abu Dhabi)
EMISK/EPA	Environmental Monitoring Information System of Kuwait project by the Environment Public Authority (Kuwait)
FAR	Floor area ratio
GCC	Gulf Cooperation Council
HDB	Housing Development Board (Singapore)
LTA	Land Transport Authority (Singapore)
MRT	Mass Rapid Transit
MTR	Mass Transit Railway
NEA	National Environment Agency (Singapore)
PACI	Public Authority for Civil Information (Kuwait)
PAHW	Public Authority for Housing Welfare (Kuwait)
PAP	People's Action Party (Singapore)
SCAD	Statistics Centre (Abu Dhabi)
SIT	Singapore Improvement Trust
UEC	Urban expansion coefficient
ULA	Urban living area
UN	United Nations
UPC	Urban Planning Council (Abu Dhabi)
URA	Urban Redevelopment Authority (Singapore)

Executive Summary

This report presents the key findings of the Resource Urbanisms project that LSE Cities at the London School of Economics and Political Science led between 2015 and 2017. The research, supported by the Kuwait Programme at the LSE Middle East Centre, focuses on two natural resources, land and energy, and explores their relationships with city form, housing and mobility. It analyses these relationships through a comparative case study approach by focusing on Kuwait and Abu Dhabi in the Gulf, and Hong Kong and Singapore in East Asia. Both the Gulf and East Asian case studies have similar income levels, but exhibit contrasting forms of urban development. More importantly, Kuwait and Abu Dhabi are endowed with vast natural resources (land and oil), while Hong Kong and Singapore possess limited natural resources, making them useful cases for comparative purposes.

The research is based on a mixed method approach developed by LSE Cities and the project partner, the European Institute for Energy Research (EIFER). This approach compares the evolution of urban forms and infrastructure and uses remote sensing, energy modelling, transport accessibility analysis and data visualisation at multiple spatial scales to uncover and establish relationships between different variables. The research developed a new metric, urban living area (ULA), to represent more accurately the land where urban living takes place. The key findings of this research are:

01 The shape of cities has a considerable impact on resource efficiency, making it a critical factor for global sustainability. Earlier studies have shown that urban areas consume between 67 and 76 per cent of the world's energy as a result of the concentration of affluent populations and energy-intense activities. Besides wealth levels, climatic conditions and different types of economic activity, the physical configuration of cities determines energy demands. All within high-income contexts, Kuwait's and the UAE's annual energy consumption per capita is 375 GJ (gigajoules) and 325 GJ respectively compared to 214 GJ in Singapore and 82 GJ in Hong Kong. This study shows that these differences can in part be explained by their respective urban forms and the energy demand of buildings and transport systems. In particular, the size and arrangement of buildings, and the degree of dependence on private motorised modes, directly impact a city's energy requirements and resource consumption patterns.

02 There are fundamental differences between the city models examined in the Gulf States compared to those in East Asia. These differences are most evident in relation to urban form, densities, transport infrastructures and housing typologies. Average densities within the urban living areas are 9,848 and 4,428 pers/km^2 in the city of Kuwait and Abu Dhabi respectively and substantially lower than those in Singapore with 23,817 pers/km^2 and Hong Kong with 29,554 pers/km^2. While all cities feature mature urban highway systems with total lengths between 166 km (Singapore) and 309 km (Kuwait), it is only in Singapore and Hong Kong where this is complemented by extensive urban rail systems of 275 km and 268 km respectively. These differences are further reflected in differences in housing stock. 78 and 73 per cent of housing areas in Kuwait and Abu Dhabi are house-type-based (typically low- and medium-density villas) respectively, while apartment housing dominates in Singapore (45 per cent) and in Hong Kong (94 per cent).

03 All cities displayed considerable intra-urban differences that exceed initial expectations. Diverging from their dominant spatial patterns, Singapore and Hong Kong feature some relatively low-density residential areas while Kuwait and Abu Dhabi include high-density clusters. Residential and job peak densities, in Kuwait, for example, at 52,941 pers/km^2 and 98,091 jobs/km^2 respectively, were much higher than expected. The Gulf cities, in particular, allow for a relatively clear distinction between the type of housing and modes of transport used by nationals and non-nationals. This research showed that almost all Kuwaiti nationals live in densities below 10,000 pers/km^2, and 99 per cent travel by private car, while non-Kuwaitis mostly live in apartments and use public transport extensively.

04 All four cities have become denser since 2000, but historically have been going through phases of densification and de-densification. Overall, urban growth prior to 2000 often included processes of de-densification when the rate of horizontal physical expansion exceeded population growth. However, key waves of de-densification looked very different. In Hong Kong, for example, this was the period from the 1950s to the 1980s, which addressed the city's problem with overcrowding in hyper-dense areas. In Kuwait, by contrast, following the country's occupation during the Iraq War, the city densified until the 2000s. More recently, absolute growth of the urban living area in Kuwait and Abu Dhabi far exceeds that of Singapore and Hong Kong, which has almost plateaued since the late 1990s.

05 All four cities rely on active state intervention and have been shaped by intentional policy, planning and infrastructure development. Urban development in the four cities features as a central instrument for broader socio-economic development. Governments actively shape development through master planning or strategic planning backed by strong land use controls, strategic infrastructure investment and building codes. There exists a particularly strong tradition in infrastructure-led development. Kuwait, for instance, led the city's expansion by developing a highway network, which, between the 1960s and 1990s, grew at a faster rate than the city's urban expansion. Abu Dhabi has replicated a similar infrastructure growth model more recently. In Singapore and Hong Kong, rail network expansion has been closely synchronised and at times fully integrated with urban projects and property development.

06 Natural resources, above all land, play a central role in determining urban form at the macro and micro scale. Land availability is one of the most important differences between Kuwait and Abu Dhabi, and Singapore and Hong Kong. Three per cent of Kuwait's territory is built up, with 42 per cent potentially still available. By contrast, in Hong Kong, 22 per cent of land is already developed and only 26 per cent remains potentially available for development. The availability of oil is important in shaping urbanisms insofar as it is the source of wealth through which urban development takes place, allowing cities to pursue modernist goals and re-engineer physical spaces. However, there is limited evidence that oil endowment directly impacts physical urban form over and above general economic wealth levels.

07 Energy prices have a more nuanced and indirect impact on the nature of urban growth. In the four case study cities, patterns of urban growth during different decades were found to be associated with energy prices. While the analysed sample size does not allow for statistically grounded conclusions, the established patterns suggest a correlation between fuel prices and the urban expansion coefficient – an indicator used to assess densification patterns – with higher prices associated with more compact patterns of development. Similarly, and taking into account actual fuel affordability, the ratio between GDP per capita and pump price of petrol (gasoline) suggests that higher levels of affordability are associated with greater levels of de-densification. Electricity prices may have a more indirect relationship with their increase. For instance, recent electricity price increases in Abu Dhabi may render cooling energy costs for larger houses less affordable, thus reducing the demand for such housing typologies.

08 Non-resource factors impacting urban development were found to be critical, complex and often interrelated. Although not directly addressed by this study, the evidence collected in each of the case study cities suggests that key non-resource factors of urban development need to be considered alongside the analysed land and energy conditions as well as other natural resources such as water. Above all, these include context-specific circumstances linked to the political economy, culture, history of a city, with key moments of development, lock-in effects of physical infrastructure, wealth distribution, climatic conditions, as well as urban governance institutions playing a critical role. For example, cultural preferences for privacy may have been particularly influential in shaping housing typologies in Kuwait and Abu Dhabi.

09 In terms of energy consumption, the study confirms that high-density, compact, mixed-use and public-transport-oriented cities are more efficient than low-density cities that are dependent on private vehicles. This research shows that low-rise, low-density buildings have higher cooling energy demands as compared to mid- to high-rise buildings. Greater mixed-use development also reduces transport energy consumption, lowers commuting distances between homes and jobs and serves as a prerequisite for more sustainable travel by facilitating non-motorised modes of travel, such as walking and cycling. However, the advantages of compact urban development in terms of energy efficiency have to be considered alongside a range of other implications that were not part of the analysis of this study.

10 Cooling energy efficiency is centrally driven by compact urban morphologies and building designs. This study conducted cooling energy demand modelling for 20 different urban morphology samples representing five distinctive building typologies in each of the cities. The results revealed a factor of three difference mainly as a result of urban and building designs between the most energy-efficient sample, Taikoo (podium towers typology) in Hong Kong with a calculated consumption of 135 kWh/m^2 per year, and the least energy-efficient sample, Al-Falah (smaller villa type) in Abu Dhabi with a consumption of 410 kWh/m^2 per year. Furthermore, the modelling confirmed a negative correlation between compact morphologies and cooling energy demand with higher densities and building heights resulting in lower energy demands. Particularly at building density levels of below and around a floor area ratio (FAR) of one, cooling energy demands are considerably higher, often twice the value compared to typologies with FAR three or more.

11 Transport energy efficiency is closely related to density, mixed-use and public transport availability. Based on calculations of the average distances between residential and employment areas in Kuwait and Hong Kong as well as a job and micro accessibility analysis for the 20 sample neighbourhoods, this study revealed considerable differences in city access and transport energy demand. Calculated average one-way commuting distances in Kuwait are 17.8 km compared to 12.6 km in Hong Kong. Commuting times diverge even more, with 51 minutes in Kuwait and 24 minutes in Hong Kong as a result of efficient public transport. In terms of energy demand for journeys to work, the calculations established a factor of five difference between the annual per capita transport energy demand in Kuwait of 15.8 GJ and 3.1 GJ in Hong Kong. There was a factor of 18 difference for the calculated transport energy demands of the 20 sample neighbourhoods, mostly determined by location, job-related travel, density, mixed use and transit availability.

Table 1: Data Matrix

Stream	Indicator	Kuwait	Abu Dhabi	Singapore	Hong Kong
Society	Population (pers)	4,178,572 (2015)	1,720,211 (2015)	5,535,002 (2015)	7,305,700 (2015)
	Number of jobs (pers)	1,703,145 (2015)	n/a	n/a	2,543,460 (2011)
Wealth	GDP per capita (current US$)	28,975 (2015)	39,102 (2015 UAE)	53,630 (2015)	42,351 (2015)
	GDP per capita, PPP (constant 2011 international US$)	69,329 (2015)	65,975 (2015 UAE)	80,892 (2015)	53,490 (2015)
Resource	Total energy consumption per capita (gigajoule)	375 (2014)	325 (2014 UAE)	214 (2014)	82 (2014)
	Annual residential energy demand (per cent of total demand)	18% (2015)	7% (2015 UAE)	7% (2015)	16% (2015)
	Annual transport energy demand (per cent of total demand)	29% (2015)	21% (2015 UAE)	23% (2015)	27% (2015)
	Electric consumption (kWh per capita)	15,213 (2014)	11,264 (2014 UAE)	8,845 (2014)	6,073 (2014)
	Pump price for petrol (US$/litre)	0.22 (2014)	0.47 (2014 UAE)	1.58 (2014)	2.06 (2014)
	Metropolitan area (km^2)	852 (GIS)	1,584 (GIS)	719 (GIS)	1,109 (GIS)
	Urban living area (km^2)	424 (GIS)	389 (GIS)	232 (GIS)	247 (GIS)
	Urban living area density ($pers/km^2$)	9,848	4,428	23,817	29,554
	Land available for future development (m^2/person)	2,000 (GIS)	22,000 (GIS)	30 (GIS)	40 (GIS)
Transport	Length of highway network (km)	309 (GIS)	284 (GIS)	166 (GIS)	226 (GIS)
	Length of railway network (km)	0	0	275 (GIS)	268 (GIS)
	Number of railway stations	0	0	102	89
	Motorisation rate (cars/1,000 persons)	366 (2014)	359 (2011)	104 (2015)	75 (2014)
	Share of commuting trips by car and taxi (per cent of total trips)	55% (2010)	59% (2015)	26% (2010)	8% (2011)
	Share of commuting trips by bus or rail (per cent of total trips)	39% (2010)	18% (2015)	56% (2010)	80.4% (2011)
	Calculated one-way commuting distance (km/passenger/day)	17.8 (GIS)	n/a	n/a	12.6 (GIS)
	Annual road fatalities (per 100,000)	18.7 (2013)	10.9 (2013 UAE)	3.6 (2013)	1.8 (2013)
Society/Housing	Share of foreign born population (per cent of total population)	69% (2015)	84% (2014)	29% (2015)	40% (2011)
	Share of population living in apartments (per cent of total population)	34% (GIS)	43% (GIS)	78% (GIS)	96% (GIS)
	Share of apartments in total housing area (per cent of total area)	13% (GIS)	10% (GIS)	45% (GIS)	94% (GIS)
Environment	CO_2 emissions (metric tons per capita)	25 (2014)	23 (2014 UAE)	10 (2014)	6.4 (2014)

Note: All data is for the metropolitan area unless otherwise stated

Kuwait CBD

While the city's urban area has expanded almost a hundredfold since the discover of oil, many plots next to high-rise buildings remain vacant.

Photography: Alexandra Gomes

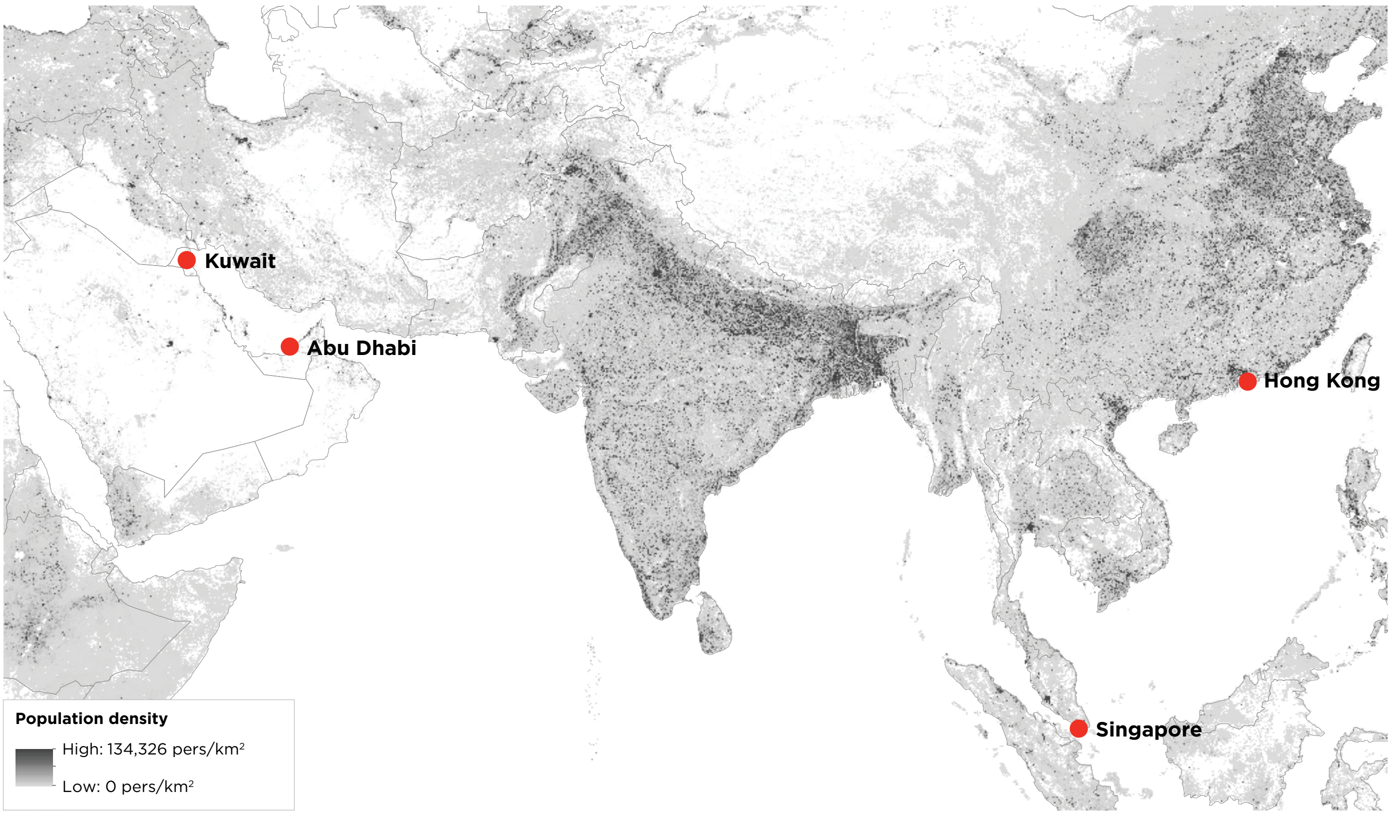
1 Introduction

This report resents the key findings of the Resource Urbanisms project that LSE Cities at the London School of Economics and Political Science led between 2015 and 2017. This research, supported by the Kuwait Programme at the LSE Middle East Centre investigates questions of urban form, geography and sustainability in Kuwait and the Gulf States as part of a broader comparative analysis of divergent forms of urban growth in Asia. Given the distinct patterns of urban development, and the central role of land availability and natural resources, particularly oil, in Gulf Cooperation Council (GCC) states, this research focuses on two natural resources, land and energy, and explores their relationships with urban form, transport and housing. It analyses these relationships through a comparative case study approach focusing on the city of Kuwait and Abu Dhabi in the GCC, and Hong Kong and Singapore in East Asia. Both the GCC and East Asian case studies are cities with similar income levels, but exhibit contrasting forms of urban development. More importantly, Kuwait and Abu Dhabi are endowed with vast amounts of natural resources, while Hong Kong and Singapore possess limited natural resources, making them useful and contrasting cases for comparative purposes.

This research is guided by the common assumption that cities and urban development are directly affected by the availability and costs of natural resources and that, in turn, different forms of urban development result in substantial differences in resource use. While there is a substantial body of comparative work that explores these topics in cities in the United States and Europe, there are far fewer empirical insights on cities where current urban growth is most pronounced. Furthermore, comparative analysis of cities in the Gulf region, and particularly in comparison with East Asian cities, has only recently begun to emerge. The research therefore has four main objectives: first, it aims to analyse the models of urban development that have emerged in Kuwait, Abu Dhabi, Hong Kong and Singapore through an inter-urban and intra-urban comparison. Second, it seeks to compare the GCC models of urbanisation (Kuwait and Abu Dhabi) with the contrasting forms of development in Hong Kong and Singapore. Third, it intends to provide fresh evidence on the relationship between the built environment, land availability and energy costs, with a particular focus on transport and urban form as well as housing and urban morphology. Finally, it seeks to better understand the dynamics between the availability and costs of resources, government interventions, urban form and infrastructure, and environmental outcomes.

The report is presented in two main parts (A and B), which follow this introduction, a brief review of the general dynamics between cities and resources, as well as a methodology section. Part A, 'From resources to urbanisms', presents the comparative evolution of urban development across the four case studies within a historical context and tests the degree to which land and energy resources may have shaped physical city development patterns within and across the four cases. It is divided into three sections. The first offers a broad overview of resource conditions, urban form and planning in each case study city, focusing on the strategies each city has adopted to manage resource

Figure 1: Case study city locations



scarcity/abundance. The second provides insight into each city's urban growth over time, namely changes in urban footprints, transport infrastructure and housing typologies, between roughly 1920 and 2015. It also reflects on the similarities and differences in the dynamics of urban growth across the four case study cities, and using Kuwait's example, highlights the importance of studying intra-urban differences to develop a more in-depth understanding of urban growth and resource consumption patterns in cities. The third section discusses the role that natural resources may have played in shaping urban form in each of the four case study cities.

Part B, 'From urbanisms to resources', analyses the impact of urban form on energy consumption at the micro and macro level. It is divided into two sections. The first section examines the cooling energy demand of dominant building typologies in each city. The second section analyses metropolitan and local accessibility levels as a result of land use and morphological configurations, and presents the transport-related energy demand for micro and macro mobility.

The report concludes by highlighting key research findings.

1.1 Point of Departure

Global urbanisation and urban change are increasingly linked to environmental sustainability and resource use. Studies have shown that urban areas consume between 67 and 76 per cent of the world's energy as a result of the concentration of affluent populations and energy-intense activities. These generate between 71 and 76 per cent of CO2 emissions (IPCC, 2014).

A key issue with regards to urban sustainability relates to the physical shape of cities, their urban forms and infrastructures. The choices that countries and cities make today about managing urban growth will lock in the economic, social and environmental benefits (or costs) for centuries to come. The life span of capital-intensive, largely irreversible urban infrastructure such as roads and buildings typically ranges from 30 to 100 years, and the path dependencies created by urban form are sustained even longer.

It is widely suggested that a more compact and connected model of urban development may not only be more resource-efficient but ultimately more effective in harnessing the growth potential of cities as it facilitates efficient access to people, services, goods and ideas (IPCC, 2014; OECD, 2012; GCEC, 2014). A recent comprehensive review of existing global evidence on compact city development concludes that there are significant benefits associated with compact urban form, including higher productivity, improved access to jobs and services, 'preservation of urban green space, greater energy efficiency, pollution reduction and safer urban environments,' (Ahlfeldt and Pietrostefani, 2017, p. 4). However, it can also increase congestion and negatively impact on health, well-being and housing affordability if not carefully managed (Ibid).

In contrast, urban sprawl generally involves greater resource consumption and unsustainable growth. Besides various overlapping market forces and policy choices, typical drivers of urban sprawl are poor planning, the unrestricted availability of land and low energy costs.

In this regard, both Kuwait and Abu Dhabi are useful case study cities as, despite some constraints on how land can be developed (see section 1.4), they have access to easily available land for new development and cheap energy, which may have created the conditions for considerable levels of urban sprawl and motorisation. It is likely that low-density developments and the consequent demand for substantial investments in road infrastructure may have further reinforced the use of more individualised modes of transport and created an urban accessibility pathway characterised by sprawling and car-oriented urban development. In addition, a range of energy and housing policies may have exacerbated such low-density development. Hong Kong and Singapore serve as useful comparative case study cities as they face severe land constraints and have high energy prices, which combined with high population pressures may have resulted in high-density development and relatively low motorisation rates. Nevertheless, with increasing densities and severe land constraints, it is likely that they face their own specific challenges related to urban growth and sustainability.

This report provides a deeper understanding of urban development patterns within and across differing models of city growth in the four case study cities. The research not only focuses on the way in which availability and costs of natural resources such as land and energy give shape to cities, but investigates how dwelling and transport patterns impact on related transport and building energy demands. These topics are relatively underexplored in the GCC context.

1.2 Natural resources and urban development

The availability of natural resources is frequently used to understand city formation, while the costs of natural resources, primarily of land and energy, are seen to play an important role in shaping city growth and urban development (Carlino, 2011; Creutzig, 2014; Kostof, 1991; Rappaport and Sachs, 2003). Freeman (1945, p.30) suggests, 'resources are the cornerstone of urban development' and many cities have developed around resources such as water, minerals, oil and gas.

Countries with scarce natural resources have depended on trade to meet basic needs and, increasingly in the twentieth century, have relied on industrialisation and the development of a competitive service sector to achieve economic growth and urbanisation. As a result, scholarship on urbanisation in resource-poor cities and countries, particularly in the East Asian context, has focused on economic development and industrialisation to explain changes in urban development patterns (Huat, 2011; Phang, 2007). More specifically, the literature has argued that urban development in such cities has been used by their respective states as a means to achieve rapid economic growth, enhance wealth levels, improve quality of life and maintain 'social and political control' (Cho and Križnik, 2017, p.11).

A particularly relevant resource condition affecting urban growth is a scarcity in land and its political economy. For example, land-scarce economic policy is a fundamental driver of urban form in land-poor city states such as Hong Kong and Singapore. Trade relationships with the immediate hinterland beyond its borders allow Hong Kong to outsource industrial and manufacturing activities while developing a high-density, service-oriented economy (Zhang, 2000). Cartier (1999) further emphasises the importance of property markets in such land-constrained cities, often among the most profitable in the world. However, and as argued by Addae-Dapaah (1999) for the case of Singapore, even in extreme cases of land constraints there exists an underutilisation of land as a result of a considerable demand for lower-density housing.

Cities are also shaped by resource abundance and recent research shows that urbanisation itself is also directly correlated with resource exports. Using a sample of 116 developing nations between 1960 and 2010, Gollin et al. (2016) argue that while urbanisation has traditionally been linked to industrialisation (Acemoglu et al., 2002; Jedwab, 2013) and economic growth (Bertinelli and Black, 2004; Davis and Henderson, 2003; Fay and Opal, 1999; Glaeser, 2013; Jedwab and Vollrath, 2015), it can also be explained through resource exports. In support of this claim, they show that countries that are dependent on natural resource exports are just as likely to experience a high rate of urbanisation as those that depend on manufacturing. Yet, they point out that the nature of urbanisation differs depending on a country's economic base. Urbanisation in countries that are primarily dependent on resource exports (such as Kuwait, Saudi Arabia and Nigeria) is concentrated in 'consumption cities' where a large number of workers are employed in 'non-tradable services such as commerce, transportation, personal, government services' (p.37). In contrast, urbanisation in countries with strong industrial bases is concentrated in 'production cities' where workers are largely employed in the manufacturing sector.

Other scholars suggest that in addition to the degree of dependence on resource exports, the nature of the state itself (Gilbert and Healey, 1985; Walton, 1993), the type of 'institutions governing land markets' and the system of property rights (Henderson, 2004, p.2) are integral factors that influence resource use and urbanisation patterns across cities. Pistor and Schutter (2015, p.7) further argue that 'beyond instances of absolute scarcity, essential resources are scarce only in relative terms – they are human made and result from politics and institutional choices'. Logan and Molotch (1987, p.306) suggest that 'the market in land and buildings orders urban phenomena and determines what city life can be'.

More recently, an increasing number of scholars have studied the manifestations of oil-based development in an urban setting, particularly in cities of the Middle East and the Persian Gulf (Al-Nakib, 2013,p.18, 2016; Alissa, 2013; Bet-Shlimon, 2013; Crinson, 1997; Damluji, 2013; Fuccaro, 2009, 2013a, 2013b; Lawless and Seccombe, 1993). Using a historical lens, they focus on labour camps, new company towns and older 'urban settlements' that served as key physical sites of oil-based development and modernity. Many argue that oil should not simply be understood as money and rent but as an agent that has 'upset delicate environmental and ecological balances' (Fuccaro, 2013a), 'fostered a desire of rapid modernisation' (Al-Nakib, 2013, p.8), created 'new geographies of consumption and leisure' (Fuccaro, 2013b, p.53) and 'played a variety of roles in a city's political, economic, and social affairs related to urban development' (Bet-Shlimon, 2013, p.39).

Gilbert and Healey's (1985) work on urban development in an oil-based economy, namely Valencia in Venezuela, also clearly lays out how oil influences urban development. By focusing on the Venezuelan state and its use of oil income, they show that increase in oil wealth facilitated land speculation and construction activity, frequently leading to inefficient and inequitable patterns of urban growth. They show that changes in global oil prices can influence the pace of construction and building activity in oil-dependent countries. They also suggest that oil revenues can 'reduce the need for economic efficiency in urban design', leading to environmental degradation, traffic congestion and air pollution (Ibid, p.13).

Other scholars have pointed to the environmental and fiscal risks of resource consumption in oil economies. Here low energy prices and high incomes imply high consumption, which in turn leads to particular forms of urban development (see Creutzig (2014) for the link between fuel price and urban form). Hertog and Luciani (2012, p.236) show that 'per capita oil and gas consumption, and by implication, CO_2 emissions in the Gulf Cooperation Council countries are uniquely high'. With increasing demand for electric power in particular, they suggest that countries in the Gulf will need to develop strategies for sustainable energy. Gharibi (2016) points to the unsustainable (single-family, car-based) patterns of urban development in Muscat, Oman seen in the aftermath of the discovery of oil. Unsustainable patterns of this kind have also been documented by AlShalfan (2013) in the case of Kuwait, and Dempsey (2014) in the case of Abu Dhabi.

Traditionally, oil economies have been studied through the lens of the rentier state model. Katiri et al. (2012, p.166) describe rent as 'any payment to the owner of natural resources that remain once labour, capital, and any other inputs to the extraction have been paid'. A resource-rich country where rents accrue to the government, and the government manages and distributes rent, is known as a rentier state. The term 'natural resource curse' has also been used to describe resource-rich countries that have been unable to achieve high living standards and growth despite abundance of resources (Auty, 2001; Bjorvatn et al., 2012; Frankel, 2010).

Yet, others have suggested that such generalisations need to be revisited as there is no evidence of the natural resource curse (Davis, 1995; Herb, 2005). Hertog (2010) points out that a number of rentier states also have efficient state-owned enterprises that enhance the value of production. Other scholars show that policy and political economy factors are critical in influencing economic development and growth in resource-dependent rentier states' economies (Chaudhry, 1994; Findlay and Lundahl, 2001; Murshed, 2001).

Holding other factors constant, this study aims to compare and analyse patterns of urban form (particularly in relation to density and environmental efficiency) in 'land and energy-rich' Kuwait and Abu Dhabi and, by contrast, Hong Kong and Singapore, which are more limited in terms of available land and cheap energy supply. While there is increasing evidence available on the relationships between resource dependence, urbanisation rates, modernisation and standards of living, few studies explore patterns of urban development through a comparative lens.

1.3 Methodology

This research uses a comparative case study approach to develop a deeper understanding of urban development patterns within and across Asian cities with divergent resource conditions. For this purpose, it focuses on two GCC cities, Kuwait and Abu Dhabi, and compares them to two East Asian cities, Singapore and Hong Kong, all high-income Asian city states that feature divergent and, in some aspects, polar opposite natural resource conditions, urban forms and mobility patterns.

To investigate the way in which availability and costs of natural resources (specifically land and energy) give shape to cities and, in turn, how dwelling and transport patterns impact related transport and building energy demands, data was gathered and analysed through a mixed methods approach developed by LSE Cities and its partners. This approach involves primary and secondary research including satellite remote sensing, urban modelling, stakeholder interviews and workshops, and makes use of data visualisation and analysis at multiple spatial scales to uncover and establish relationships between different variables.

1.3.1 Establishing the empirical basis

As part of the data collection process, a number of datasets (including spatial, statistical and census data) were obtained through desktop research and local institutions. Archival research was used to locate relevant historical maps, which were subsequently geo-referenced and digitised for use in GIS applications.

As all case study areas were analysed at the macro and micro level, spatial and statistical data were collected at national, regional, metropolitan and city scales, and when possible complemented by more granular analysis at the neighbourhood, block or building level. In order to provide a historical urban overview of city growth, satellite images, aerial photography, maps and photos were collected and classified through GIS remote sensing. Time series data was collected for any available years within the 1900 to 2015 period. In addition, semi-structured interviews were carried out with key experts in each of the case study cities to triangulate data and identify key events, policies and themes related to urban development, resources (land and energy) and city growth. These were complemented with secondary research on the topic.

During the course of this research, interaction with the team of local experts, the Kuwait Programme at the LSE Middle East Centre, and the Kuwait Foundation for the Advancement of Science (KFAS) was fundamental in guiding the research agenda. Three workshops were organised in Kuwait, Abu Dhabi and London to obtain feedback on preliminary research findings.

As there has been limited comparative work of this nature previously, the team experienced a number of challenges related to data collection, creation and reliability during the course of this research.[1] For this reason, data for different indicators was collected through a variety of sources and cross-referenced to determine the most reliable and complete dataset for each indicator. When data was not available through formal institutional sources, spatial data was collected from open sources and big data projects such as OpenStreetMap, Google Maps and Google Earth.

It is important to note that data was only collected up to the year 2015 as most of the project data collection process took place in 2016, and it was necessary to create an end-date to allow for comparison.

1.3.2 Analysis

Following the data collection stage, different forms of analysis were used to explore and compare the four case study cities at different scales. Data was analysed both quantitatively (using statistical analysis) and qualitatively (drawing on key themes, patterns from interviews, policy documents, academic literature and visualisations produced for this research) to assess whether urban development in each of the four case study cities has directly been affected by the availability and costs of land and energy, and whether different forms of urban development have led to substantial differences in resource use.

The most central part of the analysis included the following three components[2]:

a) Description and comparison of the evolution of urban forms, infrastructures and building typologies

As the first step, changes in urban development were documented at the macro and micro scale, and definitions and classifications of urban form and morphologies were developed.

At the macro level, the evolution of each city's transport infrastructure, urban footprint, work and residential densities was documented, calculated and visualised over time. GIS spatial-statistical analysis was used to compare levels of compactness, density and mixed use. In addition, strategic transport infrastructure in each city was documented by system length, highway interchange points and transport mode.

Urban expansion in each of the cities was examined through historical archives of satellite images, paper maps and aerial photographs dating back to 1940. These maps were digitised, and growth in ULA (see box 1) was calculated and visualised, when possible, at 10-year intervals until 2015.

At the micro level, urban morphologies were investigated at a scale of 500 by 500 metres. The most representative building typologies were identified and mapped at the lowest administrative unit within and across different areas in the case study cities. Each of the samples were represented by a 3D digital model and include basic information on the footprint, position, distribution and height of all buildings, as well as local accessibility.

b) Urban form, transport energy demand and accessibility analysis

To investigate the relationships between macro accessibility, mobility behaviour and energy consumption, data related to macro mobility was linked to data on transport energy consumption using statistical and GIS software. At the micro level, energy consumption of different urban morphologies was calculated from the neighbourhood scale to the building scale to capture horizontal and vertical mobility within each urban morphology sample.

c) Cooling energy modelling and analysis

Cooling energy modelling was conducted by the project's partner organisation, the European Institute for Energy Research (EIFER) at Karlsruhe Institute of Technology, to assess average annual cooling energy demands of most representative and distinctive building typologies in each of the case study cities. In addition, at the neighbourhood scale, macro morphological parameters such as building density, surface-to-volume ratio and height and surface coverage were calculated to explore effects on cooling energy demand of different morphology types.

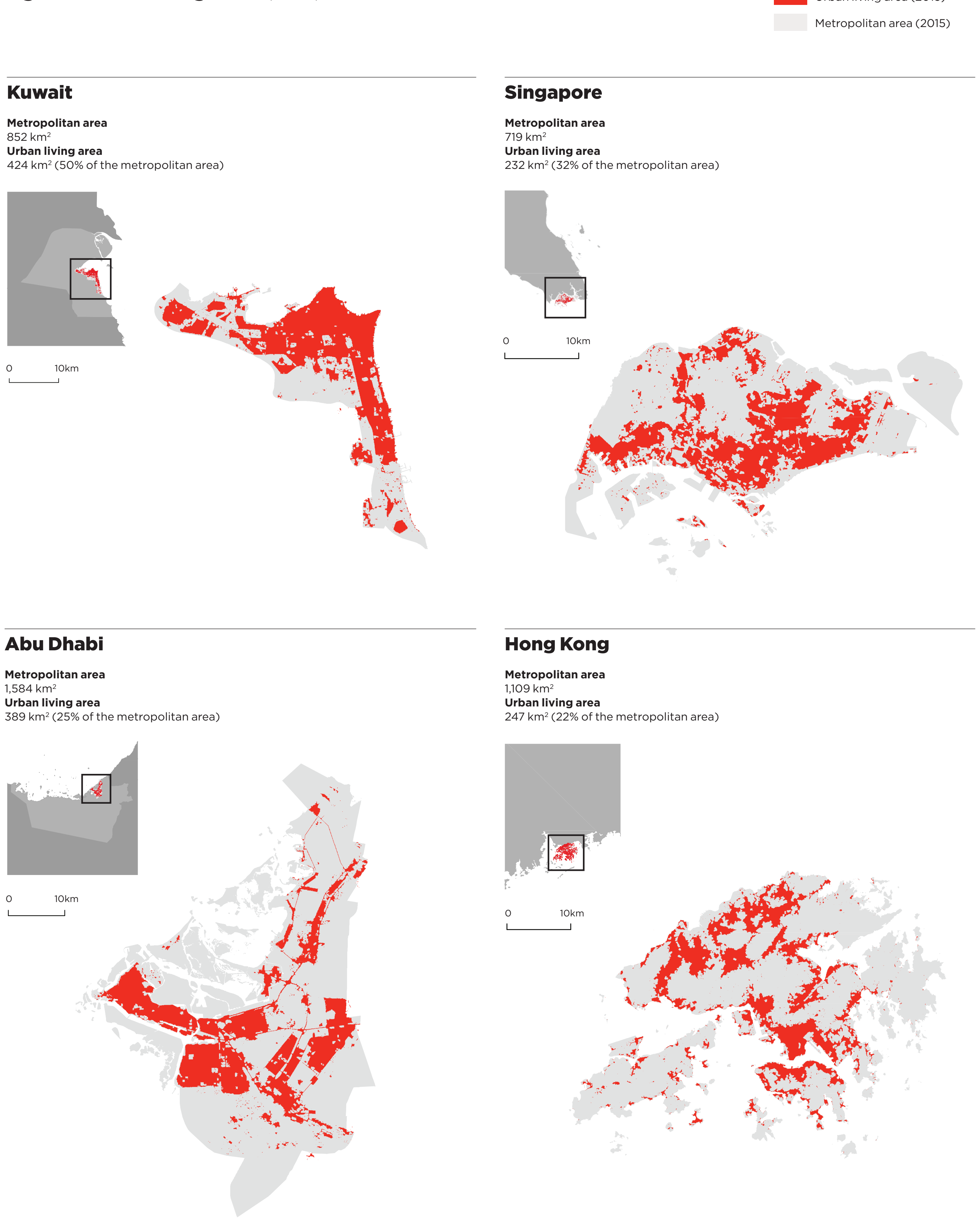
Box 1: Urban living area

Urban living area (ULA) is a measure developed by LSE Cities to calculate the total developed land within a metropolitan area. It includes all built-up areas as well as small open spaces adjacent, or close, to the built-up areas. However, it excludes large, unoccupied spaces, 'dead' built-up spaces such as isolated roadways, and areas occupied by large storage structures, such as shipping containers or oil storage tanks that are included in traditional measures of built-up areas.[3] Such areas have been excluded as they are scarcely used by residents in day-to-day life, and can distort calculations of residential and workplace density in a city. The ULA hence provides a means to identify the boundaries within which people live, work and travel, which is particularly important when exploring the use of land as a resource.

The four maps (in figure 2) illustrate the total land area of the case study cities in grey, metropolitan boundaries – in the case of Kuwait and Abu Dhabi – in light grey, and the ULA in red. Kuwait's ULA is 50 per cent of its metropolitan area but only 2 per cent of the total territory. In Abu Dhabi, the ULA is 25 per cent of its metropolitan area and 1 per cent of the total territory. In Singapore, it is 32 per cent of its metropolitan area, and in Hong Kong, 22 per cent. This demonstrates that Kuwait and Abu Dhabi have space to grow not only within their metropolitan boundaries, but also beyond them. Kuwait is already expanding to the northern, western and southern sides of the bay through the construction of new cities.

However, it is important to note that, although Kuwait and Abu Dhabi have space to grow beyond their metropolitan boundaries, this space often comprises of oil fields and military areas, constraining future development. Likewise, in Singapore and Hong Kong, the grey areas include protected green areas, water reservoirs, steep land that cannot be used for construction, and some industrial areas with temporary structures (e.g. ship containers, gas holders), leaving limited vacant land for expansion.

Figure 2: Urban living areas (ULA)



1.4 The four case study cities

Kuwait, Abu Dhabi, Singapore and Hong Kong are four particularly unique cases of Asian urban development. All four can be characterised as high-income city states equipped with considerable powers to determine urban development. However, the makeup of their populations, their political economies and cultures vary considerably. They also represent contrasting cases of Asian urbanisms and operate under diverging natural resource conditions – most obviously in relation to land availability. Figure 3 illustrates the considerable difference in Kuwait and Abu Dhabi's overall land area on the one hand, and Singapore and Hong Kong's overall land area on the other. As can be seen in Exhibit A, Abu Dhabi faces the lowest levels of physical constraints to development, while Kuwait, Singapore and Hong Kong face considerable physical constraints to development. However, when compared with the two East Asian cities, Kuwait has significantly more land available for development after accounting for all physical constraints.

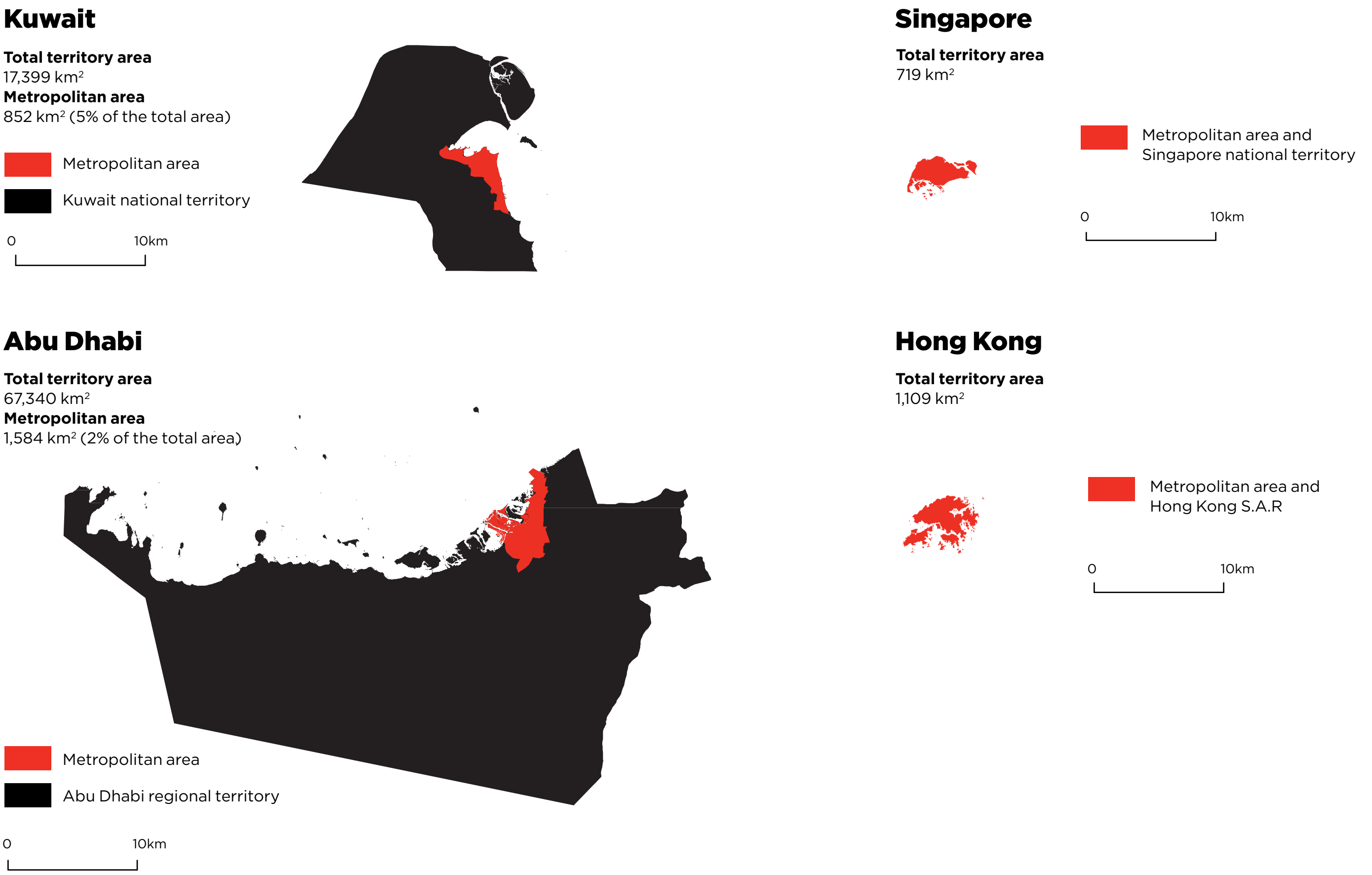
The diverging densities of the GCC and East Asian cities are among the most fundamental differentiators of urban form (see Exhibit A). Overall, a higher percentage of the population lives in low-density areas in the GCC cities as compared to the East Asian cities. In Kuwait, for instance, 71 per cent of the population lives in densities less than 20,000 pers/km^2, while in Singapore and Hong Kong only 38 per cent and 28 per cent of the population respectively lives in similarly low densities.

Average densities within the urban living area (ULA) range from 4,428 pers/km^2 (Abu Dhabi) to 29,554 pers/km^2 (Hong Kong). A closer look at the distribution of residents by square kilometre across a 100 by 100 kilometre urban region reveals further differences. Peak densities range from 39,142 pers/km^2 in Abu Dhabi to 112,941 pers/km^2 in Hong Kong.

Furthermore, high-density neighbourhoods in Kuwait are clustered mostly in its central neighbourhoods, although the edges of the city also host a mix of high- and low-density neighbourhoods. In most cases, density peaks represent non-Kuwaiti neighbourhoods (see also Box 3). Peaks in Abu Dhabi are unevenly distributed as they are located in the CBD area and two other mainland clusters. Densities in Singapore are more homogenously distributed, while in Hong Kong they take a more polycentric shape due to natural barriers that serve as constraints to development.

When analysing the link between population densities and housing typologies, this research finds that Kuwait is the only city where the majority of the population (65 per cent) lives in low-density housing [4]. In Abu Dhabi nearly 60 per cent of the population lives in apartments and in industrial

Figure 3: Case study territories/countries and metropolitan areas at the same scale



NW Al-Sulaibikhat, Kuwait

Shape and physical configuration of cities directly impacts energy requirements and resource efficiency, making urban morphologies and building typologies a critical factor for sustainable development.

Photography: Alexandra Gomes

areas (workers' residential cities). In Singapore and Hong Kong, over three quarters of the population lives in apartment buildings. However, in Abu Dhabi, although a majority of the population lives in apartments and buildings in industrial areas, these typologies cover only 27 per cent of the total ULA, while low-density housing consumes over 70 per cent of the total ULA. Hence, apartments and industrial areas are characterised by substantially higher residential densities. In Hong Kong, apartments house 96 per cent of the population, and also cover 94 per cent of the total ULA, suggesting a more even distribution of the population by typology.

Considerable differences between the cities also exist in relation to how people travel within them. In Kuwait and Abu Dhabi, there is no rail infrastructure, over 50 per cent of trips are made by private vehicles, while the remainder are made by bus, taxi and walking. In Singapore nearly 30 per cent of total trips are made using private vehicles, while approximately 60 per cent are made using public transport and eight per cent by active transport (walking and cycling). In Hong Kong, only seven per cent of trips are made by private transport, with residents relying almost exclusively on public transport. Overall, public transport dependence is significantly higher in Singapore and Hong Kong than in Kuwait and Abu Dhabi.

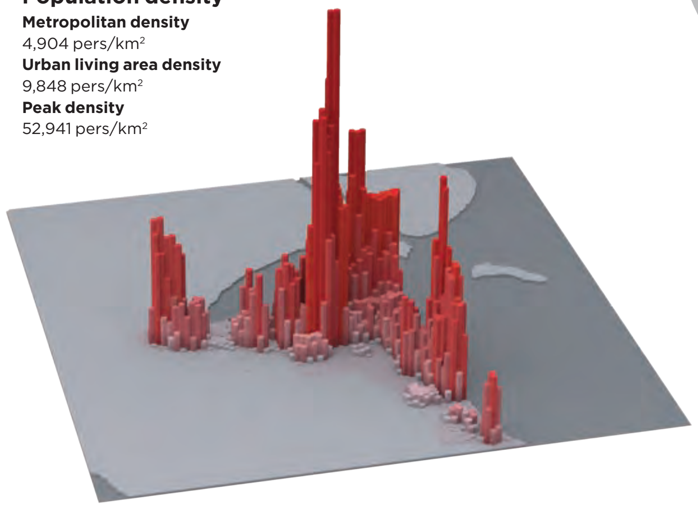
EXHIBIT A: Introducing the four cities

The figures below provide a snapshot of Kuwait, Abu Dhabi, Singapore and Hong Kong's divergent socio-spatial characteristics including population, land area, residential densities, housing typologies and transport modal share.

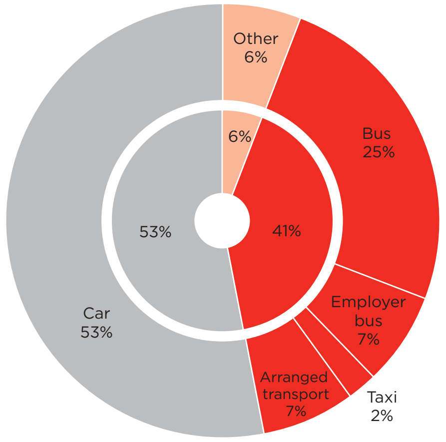
Kuwait

Total population
4,178,572
Total area
17,399 km²

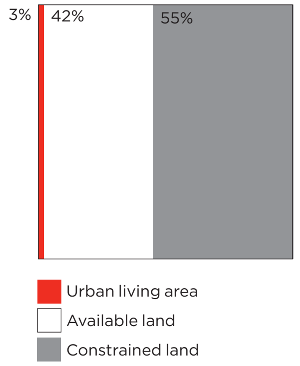
Population density
Metropolitan density
4,904 pers/km²
Urban living area density
9,848 pers/km²
Peak density
52,941 pers/km²



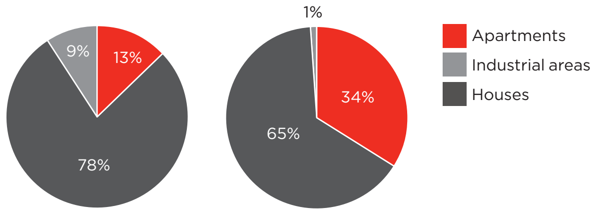
Transport mode share



Land availability (of total territory)



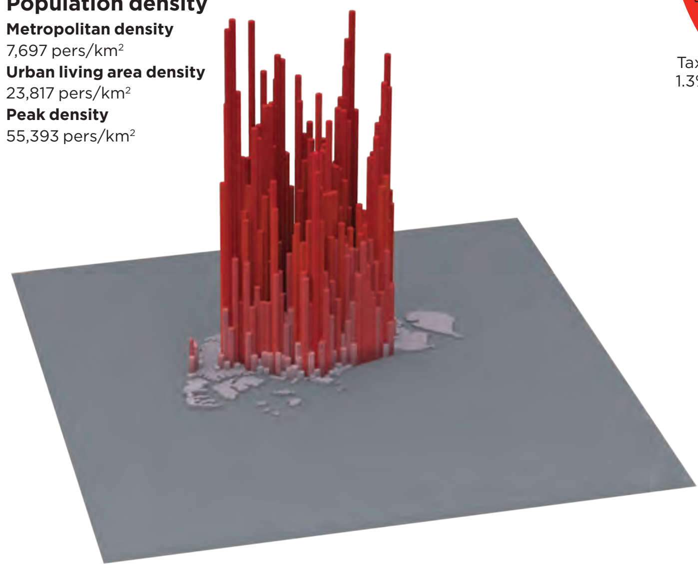
Housing typologies



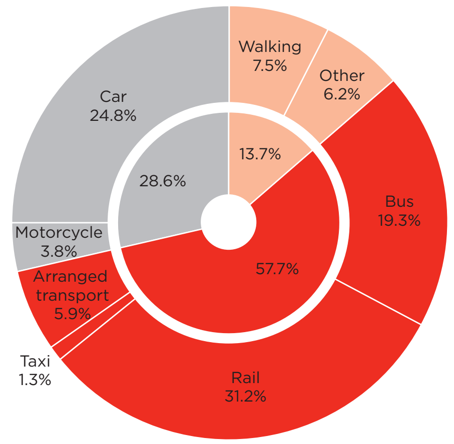
Singapore

Total population
5,535,002
Total area
719 km²

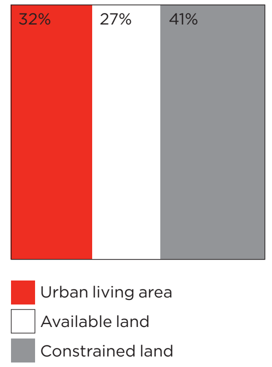
Population density
Metropolitan density
7,697 pers/km²
Urban living area density
23,817 pers/km²
Peak density
55,393 pers/km²



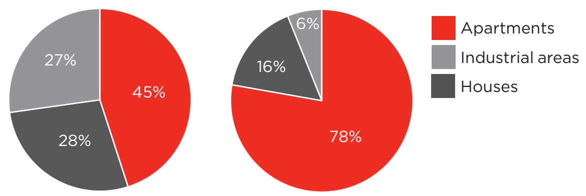
Transport mode share



Land availability (of total territory)



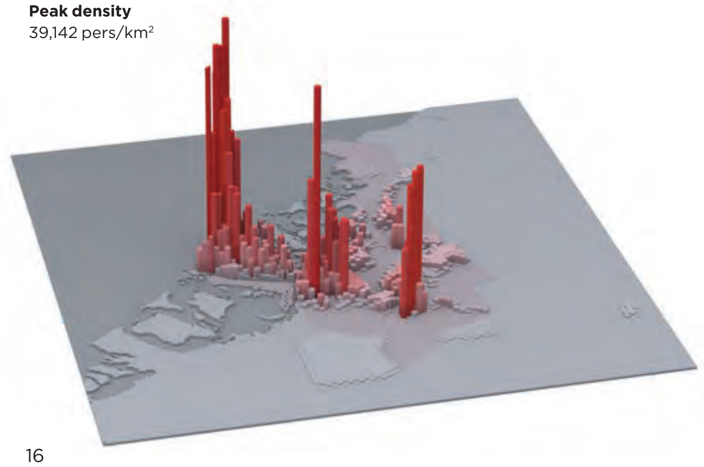
Housing typologies



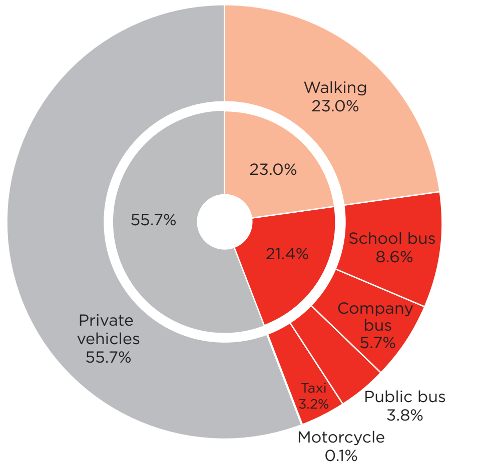
Abu Dhabi

Total population
2,784,490
Total area
67,340 km²

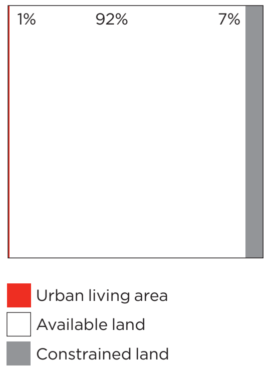
Population density
Metropolitan density
1,086 pers/km²
Urban living area density
4,428 pers/km²
Peak density
39,142 pers/km²



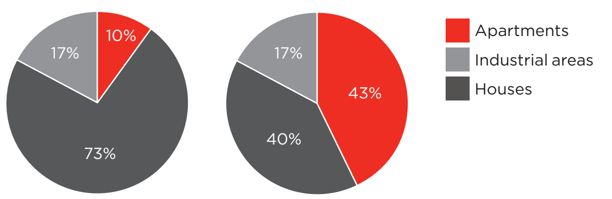
Transport mode share



Land availability (of total territory)



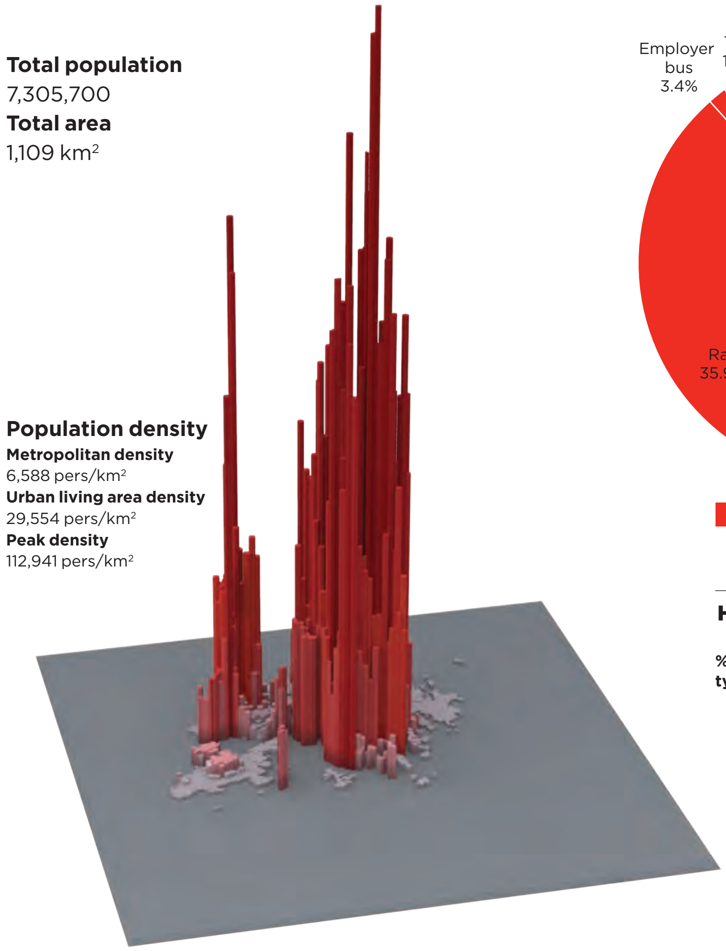
Housing typologies



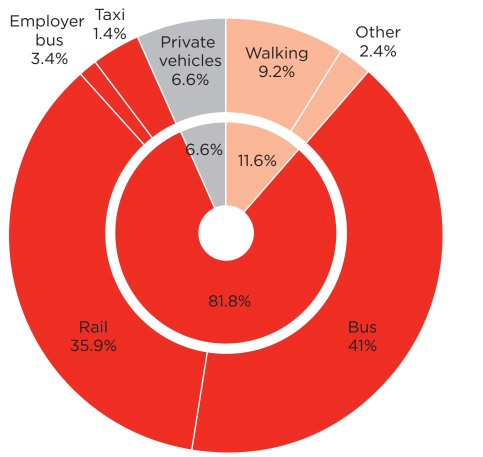
Hong Kong

Total population
7,305,700
Total area
1,109 km²

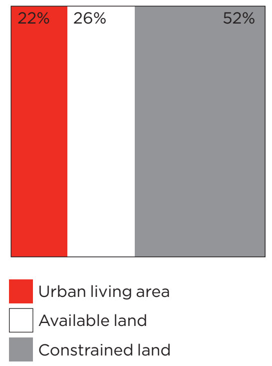
Population density
Metropolitan density
6,588 pers/km²
Urban living area density
29,554 pers/km²
Peak density
112,941 pers/km²



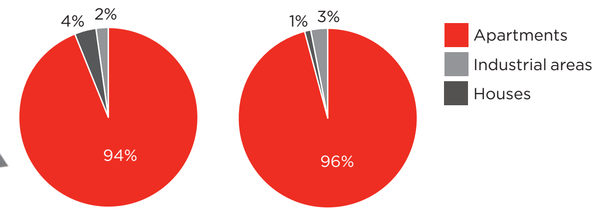
Transport mode share



Land availability (of total territory)



Housing typologies



2 Part A: From resources to urbanisms

Natural resource conditions are among the primary explanatory factors that impact the type of urban development and urban change that can be observed in different global contexts. This chapter examines the role that land and energy, specifically their availability and costs, may have played in influencing urbanisms in Kuwait, Abu Dhabi, Singapore and Hong Kong. An introduction to each of the four cities traces changes in urban growth patterns roughly over a 95-year period (1920–2015), explores similarities and differences in these patterns, and analyses the impact that land and energy have had on their dynamics of growth.

2.1 Resource conditions, wealth creation and urban planning regimes

This section provides a detailed introduction to each of the case study cities, focusing on their natural resource conditions, underlying economic structures and institutional arrangements that define their urban planning regimes. It highlights strategies developed by each of the cities in response to land and energy availability and describes the evolution of their most prominent approaches to spatial planning.

2.1.1 Kuwait

Kuwait, a constitutional emirate and city state, with a total area of 17,399 km^2, has undergone a transformative urban boom from a small Arab maritime town to a modern-day metropolis in less than half a century. Its rapid urbanisation is directly linked to the discovery of oil in 1938, with its first export shipment in 1946. The discovery of oil marks a turning point in the city state's history as it contributed to the modernisation of society and catalysed the redistribution of new-found wealth. With the sudden overflow of oil revenues (Kuwait has the sixth largest oil reserves in the world)[6], a welfare state was established during the reign of Abdullah Al-Salem Al-Sabah to share the wealth among Kuwaiti citizens and improve their quality of life. Together with free healthcare, free education and extensive subsidies, generous housing policies were put in place to achieve that intention, and a modern master plan was created in 1952 to translate these new welfare provisions into physical reality.

From the outset, land availability in the city state aided the state's aspirations to redistribute wealth: the vast spread of desert beyond the Kuwait Old Town's walls provided a clean canvas for new housing, health, educational and industrial areas. As per the master plan, strict land use zoning was introduced, and residents of the walled town had to move out so that the area within could become an entirely redeveloped commercial and business centre. For this purpose, the state utilised land acquisition schemes to acquire people's homes. In exchange, it provided them with plots and built homes in new urban areas.

The redesign of the city under the 1952 master plan was based on a set of radial roads that were built from the new city centre outwards and intersected with ring roads.

Box 2: Wealth, petrol affordability, and national urban densities

Literature exploring the impact of fuel prices on densities and urban form suggests that urban density is 'a function of transport costs', and that therefore fuel prices can shape city size and urban form (Creutzig, 2014, pp. 74-75). However, it also suggests that causality remains unclear. To investigate this further, the scatter plot (Figure 4) looks at the relationship between petrol affordability (the percentage of per capita GDP required to purchase a 1,000 litres of petrol) and national urban density (national urban population divided by national urban land). It illustrates a negative correlation between the two, with higher petrol affordability associated with lower density levels. The observed correlations should, however, be viewed with caution as the petrol affordability here only accounts for petrol prices in 2014 and hence excludes historical price fluctuations. The results indicate that the four case study cities stand out in different ways: Kuwait and Abu Dhabi with extreme levels of petrol affordability and Hong Kong and Singapore with extreme densities at more average petrol affordability levels.

The overall relationship shown here can, however, be statistically explained by GPD per capita. Figure 5 explores the link between GDP per capita and national urban density, and shows that GDP per capita is a significant predictor of urban density levels. Singapore and Hong Kong are outliers, with high GDP per capita and high density levels. Kuwait and Abu Dhabi appear to be roughly where they would be expected to be given their wealth levels. Purely on the basis of these datasets, there is limited evidence that low energy prices have had a particular effect over and above the general economic wealth effect.

Although the above findings are preliminary and do not allow for a reliable identification of causal effects, they suggest that wealth rather than cheap energy drives low urban density. They also show that the four case studies serve as outliers and extreme cases in some instances. Given that all four have similar levels of wealth, it may be that the story of urbanisms and urban density is likely to have been influenced by a confluence of structural and country-specific variables that global statistics cannot capture. Some of these factors will be explored further in the sections below.

Figure 4: Petrol affordability and national urban density[5]

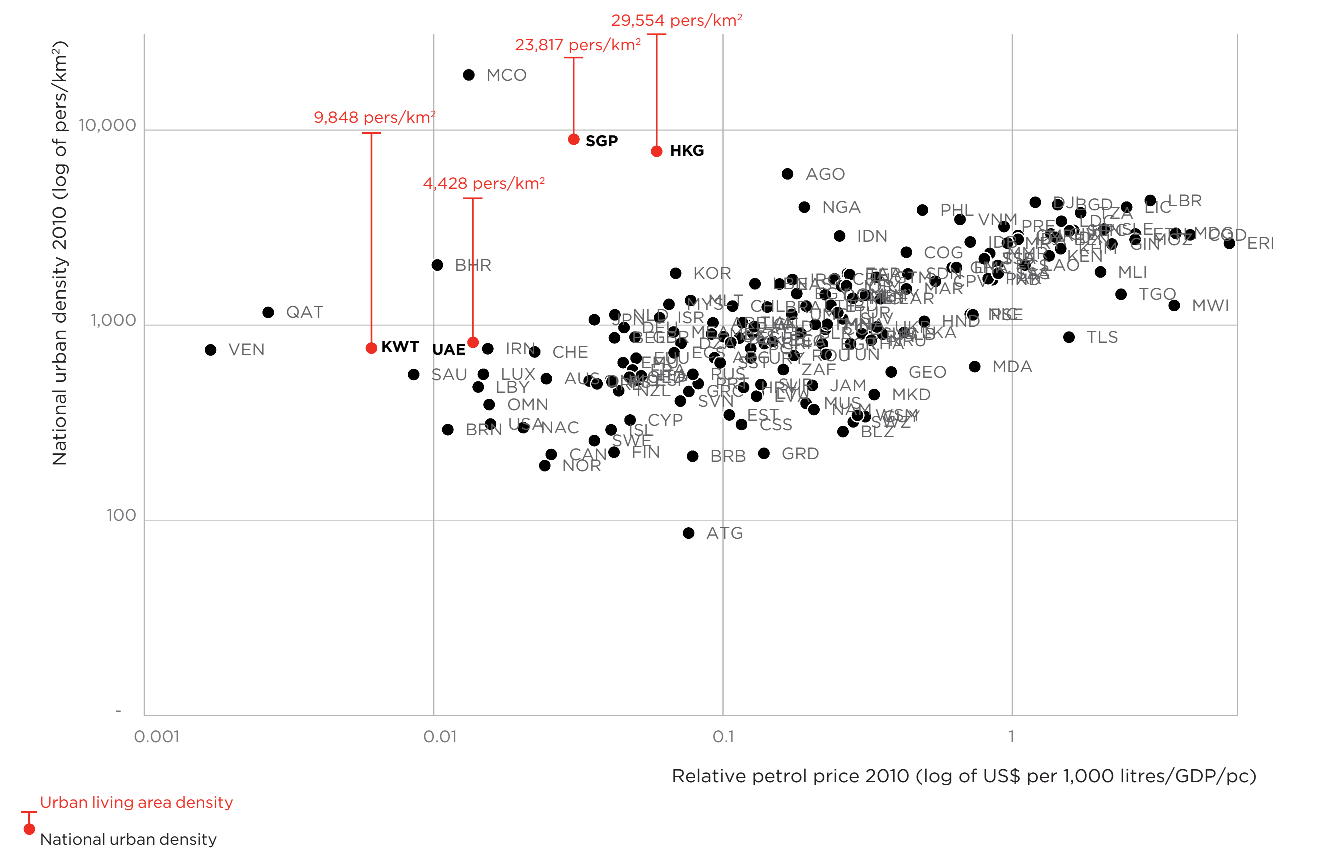
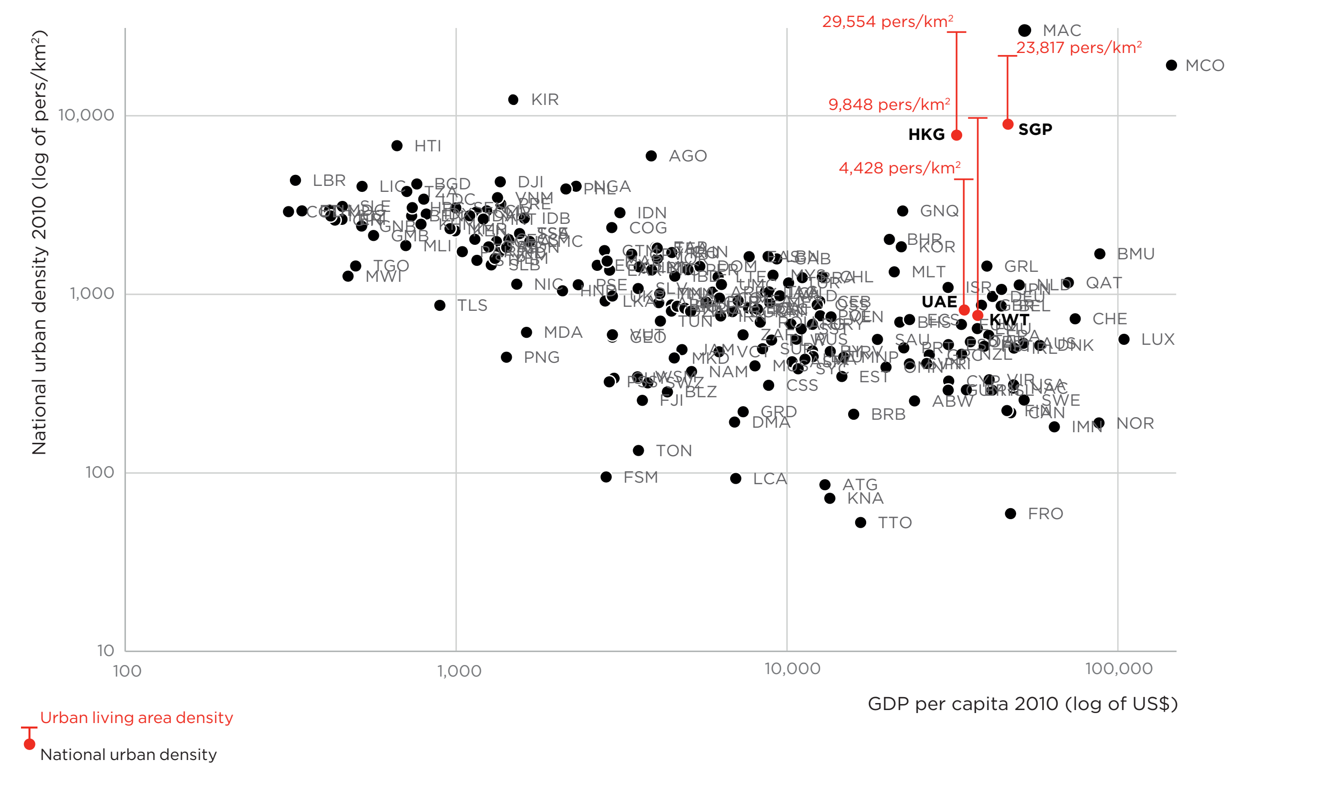


Figure 5: GDP per capita and national urban density



Kuwait Old Town (1955)
Master plans and an oil windfall saw the dense old town entirely redeveloped. A new road design connected the modern city centre to newly constructed suburbs.
Photography: Kuwait Research and Studies Centre

These roads served as the organising principle for the new plan, and were designed with the intention of ‘enabling motor vehicles to move across town with speed and safety’ (Minoprio, Spencely and Macfarlane, 1951, p.5). The roads also supported a series of mainly detached single-family housing neighbourhoods for Kuwaitis (in contrast to closely knit courtyard houses in the Old Town), in what were described as the ‘neighbourhood units’ (Buchanan, 1969, pp.5–7; Shiber, 1964, p.219). Kuwaitis whose land had been expropriated in Kuwait Town were given plots that ranged in size from 750 to 1,000 square metres,[7] and Kuwaitis with limited incomes were provided built homes[8] on 250 to 500 square metre plots (Shiber, 1964, p.224). Housing for the non-Kuwaiti population was developed by the private sector on private land and predominantly comprised small apartment-type buildings (Ibid, pp. 223–224).

Over time, a series of new master plans[9] were created to accommodate the growth in population, using similar planning principles to those implemented through the first plan. Variations in housing distribution and plot sizes also took place over time (see Exhibit D).

After the discovery of oil, the state also began to heavily subsidise energy for industrial and domestic use. As there were minimal natural fresh water resources in the country, funds were also invested in modern water production facilities, helping to meet the rise in demand for water in the city state.[10] In addition, land was indirectly subsidised through the Land Purchase Programme. Under this programme, the state purchased land from nationals at high prices, utilised it for public buildings or other purposes and at times sold the remaining land back to the public at low prices (Herb, 2014).[11]

As such, Kuwait experienced uninterrupted growth in both population size and urban expansion from the early 1950s to the mid-1980s. The urban area grew more than 50 times, at an extremely high growth rate. In 1951, Kuwait Town covered only 4.9 square kilometres of the vast desert, surrounded by some small settlements farther south and west. By 1977, the urban living area had reached over 143 kilometres squared (see Exhibit B).

As the city expanded with new roads and modern infrastructure, and the economy flourished, the quality of life substantially improved for Kuwaitis, who were able to live with their families in new and modern housing. During this time, the immigrant population also started growing, and a high number of migrants from South Asia, Iran, Iraq and Egypt found work in the construction industry and aided the state’s infrastructure development. Some (including Palestinians, Lebanese, Egyptians and South Asians) found work as ‘technicians, schoolteachers, nurses, doctors, and dentists’, professions that Kuwaitis needed further training in (Al-Nakib, 2016, p.95). By 1961, the non-Kuwaiti population comprised almost 50 per cent of the total population, and by 1965 it had surpassed the local population (CSB, 1990, p.21). To accommodate incoming groups, new housing was developed in the form of multi-family units. This created clusters of high-density living for the non-Kuwaiti population within the expanding metropolitan area.

At the same time, generous housing welfare provisions were maintained for the local population in the form of villas and plots. In 1974, a Housing Authority[12] was established to develop and build homes for Kuwaiti citizens, and to accommodate the increase in demand for housing (partially caused by the increase in population growth). During this period, the oil industry was nationalised, and with global increases in oil prices, oil revenues for the state almost quadrupled within one year, leading to an increase in GDP per capita between 1973 and 1974 from 5,953 to 13,479 current US$ (World Bank, 2017). This influx of oil wealth allowed for the continuation of the heavy subsidisation of the housing scheme, and meant that land was provided to citizens at nominal rates, while loans to buy or build the homes were provided with no interest.[13]

Modern construction methods and new house designs (for villas and government houses), coupled with the new morphology of the city, dictated certain energy demands particularly related to cooling energy. As the city expanded further and housing development continued, energy consumption increased in parallel. Electricity tariffs, however, remained constant with the last increase taking place in the mid-1960s. In addition, the state subsidised – and continues to – 95 per cent of the cost of producing and delivering electricity, resulting in consumers paying less than 1 US cent per kWh (Krane, 2013). Partially as a result of this policy, energy consumption is one of the highest in the Middle East.

Today, the city has grown approximately a hundredfold since the discovery of oil, and the cost of privately owned land is among the highest in the Middle East region.[14] While the city has some iconic high-rise buildings and high-density neighbourhoods (particularly in the central neighbourhoods, and the edges of the city), it remains a sprawling low-density city dotted with vacant plots that are frequently used for parking cars. The city has been designed for cars, and has poor pedestrian infrastructure. Weather conditions, cultural housing preferences, the absence of an efficient public transport, and the availability of cheap petrol, among the cheapest in the world,[15] have all contributed to car-dependent sprawl and long commuting distances.

Unlike some Middle Eastern cities, non-nationals live in central neighbourhoods. However, there is limited interaction between non-nationals and nationals, and there are clear differences in the way in which Kuwaitis and non-Kuwaitis live and travel in the city. Broadly, non-Kuwaitis live in high-density clusters, and are relatively more dependent on public transport (primarily buses), especially in instances where they earn low incomes.[16] In contrast, Kuwaitis live in large single-family homes[17] and are dependent on private vehicles (which is a direct result of the state's policies on land, housing and energy). As a result, the Kuwaiti population enjoys a high standard of living but also consumes significantly more land and energy resources than the non-Kuwaiti population.

Yet, though the state provides housing for Kuwaitis, supply of housing has been unable to keep up with demand. In some instances waiting times for housing have reached up to 18 years (AlShalfan, 2013). This is partially because new housing developments require high infrastructure investment and spending. In addition, oil fields can serve as physical constraints to infrastructure development. Moreover, as the oil and gas sector is the source of 95 per cent of the country's export revenues (OPEC, 2017), global oil prices impact the state's ability to undertake infrastructure development. With falling oil prices, this approach may prove unsustainable, making alternative planning paradigms more appealing.

2.1.2 Abu Dhabi

Abu Dhabi is the capital of the United Arab Emirates (UAE), a federation of seven emirates, each of which is ruled by an absolute monarch. It is also the capital of the Emirate of Abu Dhabi, the largest of seven emirates of the union. With 67,340 km^2, it accounts for nearly 86 per cent of the total territory of the UAE (EA, 2008). The city of Abu Dhabi has a population of 1.7 million (2015), mostly settled on Abu Dhabi Island, one of the many offshore islands extending into the Arabian Gulf and separated from the mainland only by a narrow channel (SCAD, 2016).

Abu Dhabi is located in an extremely arid environment. Water resources are scarce and approximately 80% of water supply has to be produced by large desalination plants powered by natural gas – a cheap by-product of oil production in the country and the wider region (SCAD, 2015, p.11). Likewise, 99.7% of the electrical power is generated by thermal combustion using natural gas (Ibid, p.7). In contrast, the Emirate of Abu Dhabi holds approximately 6.2% of the global proven oil reserves (OPEC, 2015, p.26). With a UAE national population in the Emirate being only 19 per cent of the total population, these oil resources translate into an extraordinary wealth for the Emirati population (SCAD, 2015). Prior to the oil price drop in 2015, earnings from oil exports contributed to over half of the Emirate's GDP (SCAD, 2016), making the state highly dependent on oil income for government spending.

Urban development in modern Abu Dhabi can broadly be divided into three key phases: 1963–1973, 1974–2004 and 2004–2015. Before the first oil resources were discovered by British prospectors near the western shores of Abu Dhabi Island in 1958, only a few thousand fishermen were settled in a small village, made of a small number of huts built with palm and dry mud.

Living conditions started to improve in Abu Dhabi when Sheikh Zayed bin Sultan Al Nahyan, Emir from 1966 to 2004 and President of the UAE from 1971, launched new infrastructure development with the oil revenue (Al-Rashedi, 2011, p.34). This was part of the first phase of urban development in the city. Between 1965 and 1968, several master plans were produced by British planners and consultants working in the region.[18] At the city level, the plan that had the most important impact was the plan developed by Arabicon Consultants in the late 1960s under the supervision of the Director General of Town Planning, Abdel Rahman Makhlouf.[19] This plan was responsible for the rigid hippodamian grid of the northern part of Abu Dhabi Island.

Between 1963 and the mid-1970s, the major focus of urban development was the provision of basic services. As part of the wider welfare state policies, fuel, electricity[20] and water were also highly subsidised. During this period, Sheikh Zayed also worked closely with expert planners and architects[21] to develop a standard housing unit, or bayt sha'bi (national house) to urbanise and settle nomadic Bedouin tribes. The provision of free housing was used as a means to 'build the nation' (as the British had announced their departure) and allow the population to 'contribute productively to society' in the future (Hashim, 2016, p.68). Although the national house was initially designed as a small structure (20m x 25m), plot size and gross floor space standards increased significantly over time (as high as 60m x 45m) to cater to residents' cultural values, privacy concerns and housing preferences, increasing land consumption in the city (Ibid).

In the second phase, spending grew due to rising crude oil world market prices from 1974 and the simultaneous growth in state oil revenues. In the 1970s, migration from South Asia also began to increase (Wickramasekara, 2016). The most significant land 'policy' in this period was the inception of the Khalifa Committee for Social Services and Commercial Buildings. Founded in 1976, the committee allocated residential, commercial and industrial and/or agricultural plots to Emiratis, and provided funds to build houses and businesses (Elsheshtawy, 2008, p.270).[22] It is estimated that 'over 200 apartment blocks were constructed every year in the 1980s and 1990s' through the committee (Ibid, p.271). During this period, Sheikh Zayed deliberately controlled urban sprawl against the example of neighbouring Dubai. As a result, development was relatively compact, and new urban centres were designed to house the local population in the best possible living conditions. Nevertheless, in the meantime, Abu Dhabi had grown from a small village in 1949 to become a burgeoning capital city of 374,000 in 1990. To regulate and prepare the city for rational development, a new master plan was commissioned in 1988.

The master plan finalised by Atkins, a British design consulting firm, in 1990 took note of the land requirements associated with the Emirati National House as being unsustainable as they 'diluted any sense of community in residential areas', inefficiently utilised land, and increased the costs associated with infrastructure provision (Hashim, 2016, p.71). The plan recommended the reduction of national housing plot sizes, or a decrease in incidental open spaces and side spaces that separated adjacent plots (Ibid). It also recommended the development of islands outside Abu Dhabi Island to accommodate future growth (Elsheshtawy, 2008, pp.270–271). In relation to transport, it suggested that it was critical to build 'robust' road infrastructure (highways with several lanes) in the city to improve connectivity within the city. Developments based on this plan are still visible in today's Abu Dhabi.

The most incisive event in the recent history of Abu Dhabi, and subsequent turning point of urban development policies, was the demise of Sheikh Zayed in 2004 and the involvement of a 'new generation of leaders' under Sheikh Khalifa bin Zayed Al Nahyan, who focused on 'project-based modernisation' (Hertog and Luciani, 2012, p.250). It marked an end to the period of controlled and modest urban growth after which private companies were encouraged to engage in construction activities. At this time, property ownership law was also changed, as a result of which nationals were allowed to sell land given to them by the government, and foreigners were allowed ownership under certain conditions. Measures that had been in place to prevent speculation were no longer as applicable and developers (largely functioning as quasi state operators) frequently engaged in construction activities that ignored existing regulations (Elsheshtawy, 2008). In addition, the post-2004 boom in the construction industry marked a hike in population growth rates (partially due to an increase in the migrant population) and subsequent expansion of the city.

To control development, regulatory bodies such as the Urban Planning Council (UPC) were established and given the mandate to implement planning regulations and guidelines as well as city and transport master plans. In 2007, the UPC launched its first framework plan – Plan Capital – to guide future development. This helped to somewhat regulate unfettered land development in the city, and contributed to more continuous growth. In 2007, Plan Abu Dhabi 2030 was finalised. The Plan focuses on building the city's identity, catering to the needs of the Emirati population and questions of sustainability.

In the wake of the sharp oil price drop in 2015, the government decided to deregulate energy prices by 1 August 2015. Subsequently, fuel subsidies were removed and a new pricing policy was adopted that linked local prices to global prices. In addition, for expatriates, the price of electricity was linked to production and distribution costs. Prior to 2015, fuel prices were as low as AED 1.83 (US$ 0.50) per litre (MOE, 2015a), while electrical energy prices were AED 0.05 (US$ 0.01) per KWh for nationals and AED 0.15 (US$ 0.41) per KWh for expatriates (OBG, 2013). While these were higher than other GCC countries such as Kuwait, Bahrain, Saudi Arabia and Qatar, they were among the lowest fuel and electricity prices globally (Katiri et al., 2012).[23] The policy decision on the UAE level reflects the UAE's vision to diversify sources of income, strengthen its economy and reduce dependency on government subsidies (MOE, 2015b).

Today, different phases of Abu Dhabi's urban development are clearly visible in the city's morphology: high-density city blocks from the mid-1970s with up to 18 storeys dominate the Central Business District.

On the south-western edge of the CBD, as well as on Reem and Al Maryah Island, a large number of iconic high-rise buildings have been completed more recently. The rest

Planning Abu Dhabi (1974)

Sheikh Zayed briefed by Abdel Rahman Makhlouf, Director General of Town Planning in Abu Dhabi

Photography: National Centre for Documentation and Research

of Abu Dhabi Island is predominantly built up, with villa neighbourhoods, government buildings, hospitals and malls as well as palace neighbourhoods that stretch along the southern side of the island.

There has been a rise in the construction of low-density suburban developments that are frequently located at a distance from one another, giving rise to a 'scattered' form of development. These residential neighbourhoods are located far from all amenities and facilities. With the exception of Port Zayed, most of the industrial zones – the largest being Mussafah – are located on the mainland. The mainland also hosts residential cities such as ICAD or Mafraq, built to host low-income labourers distant from the city centre. The urban typologies found in these areas are distinct.

Real estate prices in Abu Dhabi are high as compared to other cities in the Middle East; however, this is not necessarily a reflection of scarcity of land: while it may be scarce in some areas, there is land available in the north and east. Yet, given desert conditions and the way the city has developed historically, these parts of the city are not commonly perceived to be suited to development.

Due to low energy prices and car-oriented urban design (intense provision of parking and road capacity as well as poor walking facilities), car dependency has grown in Abu Dhabi. This is also because public transport did not exist until 2000, and modern air-conditioned city buses were not introduced prior to 2008.

On the whole, the city houses pockets of high-density blocks, but primarily comprises low-density developments, limited public spaces and a car-dependent population. While expatriates primarily live in high-density blocks, Emiratis live in suburban neighbourhoods, on land provided by the state. Migrant labourers live separately from the rest of the population close to industrial and construction sites. The average household size is 7.4 people per household, which is roughly equivalent to six bedrooms (ADHA, 2014). On the whole, natural resource availability and the state's welfare policies have significantly improved the quality of life Emiratis enjoy, yet these improvements are not evenly distributed among the population. In addition, resource consumption is among the highest in the region. As a proportion of total electricity consumed, the residential sector consumes 29 per cent, the commercial sector 31 per cent, the industrial sector 11 per cent and others (mainly water desalination) 29 per cent (Palasciuc, 2016).

In recent years, however, Abu Dhabi has shown a growing interest in issues of sustainability, and has been aiming to position itself as a leader in this realm. In 2002, the Mubadala Development Company was set up to facilitate the development of sustainable projects through its subsidiary Abu Dhabi Future Energy Company, or Masdar. In 2006, planning and development for Masdar City – a new city serving as a model for sustainable and carbon-free urban development – was initiated (Hertog and Luciani, 2012). It has now been partly built at the north-eastern edge of the city, and the impact of both Masdar City and other initiatives will become clearer in the coming years.

2.1.3 Singapore

Singapore is an island state located at the southern tip of the Malay Peninsula. The island served as a trading settlement in the fourteenth century, after which it came under the Malacca and Johor sultanate. The history of modern Singapore is associated with the arrival of the British in 1819, specifically when the Johor Sultanate permitted the British to establish their trading post on the island. Modern Singapore has seen a brief Japanese occupation (1942–1945), a merger with the Federation of Malaysia (1963–65) and independence in 1965 when it became a sovereign democratic republic.

The People's Action Party (PAP) has been in power in Singapore since 1959,[24] with Lee Kuan Yew Prime Minister for 31 years from 1959 to 1990, Goh Chok Tong for 14 years from 1990 to 2004 and Lee Hsien Loong from 2004 onwards. Through foreign investment, export-oriented industrialisation and public sector planning and management, Singapore's economy has grown significantly since the 1970s, with real GDP doubling each decade between 1970 and 2000 (Phang, 2007). Today Singapore has a population of 5.5 million (DSS, 2017), is largely a service-sector-based economy with a high GDP per capita (53,630 current US dollars, 2015), and operates as one of Asia's leading financial and knowledge centres.

Water, land and energy are Singapore's three most critical resources. As a small island (719 km^2) with limited land, insufficient water and natural energy sources (oil and natural gas), and a geography that makes it difficult to harness renewable sources such as hydroelectric, geothermal and wind energy (MEWR and MND, 2014), Singapore faces numerous physical and resource constraints that pose serious development challenges. To meet its immediate water and energy needs, Singapore has been importing water from Malaysia under several bilateral agreements, crude oil from a range of countries, particularly from the Middle East region (accounting for nearly 80 per cent of imports) and piped natural gas primarily from Malaysia and Indonesia.[25] To strategically manage its scarce resources, the state in Singapore has actively planned, intervened and regulated the economy, prioritised international cooperation, invested in diversification of water and energy sources, reclaimed land and has ensured that its city planning strategies optimise the use of its resources and further its economic development agenda.

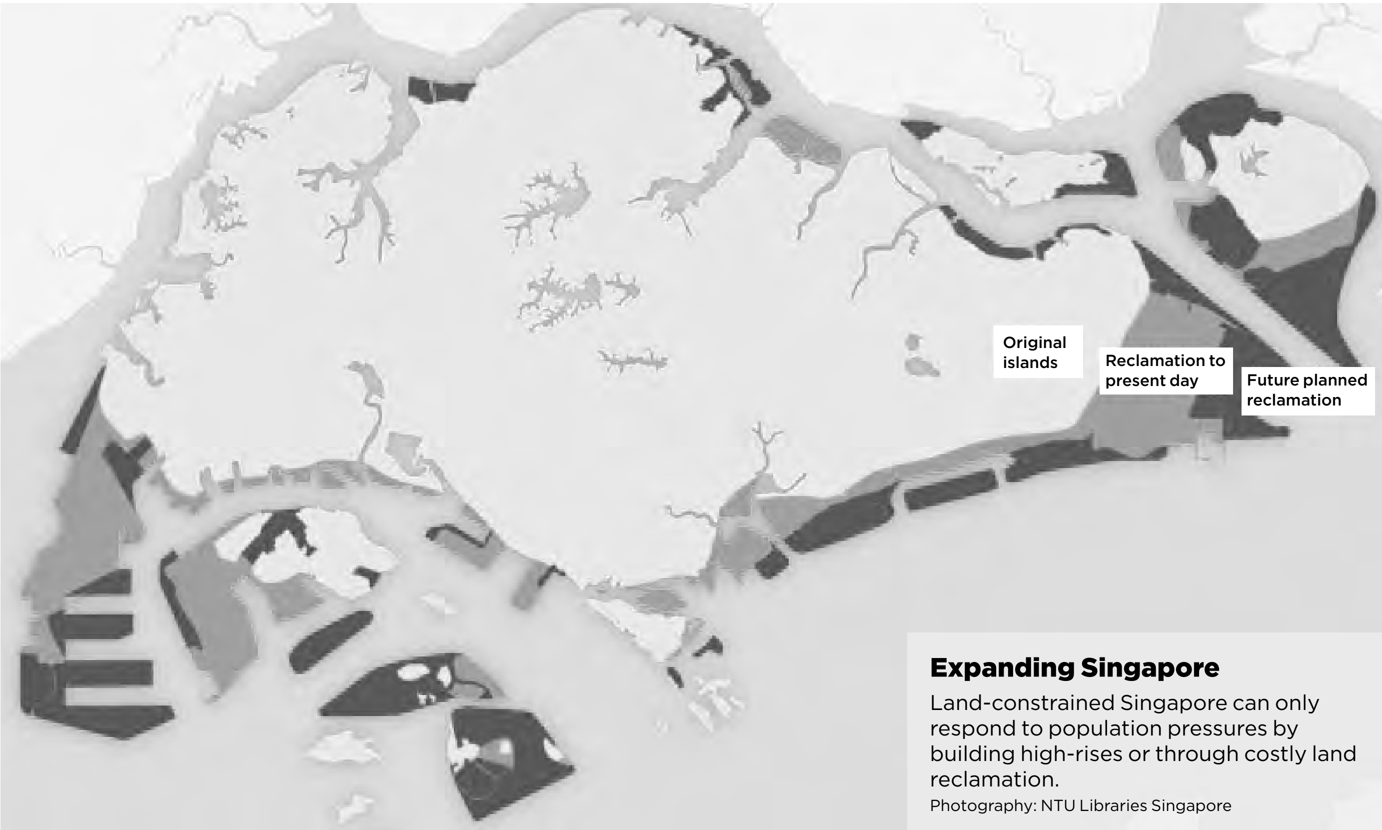
Singapore's history of town planning goes back to 1828 when the Jackson Plan was drawn up by the colonial authority to organise the city along a grid road network that also divided residential areas along ethnic lines. Over time the city's population increased, leading to overcrowding on the island. To address this situation and manage infrastructure and housing challenges, the colonial authority set up the Singapore Improvement Trust (SIT) in 1927. The city state's first master plan was drawn up by the colonial authority in 1958, and aimed to relocate the island's population to peripheral new towns to reduce densities in the crowded city centre. This was planned in conjunction with the development of public housing estates that were to be mostly located around the central water catchment area. For this purpose, the Housing Development Board (HDB) was set up in 1960 as a replacement for the SIT.

By 1965, the city was still severely overcrowded with people living in poor conditions. To improve these conditions, and optimise and control resource use in the city, the newly independent state first needed to secure access to land. In 1967, it passed the Land Acquisition Act, which was based on the 1920 British Land Acquisition Ordinance. While the former law gave the government the power to acquire private land primarily for military or industrial purposes (CLC, 2014), the latter allowed the state to also acquire private lands for residential, commercial, or industrial purposes in the public's interest (Phang and Kim, 2011). Under the new law, market value did not include any increase in land value due to public spending, and was based on a number of other stipulations[26], that allowed the state to acquire land at a relatively reasonable cost (Lim and Motha, 1980). Subsequently it acquired land primarily for the development of public housing, which it deemed necessary to meet the housing shortage, maintain political stability and 'provide the living environment for those engaged in economic activities,' (Rowe, 2005, p.70). It also acquired land for industrial estates and urban renewal, among other uses. The law gave the state significant room to implement its urban development agenda.

From 1974, the Urban Redevelopment Authority (URA) began to develop master plans in Singapore. All plans guide development over a 10 to 15 year period, and outline land use details, development intensities, while translating strategies in concept plans that set the development direction for the next 40 to 50 years.

In 1971, the country's first long-term concept plan was drawn up. Among other initiatives, it envisaged the development of the Mass Rapid Transit (MRT) system, pan-island expressways, and the development preparation of the Changi international airport. Subsequently, in 1991, the revised concept plan divided Singapore into four regional centres to reduce traffic congestion in the central city area. This, however, increased daily commuting flows to the Central Business District by public transport and private vehicles. The 2001 Concept Plan focused on providing residents with a range of housing options, set aside land for financial and service sectors and aimed to build Singapore's natural and built identity. The 2011 Concept Plan and the 2013 Land Use Plan outlined strategies to support future population and economic growth, and provide 'a high quality living environment' through the provision of affordable homes, the integration of greenery, greater transport connectivity, availability of employment opportunities and other initiatives (URA, 2011).

In Singapore, the protection of the water catchment has been a national priority as it is one of the city state's most scarce resources. For this reason it has integrated its land



Expanding Singapore

Land-constrained Singapore can only respond to population pressures by building high-rises or through costly land reclamation.

Photography: NTU Libraries Singapore

use planning with water resource management. The 1991 Concept Plan also introduced the Green Blue Plan, where green stood for foliage and blue for water. The plan aimed to 'weave together a system of open spaces' comprising of natural open spaces, parks and gardens, sports and recreation grounds, boundary separators, internal greenways and connectors, and other open areas to complement waterways and help establish a sense of garden living (URA, 1991, p.28). The 2001 and 2011 Concept Plans and 2013 Land Use Plan were also consistent with this concept. In this pursuit, a range of government agencies led by URA, including the HDB, National Environment Agency (NEA) and Land Transport Authority (LTA), coordinate plans and take joint responsibility.

As noted in Singapore's 2013 Land Use Plan (URA, 2013, p. 1), 'creating, redeveloping and optimising land in order to build a highly liveable urbanised environment' has always been a matter of priority for the government, and hence land supply remains one of the most critical development issues. Being an island state, Singapore can only expand vertically by building high-rises, or horizontally through costly land reclamations, which it has been doing extensively for decades. Through coastal reclamations, total land area has grown from 581.5 km^2 in the 1960s to 719.2 km^2 today (DSS, 2017b). However, it still has to deal with the land supply limitation, particularly as, by 2016, 80.1 per cent of developable state land had already been used for development purposes (SLA, 2017).

Given Singapore's land constraints, the city has been designed to support higher densities. The city state has focused on compact urban growth by building residential areas and their associated amenities around major MRT stations (URA, 2012). More than 80 per cent of its population now lives in high-density HDB public housing estates, and only a fraction of the population presently lives in low-density landed houses.[27] On average, three residents live in one apartment and the average apartment size is around 27.6 m^2 (compared to 40 m^2 in 1968) (Teoalida, 2017). Throughout its development history, the HDB has thus been increasingly embracing higher-density typologies. While older housing typically has five to eight floors, newer generations can go as high as 55 floors.

While the city has adopted a number of mechanisms to manage its land constraints, these constraints have also served as the driving force for its transport planning efforts. Since the development of its first concept plan, the government has focused on the construction of a high-quality public transport network, and has deliberately aimed to restrict private vehicle ownership as this is seen to be the most 'space efficient' (URA, 2013, p. 40) way to accommodate the city's growing mobility requirements. A myriad of policies and regulations have been designed for this purpose. In 1990, the Vehicle Quota System was introduced to restrict the number of vehicle licences released annually, limiting private vehicle ownership. In 1998, an electronic road pricing system was introduced, whereby all vehicles entering congested areas were charged a fee during peak hours. Furthermore, in 2003 the government introduced a hefty fee for older vehicles to control emissions.

Although these policies have been successful and have increased public transport usage significantly, 31 per cent of the population still relies on private vehicles to travel to work (refer to Exhibit A). This is despite strict policies and significantly higher petrol prices than the global average. The government hence aims to devise mechanisms to further increase public transport usage in the future.

As the functioning of the city and economy has depended on a reasonably priced and reliable supply of energy, the government has been importing most of its energy from other countries. It has also established an energy industry that refines and trades oil, manufactures petrochemical products (housed on reclaimed land) and produces and supplies various types of energy. As a result, Singapore has managed to establish itself as a major energy trading hub in Asia Pacific. However, as 95 per cent of its electricity is generated from imported natural gas, which is indexed to oil prices, electricity tariffs in Singapore are also dependent on the trend of the oil market.[28] In addition, Singapore has not implemented energy subsidies, positioning its energy prices among the highest in Asia. In 2014, petrol was priced at US$1.58/litre compared to 1.17 in China and 0.93 in Indonesia.[29] In 2015, at 53%, the industrial sector in Singapore accounted for the biggest proportion of Singapore's total final energy consumption, while transport accounted for 23 per cent and households seven per cent (IEA, 2017).

To continue to achieve economic growth, increase energy security and improve the environment, the government has adopted six strategies under its national energy policy framework. Under these strategies, it aims to promote competitive markets, diversify energy supplies by exploring solar, improve energy efficiency, build the energy industry, invest in energy R&D, improve international cooperation and develop a 'Whole-of-Government approach' that integrates different energy-related initiatives in the country (MTI, 2007, p.6).

Singapore's unique geographical setting, combined with its particular political history and economic agenda, have made the country develop to what it is today. Singapore has managed to turn its land and energy constraints into opportunities through a myriad of policies and innovations, as well as specific transnational agreements with the surrounding regions. Singapore's urban form is a spatial manifestation of its effort to overcome its resource constraints but to also achieve economic gains. Yet, as outlined in its latest Concept Plan (2011), it will need to ensure that it is able to continue to do so in the future as well. Given the land constraints it faces, it will be essential to guarantee a balance between achieving high densities and a high quality of life for all residents.

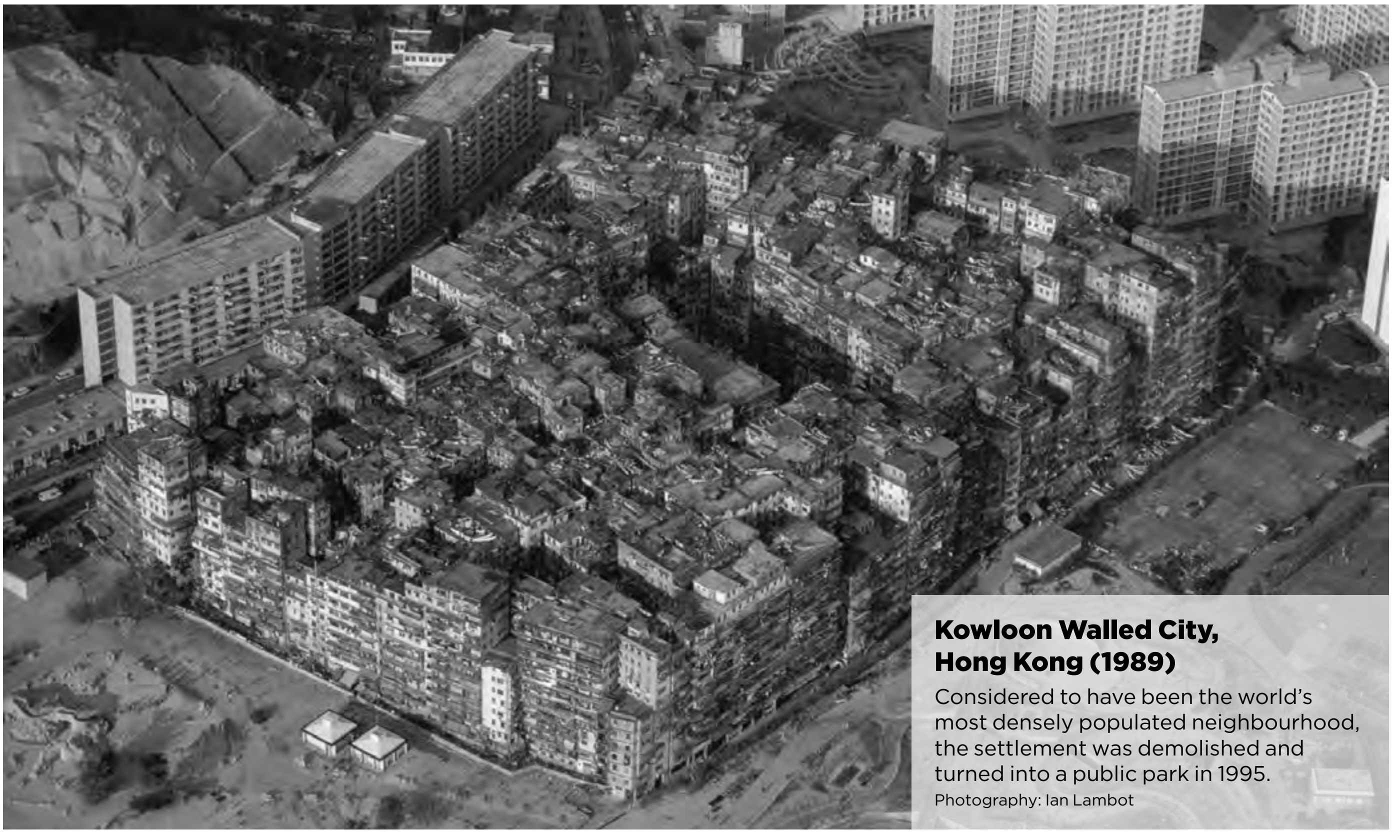
2.1.4 Hong Kong

Hong Kong is an island city state with a land area of 1,109 km^2, and a Special Administrative Region of the People's Republic of China. In 1841, Hong Kong became a British Crown Colony, and served as a military and trading post. Sovereignty over Hong Kong was handed to China in 1997 after more than 150 years of British rule. Today Hong Kong is a leading financial, trading and communication centre, with a population of 7.3 million people (CSD, 2016a). It is also one of the wealthiest cities in the world, with a service-sector-based economy[30], and a GDP per capita of 42,351 current US dollars in 2015 (World Bank, 2017).

Resource constraints have played a vital role in shaping Hong Kong's growth and economy. Land area is scarce, and the landscape is mostly steep and mountainous, with extensive swamps, constraining 'opportunities for city building,' (Shelton et al., 2011, p.2). Hong Kong also does not have sufficient coal, oil or gas resources and obtains nearly all of its energy supplies through external sources. Energy is either directly imported (oil and coal products), or produced using imported fuel inputs (electricity, gas) (CSD, 2016b).[31] Approximately 80 per cent of Hong Kong's water is imported from mainland China (Cullinane and Cullinane, 2003, p.286).

In the late nineteenth century the British claimed and leased more land from China to overcome the difficulties posed by the island's land constraints. By adding the Kowloon Peninsula, they were able to expand Hong Kong Island from 80.7 km^2 to include another 46.9 km^2 (CSD, 2016c). As this was insufficient to sustain future growth of the settlement, they took on a 99-year lease from China after the 2nd Peking Convention (1898), adding the area from north of the Kowloon Peninsula to the Sham Chun River – the border with mainland China and Shenzhen. This new area, soon to be called New Territories and Islands, measured roughly 977 km^2 (Ibid). Inhabited by indigenous groups since around AD 900, it retained its own land rights and laws. To further overcome the constraints posed by limited land availability, the British also reclaimed some land from the sea.

Pressure on land increased in the 1940s and 1950s in the aftermath of the Second World War[32] and the Chinese Communist Revolution, particularly as migrants moved from mainland China to Hong Kong and Kowloon Peninsula. In 1954 a fire in the squatter area, Shek Kip Mei, became a catalyst for new planning approaches for Hong Kong, and resulted in the public sector entering the business of public housing. In 1966, another wave of refugees moved to Hong Kong after the Cultural Revolution in China. Between 1945 and 1968, the population grew by over 600 per cent. By the late 1960s, this growth in population and the subsequent severe land shortages stretched the 'city' and available housing to its limits. In the Kowloon Peninsula, 1.5 million people were living on roughly 30 km^2 in poor living conditions.



Kowloon Walled City, Hong Kong (1989)

Considered to have been the world's most densely populated neighbourhood, the settlement was demolished and turned into a public park in 1995.
Photography: Ian Lambot

While the colonial government had initially intended not to alter land use in the New Territories save for official purposes,[33] by the 1960s it had decided to develop infrastructure in the New Territories and Islands to address the increasing population pressure, overcrowding, severe water shortages (1962–64) and civil unrest in the urban areas.[34] During this period, the colonial government also amended building regulations on a number of occasions so as to accommodate the growing population and meet the urgent need for housing. However, it was the 1962 Building Ordinance that allowed it to successfully deliver high-density living spaces. Under this ordinance, podium tower developments with an average height of 50 storeys, and 100 per cent site coverage, of up to 15 m in height, were permitted. These towers still dominate the housing sector in Hong Kong today.

To open up more land and accommodate the growing population, in 1972 the Public Housing Programme Scheme was launched, as per Governor MacLehose's 1971 reforms,[35] through which nine satellite new towns were built in the New Territories along the lines of the public housing model in Britain. Today, they occupy 88 km^2, of which 30 km^2 are reclaimed from the sea.

To ensure that the natural environment was preserved and residents had open spaces available to meet their recreational needs, in 1976 the Country Park Scheme was introduced. Under this scheme, 21 parks were established in the city. Today they cover 40 per cent of Hong Kong's total area (around 400 km^2), serving as physical constraints to development.[36]

Alongside the development of the New Territories and the increasing housing density and demand for mobility in Hong Kong Island and Kowloon, long-term land use for transport became the main concern and driver for planning. During this period, three major studies on traffic and mobility built the groundwork for the Town Planning Ordinance (1974) and the future Territorial Development Strategies: Hong Kong Mass Transport Study (1967) and Hong Kong's first (1972) and second (1989) Comprehensive Transport Studies. The 1967 Mass Transport Study became a blueprint for major road and railway development in the territory as it recommended the construction of major trunk routes, vehicular flyovers and bridges and road tunnels, all connecting the challenging terrain of the city.[37] Hong Kong's (first) Comprehensive Transport Study examined public transport and traffic flows, and the redistribution of the population, with the aim of developing a more sustainable and efficient long-term transport and planning strategy. To avoid road congestion, it recommended the implementation of the Mass Transit Railway System (MTR), marking the beginning of a fast, high-capacity public transport system in Hong Kong. The MTR opened in 1979, and continued to grow in phases, becoming a major driver for the development of the city.

Today, public transport use in Hong Kong is among the highest in the world.[38] Over 12 million passenger trips are made daily through different public transport services (THB, 2017, p.1). This accounts for over 90 per cent of total passenger trips, with about 36 per cent of all public transport passengers travelling by rail. Even though private car ownership has risen, motorisation levels are extremely

Table 2: Historical phases of urban development in Kuwait, Abu Dhabi, Singapore and Hong Kong

Period	Duration	Average ULA expansion per year (km²)				
		Kuwait	Abu Dhabi	Singapore	Hong Kong	Overall
Early growth	1930-1960	1.3	1.0	1.9	1.7	1.4
Rapid expansion	1960-2000	7.7	4.1	3.7	5.3	5.2
Acceleration or saturation	Post-2000	6.3	15.6	0.9	1.5	6.2
All periods		5.0	5.8	2.4	2.8	4.0

low at 67 vehicles per 1,000 people in 2011. In the same year, motorisation levels in Singapore were higher, at 114 vehicles per 1,000 people.[39] Hong Kong's low motorisation rates may also be linked to extremely high fuel prices, among the highest in the world.

Although transport energy consumption in Hong Kong is significantly lower than most other cities, its high-density, high-rise nature requires 'a substantial amount of energy' (EB et al., 2015, p.4). In addition, due to the type of building materials used, the climate on the island and the urban heat island effect,[40] energy demands are even higher. In 2012, buildings consumed 90 per cent of the city's electricity (Ibid, 2015). For this purpose, the government aims to adopt energy-saving policies and initiatives, particularly targeted towards building and transportation.

On the whole, resource constraints have resulted in high dependency on imports, while the shortage of land and the natural restrictions of the terrain have forced highly concentrated development on to approximately a quarter of the total land area (PD, 2007, p.38). This has led to a high-density built-up area within Hong Kong's total land area. Of this built up area, 26% is reclaimed land which accommodates 27% of its total population (PD, 2016). New towns in the New Territories house 3.4 million people – half of Hong Kong's population. High-density development has also meant that 'on average, a Hong Kong resident has 13 m² of living space available', considerably lower than the space available to residents in other high-income cities (Kandt, 2011).

Hong Kong's development represents a trajectory where the economy and city have grown impressively despite the scarcity of resources. In the current Hong Kong 2030+ outline strategy, Hong Kong is acknowledged and embedded as an integral part of the larger Pearl River Delta (PRD) region. This is part of the transition to 'one country and one system'[41] by 2047. Within a 'three-hour living circle and a one-hour intercity traffic circle,' (PD, 2016) new infrastructure now connects Hong Kong with mainland China, and has already merged Hong Kong into the mega region of the PRD. This infrastructure includes the Guangzhou–Shenzhen–Hong Kong Express Rail Link, Hong Kong–Zhuhai–Macao Bridge, the Liantang/ Heung Yuen Wai Boundary Control Point and Link Road, which is under construction. Hence, while the handover has somewhat loosened the pressure of scarcity on the city itself, the government still has to optimise land use, manage affordability and design strategies to ensure that the city is liveable. That Hong Kong has one of the most unaffordable housing markets globally, and the average living space per person is low compared to other metropolitan areas, makes it important to maintain a balance between high-rise living and quality of life – a feature also recognised in Hong Kong's 2030 planning vision (PD, 2007).

2.2 Urban growth analytics 1920–2015

This section analyses urban growth patterns for each the four case study cities roughly over the past 95 years. The key spatial parameters presented below include the evolution of city form, transport infrastructure and housing typologies. These are then explored alongside broader socio-economic changes which occurred over time in each of the four cities.

2.2.1 Spatial growth compared

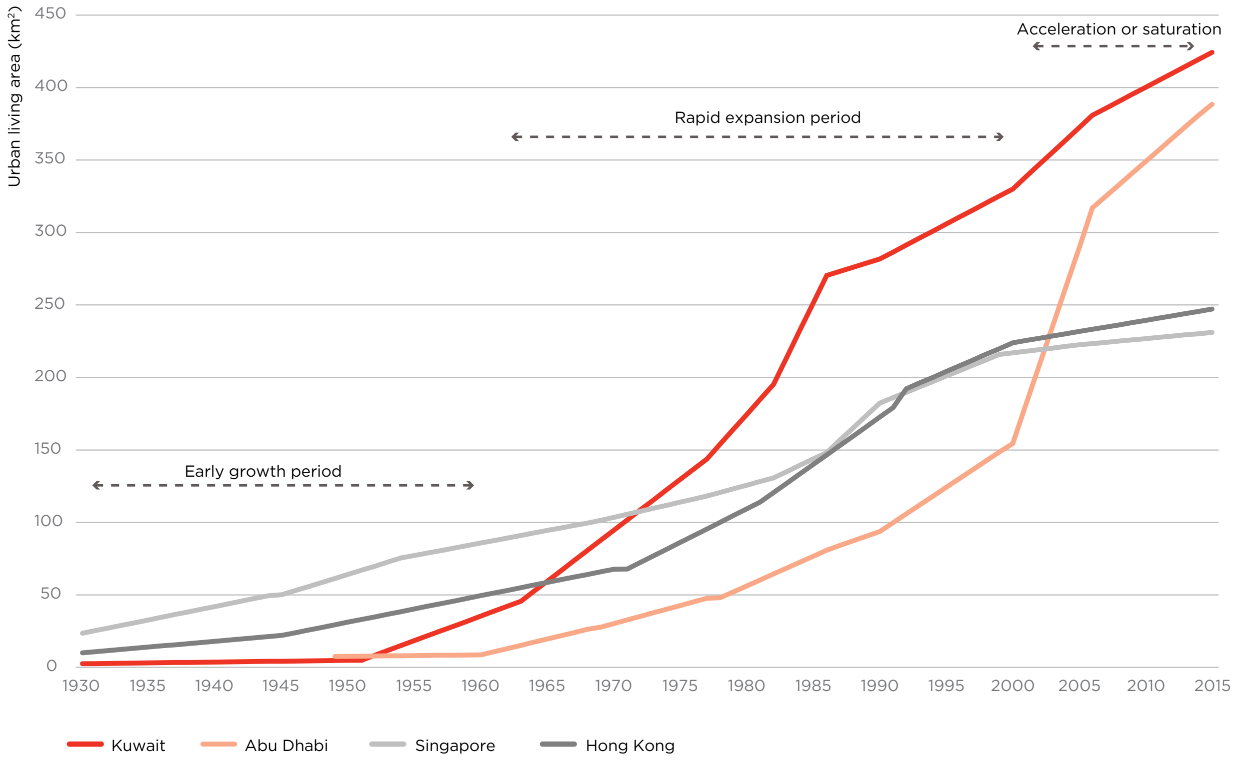
To introduce the comparative urban growth analytics conducted for the four case study cities, a helpful entry point is the physical expansion of each of the cities since the 1930s. The most relevant related analysis for this study was the documentation of the growth of urban living areas (ULA), a new measure (see Box 1) which captures the extent of the urban built-up area within which urban living and working is primarily located.

Urban expansion

The documentation of urban expansion over time (see Exhibit B) reveals three broad phases of urbanisation (Table 2) which are also illustrated in Figure 6.

In the early growth period, which lasted roughly from the 1930s to the mid to late 1960s, the ULA grew at a relatively slow rate in all four cities, although Singapore and Hong Kong grew earlier and faster than Kuwait and Abu Dhabi. Up to the 1960s, urban living areas in Kuwait and Abu Dhabi expanded at approximately 1 km² per year and in Singapore and Hong Kong at 1.8 km² per year. Analysis of an aerial photograph taken in year 1951 suggests that the city of Kuwait measured approximately 5 km² in total.

Figure 6: Growth of urban living areas, 1930-2015



In the rapid expansion phase, which lasted until 2000, each of the cities expanded quickly with Kuwait taking the lead, followed by Hong Kong, Abu Dhabi and Singapore. During this phase, Kuwait roughly added 7.7 km^2 of new urban land each year and became the largest city in terms of ULA, and the gap continued to widen over time. Urban expansion in Hong Kong was also considerable with approximately 5 km^2 of new urban living area every year.

During the third phase, the annual rate of outward expansion stabilised in the East Asian cities. This may, in large part, be due to the land constraints these cities face. However, Kuwait and Abu Dhabi experienced (and continue to) accelerated urban expansion as their annual rate of urban growth remains above their historical average with 6.3 and 15.6 km^2 respectively. Here it is important to emphasise that Abu Dhabi is presently expanding at a significantly faster rate than Kuwait. Although Kuwait and Abu Dhabi also face multiple land constraints, particularly due to desert conditions and the location of oil fields, there is still considerable land available for development within and beyond their metropolitan boundaries.

To better understand the kind of urban growth in each city at different times, the urban expansion coefficient (UEC) serves as a measure to document the level of densification or de-densification over time. Composed of the ratio between the urban land (e.g. ULA) and urban population growth, UEC values above one indicate the strength of de-densification and below one that of densification.

Figure 7 presents the evolution of the UEC in each city by decade and suggests that each city has undergone periods of de-densification and densification. Overall, de-densification was more prominent prior to 2000, with a clear trend towards densification in all cities during the most recent period. Between the 1950s and 1980s, the UEC in Hong Kong was particularly high, reaching almost a value of four and indicating a much faster rate of horizontal urban expansion than the rate at which the population increased. This was mostly due to an adjustment to the city's overcrowded living conditions, which at the time required changes to its hyper-density. Still, absolute density levels in Hong Kong remained at extremely high levels and from 2010 onwards once again began to increase. In Kuwait, the ULA increased nearly four times between 1950 and 1980, a period during which the city de-densified, although from much lower absolute levels than in Hong Kong. Since 2000, however, it has steadily densified. In Abu Dhabi and Singapore, the UEC has fluctuated over the past 65 years; however, it has not exceeded 1.6. Singapore has been densifying since the early 1990s and Abu Dhabi since 2010.

Strategic transport infrastructure

A central enabler of urban growth is the development of strategic infrastructure, above all transport infrastructure. Analysing the evolution of major public transport and highway infrastructure therefore served as the second focus of the urban growth analytics of this study and is presented in Exhibit C. The main difference across the four cities is that

Figure 7: Urban expansion coefficient, 1950-2015

Singapore and Hong Kong early on invested in and built urban rail systems, while Kuwait and Abu Dhabi only developed major roads and highways to provide for metropolitan accessibility. The construction of metropolitan highways started in the case study cities approximately at the same time, the 1960s. While Kuwait and Abu Dhabi built highways from scratch, Singapore and Hong Kong upgraded existing roads to highways as well.

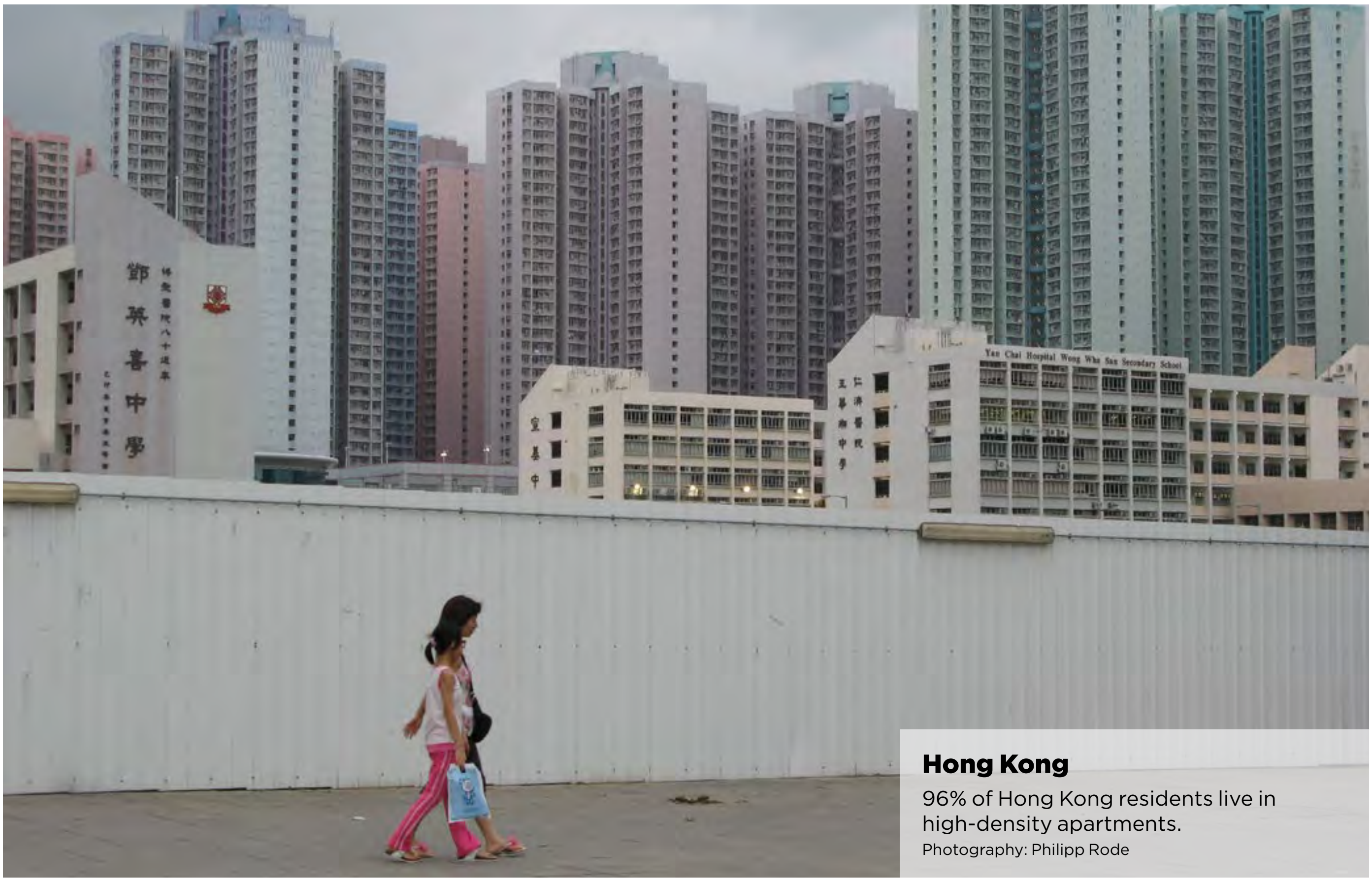
In Kuwait, the highway network grew rapidly from the 1960s to the 1990s, at a significantly faster rate than the rate at which the city was expanding. No new highways were added to the network after 1990, and the city has since been growing on the already established transport network. In Kuwait, the network also served as a guide for urban development in the city, with the ULA increasing along, and close to, highways. With increasing levels of motorisation and traffic congestion in recent years, the government is now investing in multi-level highway structures, and aims to improve traffic conditions in the city through this process.

In Abu Dhabi, the highway network has expanded more gradually over time, and in a less systematic manner, catering to the 'scattered' form of urban development in the city, and frequently connecting new developments to the city centre. As in Kuwait, Abu Dhabi has suffered from increasing traffic congestion, but the Government has been able to reduce congestion mostly by investing in road widening projects and adding lanes to existing highways. It has been able to easily do so as most highways have buffer zones available on both sides where it is illegal to utilise the land for any other purpose. Such additions to the highway network are not visible on the maps as only new roads can be mapped through satellite imagery. Today, the metropolitan area of Abu Dhabi has the largest per capita highway network with 165 km/million inhabitants, followed by Kuwait with 74 km/million inhabitants whereas Singapore and Hong Kong's highway networks each equal about 30 km/million inhabitants.

In Singapore and Hong Kong, the highway and railway networks have expanded over time to facilitate access to new developments, and together have shaped city growth. Of the four cities, Singapore's highway network has grown the slowest. Singapore has not only invested in new road infrastructure but has also changed the layout of existing major roads as a means to develop land more efficiently. Singapore and Hong Kong started building rail based public transport systems from the early 1980s. Currently, both cities have 270 km of rail network under operation, which translates into 50 km and 37 km of railway network per million inhabitants respectively. This is significantly greater than their highway network ratios.

Housing development

The third component of the urban growth analytics presented here focuses on the evolution of housing typologies summarised in Exhibit D. Of particular interest is the type of housing that was added to each city during



Hong Kong

96% of Hong Kong residents live in high-density apartments.

Photography: Philipp Rode

each of the Of particular interest is the type of housing that was added to each city during each of the analysed decades and how this has contributed to the spatial distribution of these typologies today. This analysis reveals the type of housing growth that has led to the dominance of villa-type (mostly detached) housing in Kuwait and Abu Dhabi and of apartments in Singapore and Hong Kong.

Large-scale housing expansion in Kuwait and Abu Dhabi began at a later point compared to Singapore and Hong Kong. The expansion of land to accommodate new homes in Hong Kong and Singapore has been steadier over time, while it has fluctuated for Kuwait and Abu Dhabi. Housing expansion was at its peak in Kuwait in the 1970s and 1980s, with most apartments built between the 1960s and 1980s. In Kuwait, mostly due to costs and high levels of demand, the change from large villa plot sizes to relatively smaller ones is also noticeable over time. In Abu Dhabi, the boom in construction was much later in the 2000s, with a clear dominance of detached villas. By contrast, in Hong Kong, housing expansion peaked in the 1990s, and a mix of apartment typologies was added to the city's building stock. In Singapore, housing expansion peaked in the 1950s, but low-density villas were still being added in large numbers. The shift from villas to apartments started in the 1970s, and the city has continued to build additional apartments over time.

Today, each city is host to a wide variety of typologies: from low-density detached housing to high-rise iconic buildings. Although a high percentage of land in Kuwait is occupied by villa-type typologies, it has some pockets of apartment areas. High-rise apartment buildings in Abu Dhabi are primarily located in the CBD, while detached housing is mostly scattered in locations outside the island. Similarly, high-rise typologies in Hong Kong are located in central areas, while lower-rise and house based typologies are located mostly on the outskirts. In Singapore, lower-rise apartments and villas are located quite close to the city centre.

The following pages feature three exhibits detailing urban living area growth, transport infrastructure evolution and housing development.

EXHIBIT B: Urban living areas 1945–2015

The maps illustrate the extent of the urban living area (ULA) in the case study cities during each decade roughly from 1950 up to 2015.[42] The ULA is shown in red and the current metropolitan area in light grey. The captions provide details on the total land area, population and population density for the corresponding years. These maps introduce the most fundamental patterns of urban growth.

Kuwait

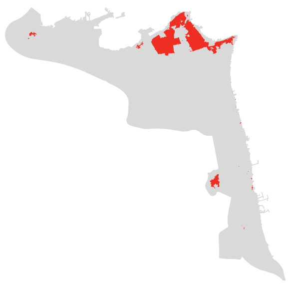
Urban living area
Metropolitan area

0 10km

1951

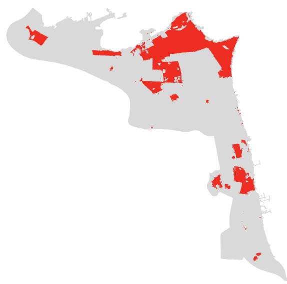
Urban living area – 4.9 km²
Population – 124,589 pers
ULA density – 25,426 pers/km²

1963



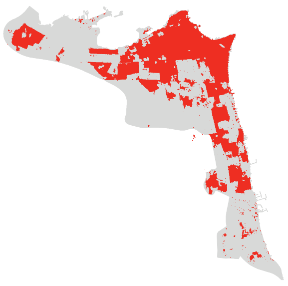
Urban living area – 45.6 km²
Population – 394,480 pers
ULA density – 8,651 pers/km²

1977



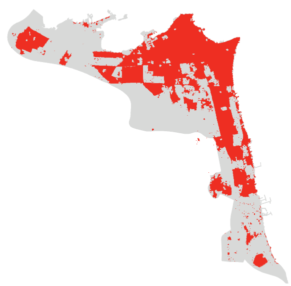
Urban living area – 143.8 km²
Population – 1,100,000 pers
ULA density – 7,650 pers/km²

1990



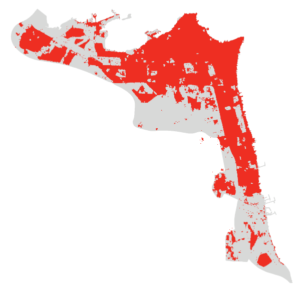
Urban living area – 281.7 km²
Population – 1,900,000 pers
ULA density – 6,745 pers/km²

2000



Urban living area – 330 km²
Population – 2,100,000 pers
ULA density – 6,364 pers/km²

2015



Urban living area – 424.3 km²
Population – 4,178,572 pers
ULA density – 9,848 per/km²

Abu Dhabi

Urban living area
Metropolitan area

0 10km

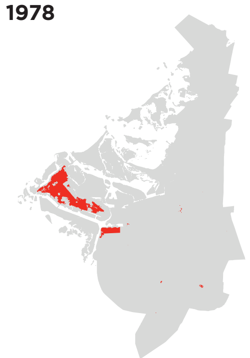
1949

Urban living area – 7.5 km²
Population – n/a
ULA density – n/a

1960

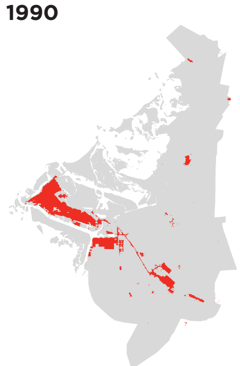
Urban living area – 8.6 km²
Population – 12,000 pers
ULA density – 1,395 pers/km²

1978



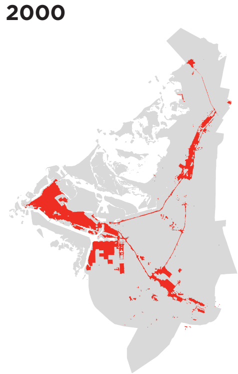
Urban living area – 48 km²
Population – 192,763 pers
ULA density – 4,016 pers/km²

1990



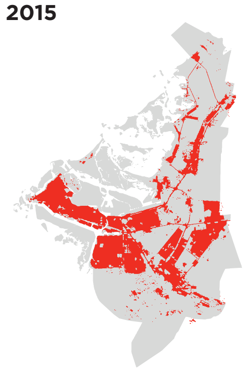
Urban living area – 93.7 km²
Population – 374,000 pers
ULA density – 3,992 pers/km²

2000



Urban living area – 154.4 km²
Population – 543,992 pers
ULA density – 3,523 pers/km²

2015



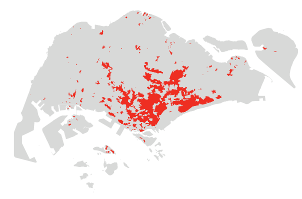
Urban living area – 388.5 km²
Population – 1,720,211 pers
ULA density – 4,428 pers/km²

Singapore

Urban living area
Metropolitan area

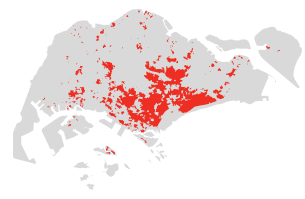
0 10km

1954



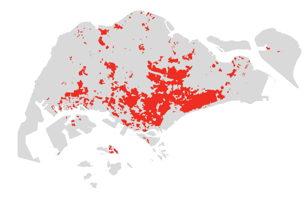
Urban living area – 75.5 km²
Population – 1,200,000 pers
ULA density – 15,894 pers/km²

1969



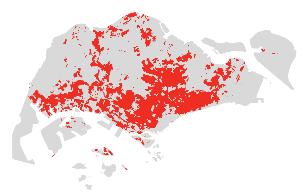
Urban living area – 101.4 km²
Population – 2,042,500 pers
ULA density – 20,143 pers/km²

1978



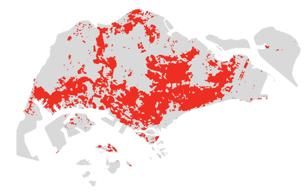
Urban living area – 120.4 km²
Population – 2,353,600 pers
ULA density – 19,548 pers/km²

1991



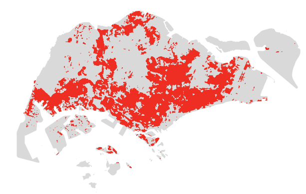
Urban living area – 184.5 km²
Population – 3,135,083 pers
ULA density – 16,992 pers/km²

2000



Urban living area – 218 km²
Population – 4,027,887 pers
ULA density – 18,477 pers/km²

2015



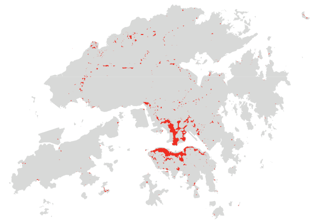
Urban living area – 232.4 km²
Population – 5,535,002 pers
ULA density – 23,817 pers/km²

Hong Kong

Urban living area
Metropolitan area

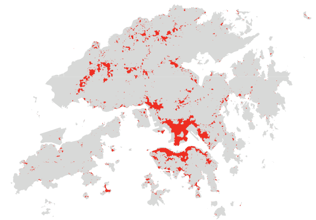
0 10km

1945



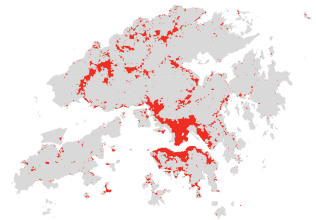
Urban living area – 22 km²
Population – 750,000 pers (1946)
ULA density – 34,091 pers/km2

1971



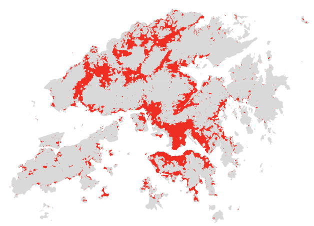
Urban living area – 67.8 km²
Population – 3,936,630 pers
ULA density – 58,062 pers/km²

1981



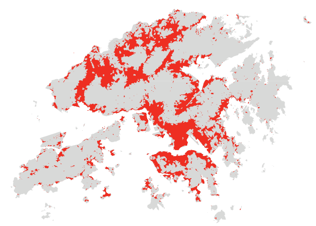
Urban living area – 114 km²
Population – 4,986,560 pers
ULA density – 43,742 pers/km²

1992



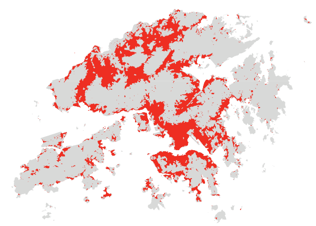
Urban living area – 192.2 km²
Population – 5,704,500 pers
ULA density – 29,680 pers/km²

2000



Urban living area – 223.9 km²
Population – 6,665,000 pers
ULA density – 29,768 pers/km²

2015



Urban living area – 247.2 km²
Population – 7,305,700 pers
ULA density – 29,554 pers/km²

EXHIBIT C: Transport infrastructures 1960–2015

Urban expansion is closely linked to the development of transport infrastructure. The maps below illustrate the evolution of highway and urban rail infrastructure over time in each of the four case study cities. The maps only show new infrastructure and do not show additions or improvements to existing infrastructure. The documented transport infrastructure developments suggest that Kuwait and Abu Dhabi have been primarily designed for car-based accessibility, while Singapore and Hong Kong share a considerable focus on public transport infrastructure alongside the development of major roads. From the 1950s to the 1990s, Kuwait developed the most extensive highway network of the four cities. Kuwait's and Abu Dhabi's highway networks have also grown more quickly than Singapore and Hong Kong's.

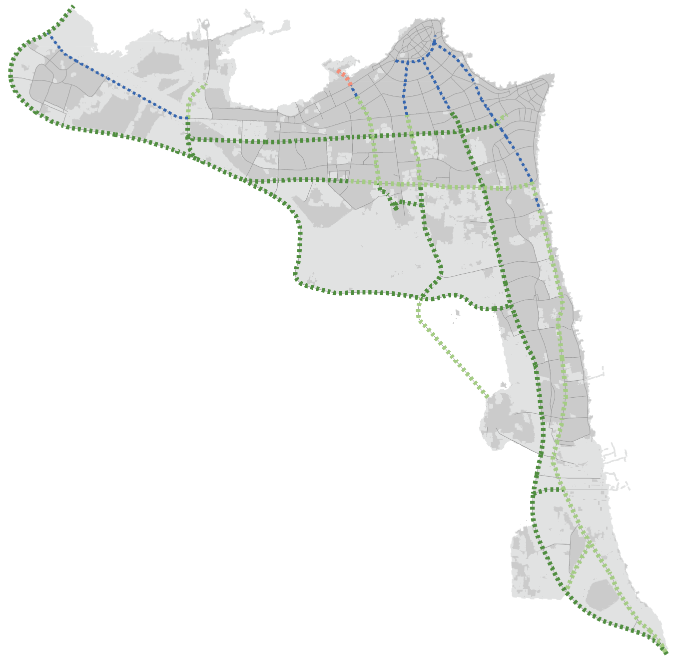
Kuwait

Highway length (2015)
309 km
Number of interchanges (2015)
164

Highways (year)
- 1963
- 1977
- 1982 – 1986
- 1990

- 2015 minor roads
- 2015 urban living area
- Metropolitan area

0 10km



Singapore

Highway length (2015)
166 km
Number of interchanges (2015)
78

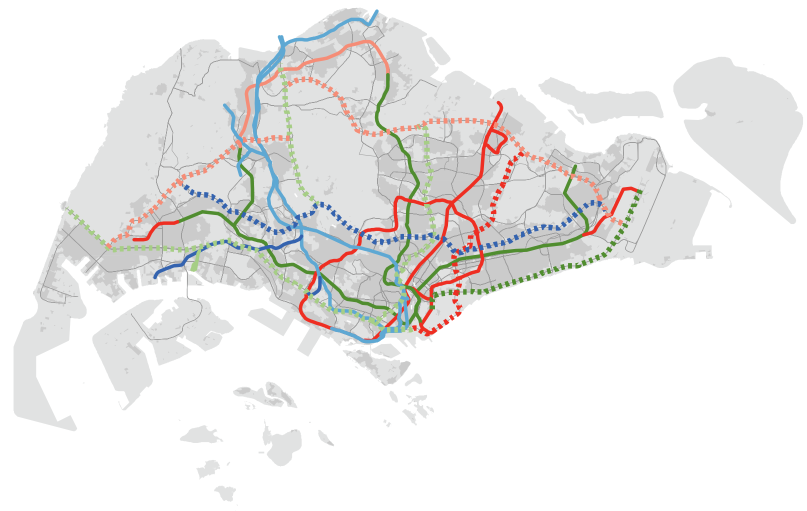
Railway length (2015)
275 km
Number train stations (2015)
102
Railway km per km² of ULA
1.2

Highways (year)
- 1966
- 1981
- 1991
- 1992 – 1998
- 2008 – 2013

Railways
- 1924 – 1954
- 1969
- 1978
- 1987 – 1990
- 1996
- 2001 – 2012

- 2015 minor roads
- 2015 urban living area
- Metropolitan area

0 10km



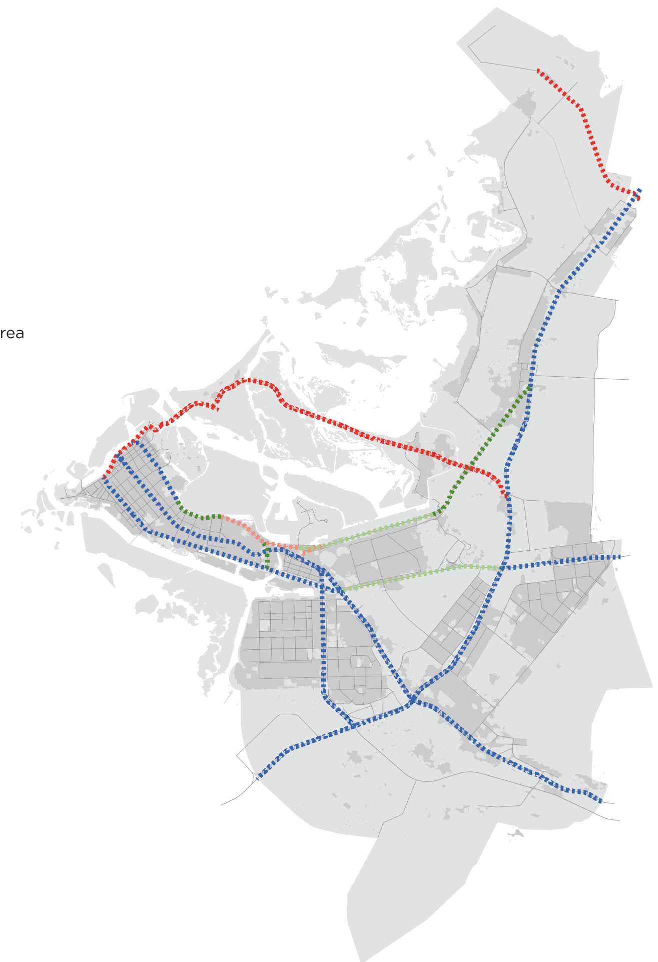
Abu Dhabi

Highway length (2015)
284 km
Number of interchanges (2015)
194

Highways (year)
- 1968 – 1978
- 1986
- 1990
- 2000
- 2006 – 2015

- 2015 minor roads
- 2015 urban living area
- Metropolitan area

0 10km



Hong Kong

Highway length (2015)
226 km
Number of interchanges (2015)
99

Railway length (2015)
268 km
Number train stations (2015)
89
Railway km per km² of ULA
1.1

Highways (year)
- 1961 – 1968
- 1972 – 1977
- 1984 – 1989
- 1997 – 1998
- 2007

Railways
- 1910 – 1930
- 1979 – 1980
- 1982 – 1988
- 1998
- 2002 – 2014

- 2015 minor roads
- 2015 urban living area
- Metropolitan area

0 10km

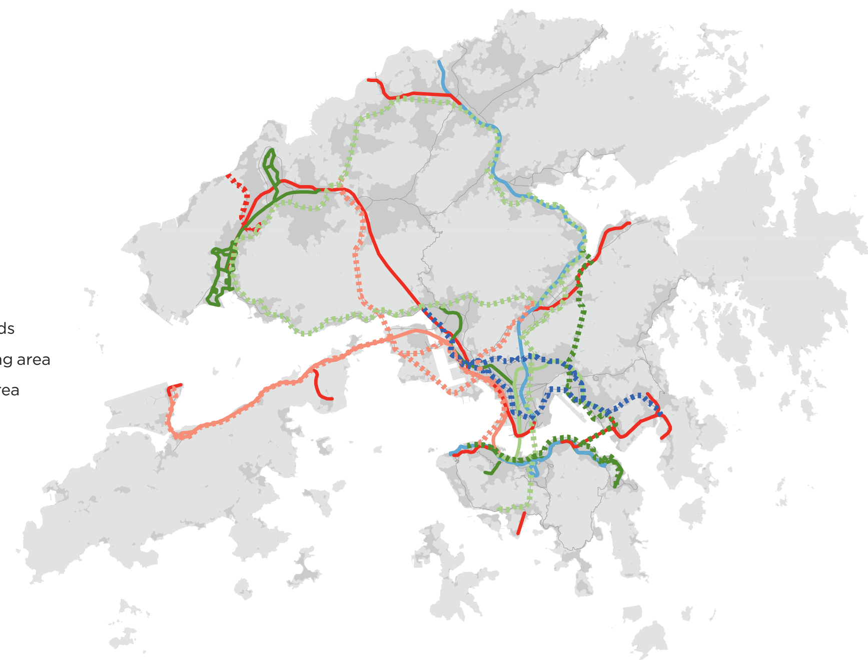


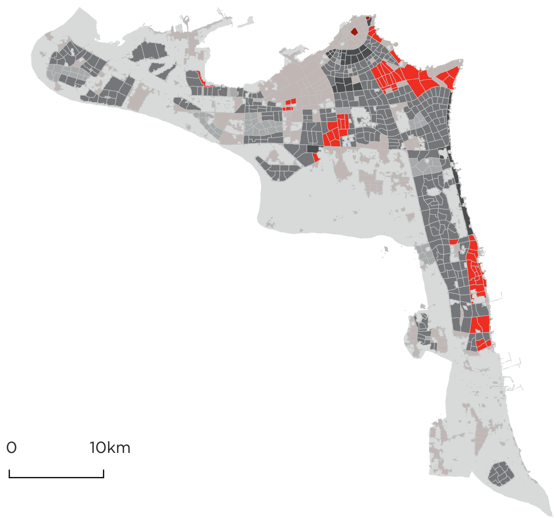
EXHIBIT D: Housing typologies 1920–2015

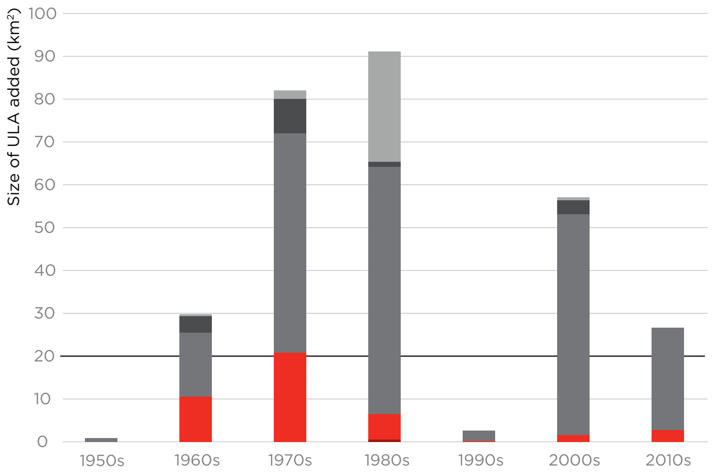
The growth and evolution over time of different housing typologies is fundamental to understanding urban development. The maps and graphs represent land expansion per decade and highlight which dominant housing typologies[43] were built in each decade. While the maps below show the spatial distribution of dominant housing typologies within each city's urban living area today, the stacked bar charts illustrate additions to the building stock (measured in land covered by each typology) for each decade between 1950 and 2015.[44] The maps reconfirm the dominance of villa-type morphologies (in greys) in Kuwait and Abu Dhabi—mostly detached typologies, and apartments (in reds) in Singapore and Hong Kong.

Kuwait

Dominant typologies

- Apartments CBD
- Apartments non-CBD
- Detached houses larger plots
- Detached houses medium and smaller plots
- Semi-detached houses
- Other land use (may include residential)
- Metropolitan area

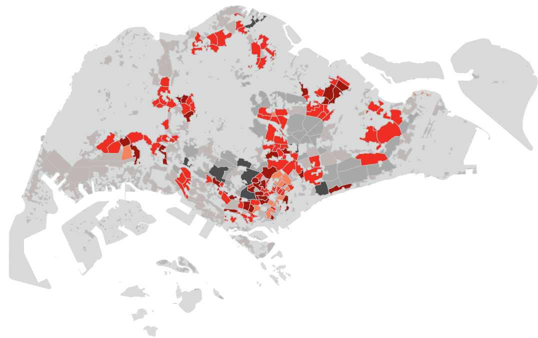


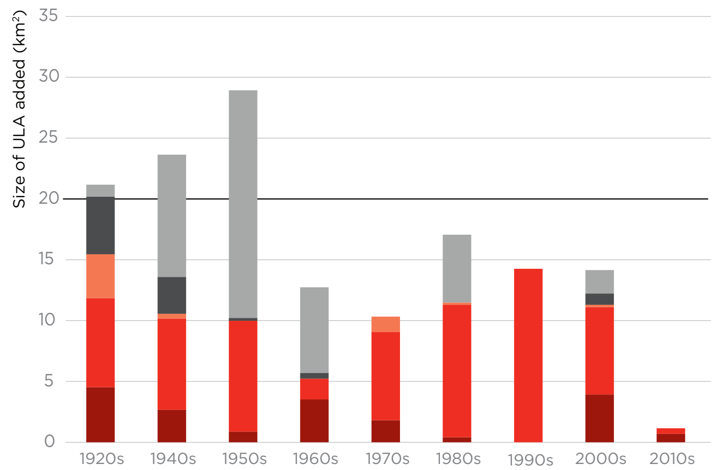


Singapore

Dominant typologies

- Apartments super and high rise
- Apartments medium rise
- Apartments low rise
- Landed housing detached
- Landed terraced and semi-detached housing
- Other land use (may include residential)
- Metropolitan area

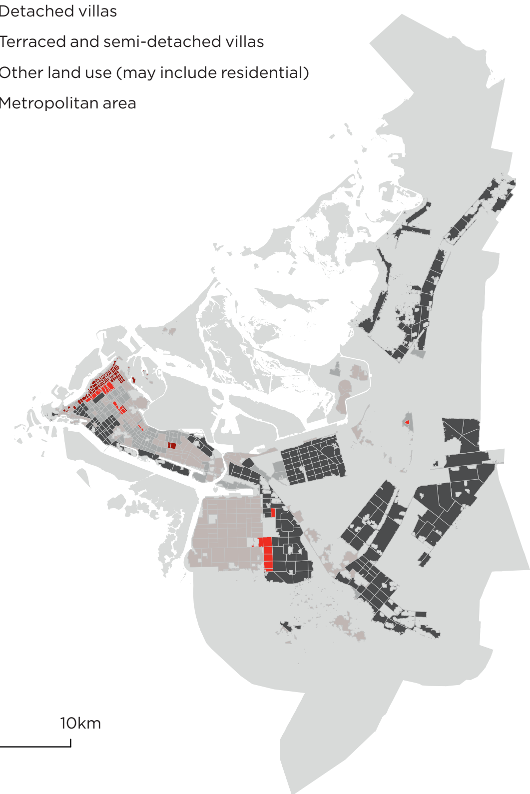


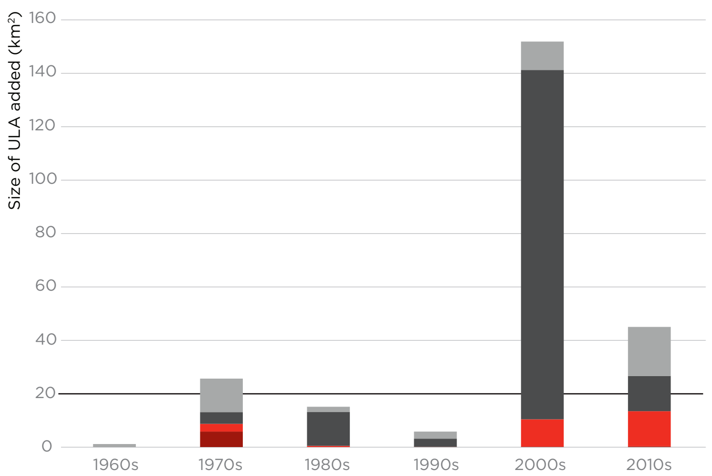


Abu Dhabi

Dominant typology

- Apartments high rise
- Apartments medium and low rise
- Detached villas
- Terraced and semi-detached villas
- Other land use (may include residential)
- Metropolitan area

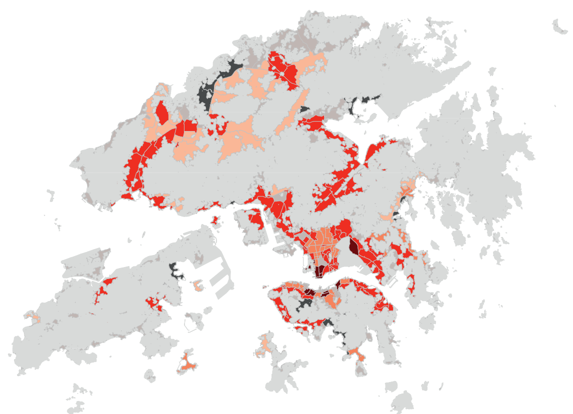




Hong Kong

Dominant typology

- Apartments dense grid
- Apartments high rise
- Apartments medium rise
- Apartments low rise
- House based typologies
- Other land use (may include residential)
- Metropolitan area



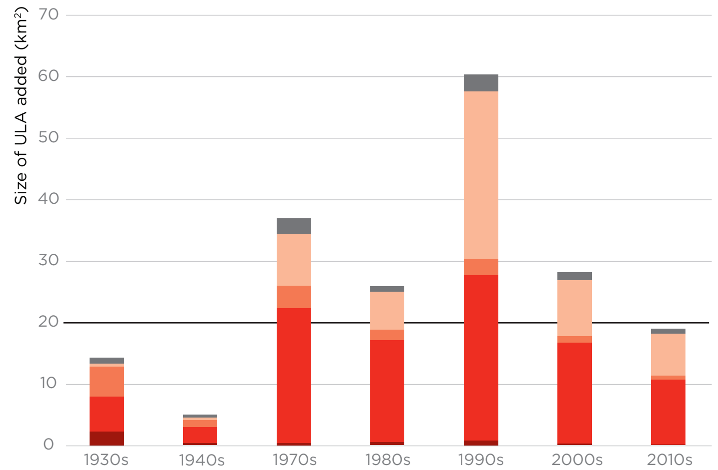
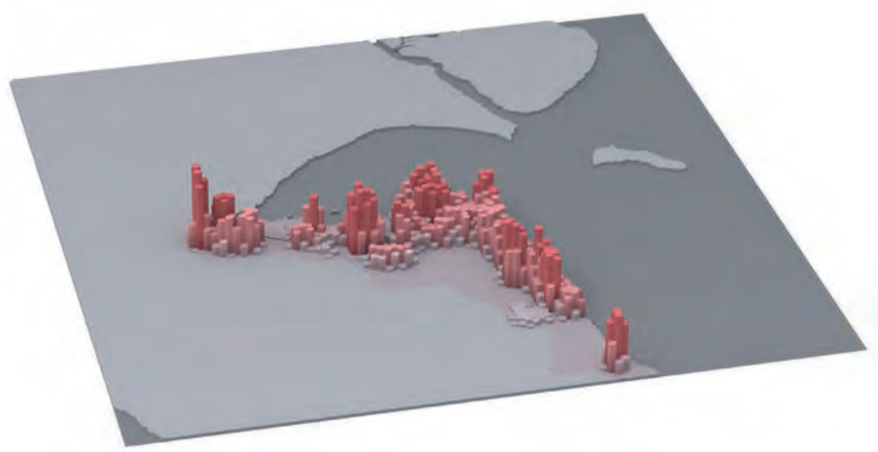


Figure 8: Disaggregating Kuwait's population

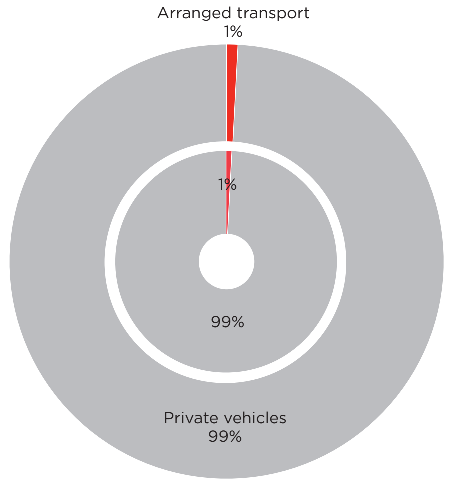
Kuwaiti population

Population (2015)
1,291,139 pers
% of the total population
31%

Urban living area density
3,043 pers/km^2
Peak density
9,888 pers/km^2



Transport mode share

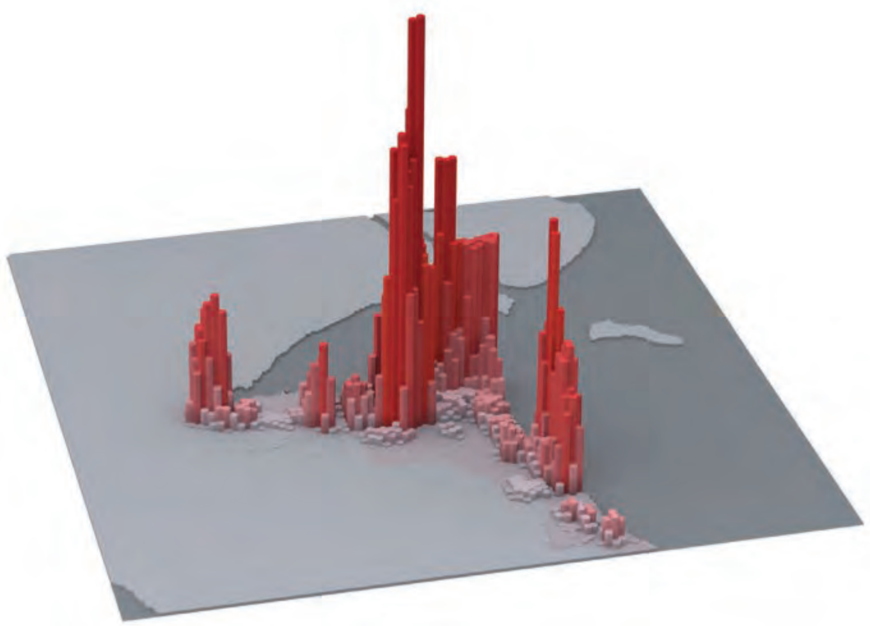


Public transport
Private motorised transport

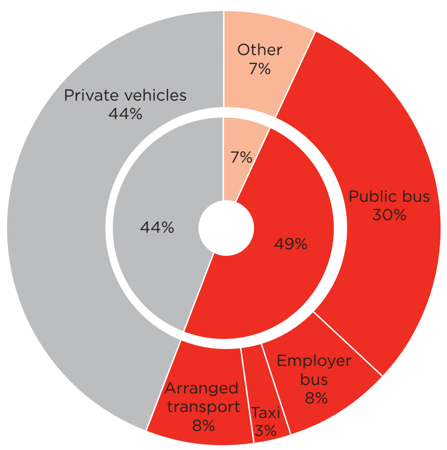
Non-Kuwaiti population

Population (2015)
2,887,433 pers
% of the total population
69 %

Urban living area density
6,805 pers/km^2
Peak density
51,582 pers/km^2



Transport mode share



Public transport
Active transport
Private motorised transport

Box 3: From inter- to intra-urban differences

The urban growth analytics for this study revealed an unexpected degree of intra-urban variation in urban form, density and housing typologies. In order to explore this important finding in greater detail, this section focuses on the specific case of Kuwait and presents an additional analysis of intra-urban variation. The focus of this analysis is the difference between housing and mobility patterns of the Kuwaiti and non-Kuwaiti population.

The density diagrams in Figure 8 illustrate the spatial distribution of residential densities for the two groups. They show that the Kuwaiti population (nearly 1.3 million people and 31 per cent of the total population) lives in low-density housing that is homogenously distributed along the urban living area (peaking at 9,888 pers/km^2). In contrast, the non-Kuwaiti population lives in high-density apartments (peaking at 51,582 pers/km^2) in the city, a major contributor to the city's higher overall density.

Similar contrasts can also be observed when analysing mobility behaviours. There is a clear division between the modes of transport used by Kuwaitis and non-Kuwaitis to travel to and from work. Kuwaitis use almost exclusively private vehicles for commuting purposes (99 per cent of total trips), while non-Kuwaitis primarily use public transport (49 per cent of total trips).[45] According to a survey conducted by Aktins (2010) for the Kuwait municipality, residents prefer not to use public transport for work trips if they have a car available at home.

The data suggests that the everyday experiences of Kuwaitis and non-Kuwaitis in the city are quite distinct from one another. The non-Kuwaiti population comprises 69 per cent of Kuwait's total population, and mostly lives in apartments and travels by public transport. The Kuwaiti population lives in low-density type villas and mostly travels in private vehicles. The physical segregation of residents for residential and commuting purposes suggests that it is important to study the city at a more disaggregated level. This separation is certainly also the case in Abu Dhabi, where a significant proportion of the non-Emirati population occupies distinctly separate spaces in the city, which may be of interest for future analysis.

2.2.2 Key growth parameters

To conclude the urban growth analytics for the four cities, it is helpful to reflect on the relationship between the spatial change covered so far, and key events and changes in broader socio-economic factors. For the latter, the study considered increasing wealth levels (i.e. changes to GDP per capita), population growth and fuel affordability (see Exhibit E).

In all four case study cities, increasing wealth levels and population growth are closely associated with increases in urban living areas (ULA). In Kuwait, the initial increase in ULA appears to have been directly related to its first oil export shipment. Moreover, the rate of urban expansion seems to have been impacted by fluctuations in global oil prices, as well as political instability in the region, in particular with regards to its involvement in the Iraq War.[46] As in Kuwait, initial increase in Abu Dhabi's ULA also appears to be related to its first oil shipment. However, urban expansion in Abu Dhabi seems to be more closely tied to Sheikh Zayed's rise to power in 1966. Here too, changes in petrol affordability and GDP (in this case interconnected) seem to have affected population densities and the rate at which the city expanded. Following Sheikh Zayed's demise in 2004, and the start of Sheikh Khalifa's term, a considerable increase in urban expansion can be observed for Abu Dhabi.

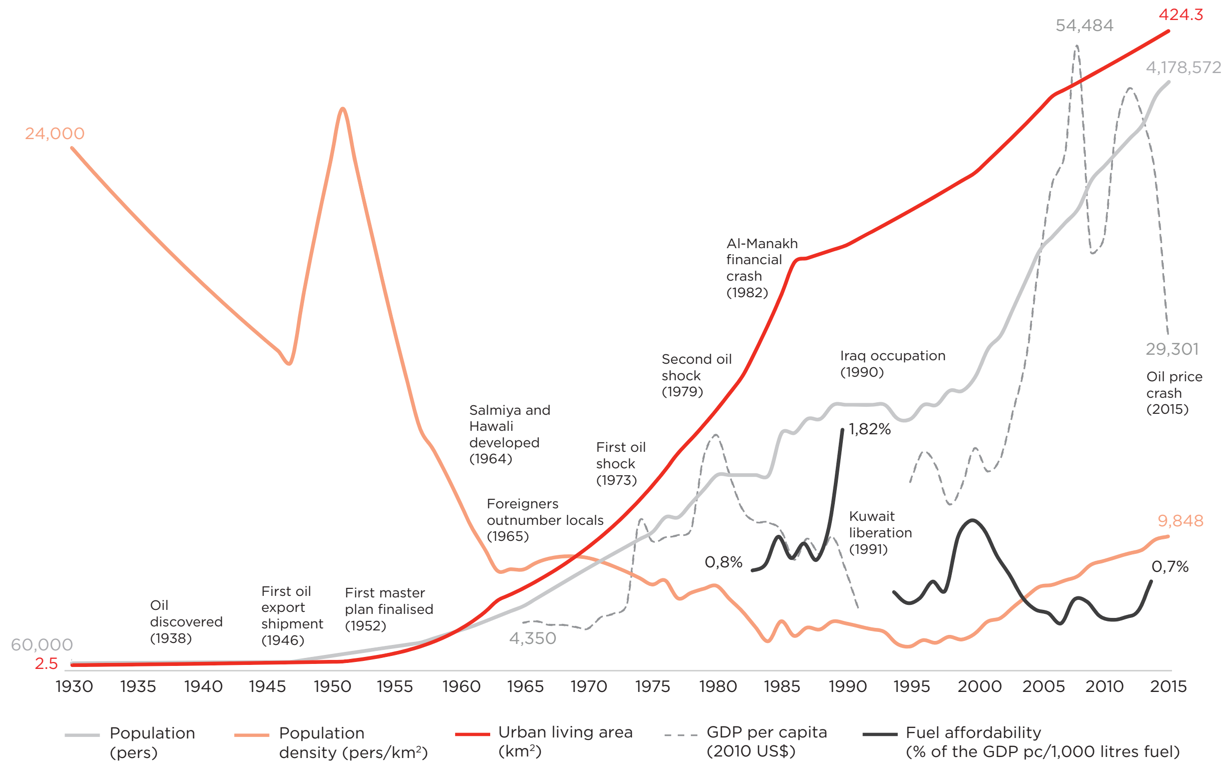
In Singapore, the ULA has grown consistently alongside an increase in GDP per capita. More recently, the ULA has expanded at a lower rate, leading to higher density in the city despite increased petrol affordability. In Hong Kong, the ULA increased at a faster rate than population growth until 1990, leading to a decrease in population density over time. Since 1990, the rate of urban expansion has only been slightly higher than the rate of population growth, and density levels appear to have stabilised. As can be seen, Hong Kong's ULA expanded significantly between the 1960s and 1970s due to a steady rise in wealth, and the development of new towns, natural park schemes, public housing and mass transit.

Overall, changes in fuel affordability in the four cities do not seem to relate much to the observed physical changes. Compared to Kuwait and Singapore, in recent years fuel has become less affordable in Abu Dhabi and Hong Kong. However, in Abu Dhabi, prices are low in absolute terms and unlikely to lead to major changes in the city's physical development. In Hong Kong, however, a reduction in fuel affordability can be observed alongside a slower pace of urban expansion. The wider impact of resource conditions, including fuel affordability, will be discussed in the final section of Part A.

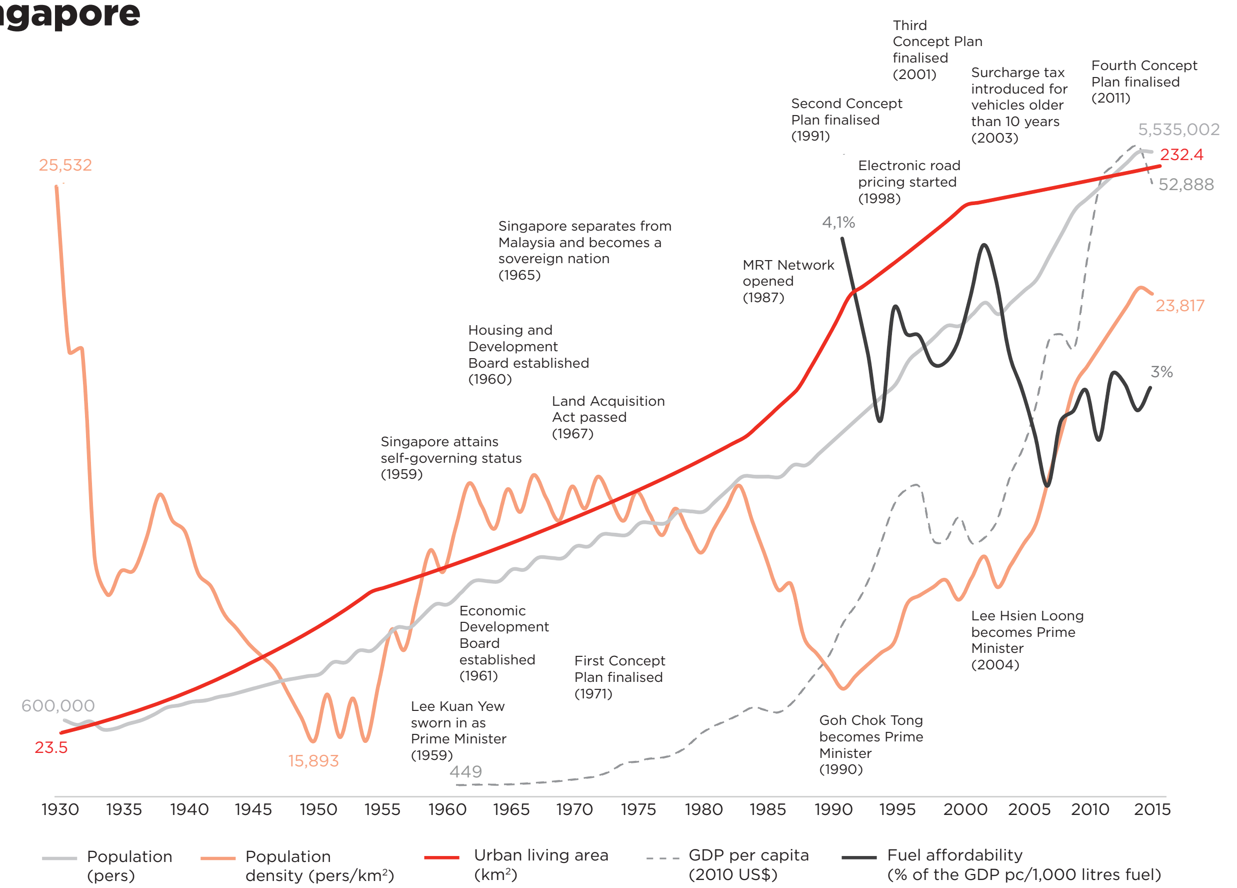
EXHIBIT E: Key growth parameters 1930–2015

The figures below illustrate changes in five key indicators, namely urban living area (ULA), population, population density, GDP per capita and fuel affordability over a 85-year period (1930–2015) in each of the case study cities. The graphics aim to better understand historical patterns, explore how changes in trends relate to key events, policies or institutional shifts, and analyse how the interplay of these key factors may have been associated with changes in ULA and density over time. Land-related indicators are shown in red, while wealth and energy affordability indicators are shown in dark grey. As each indicator is based on different scales, trend lines cannot be compared in absolute terms. Relationships between indicators can only be ascertained by comparing the gradient of each line.

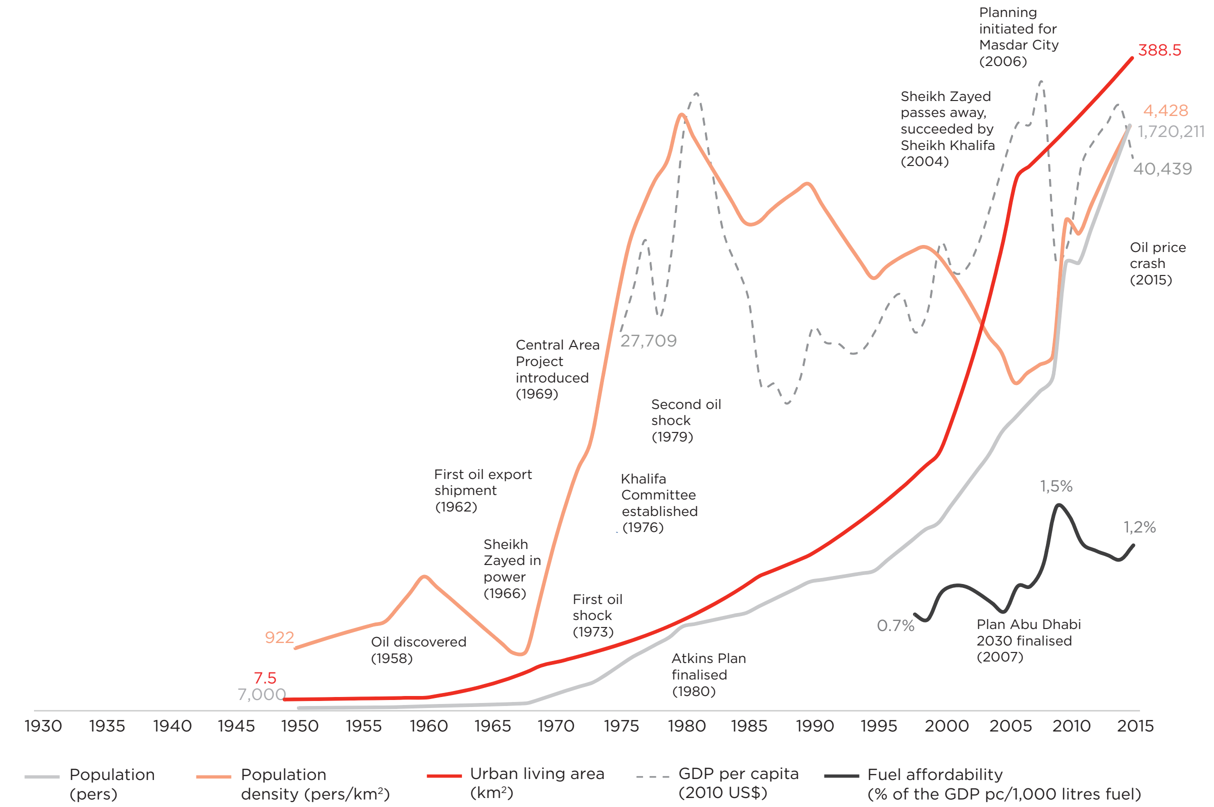
Kuwait



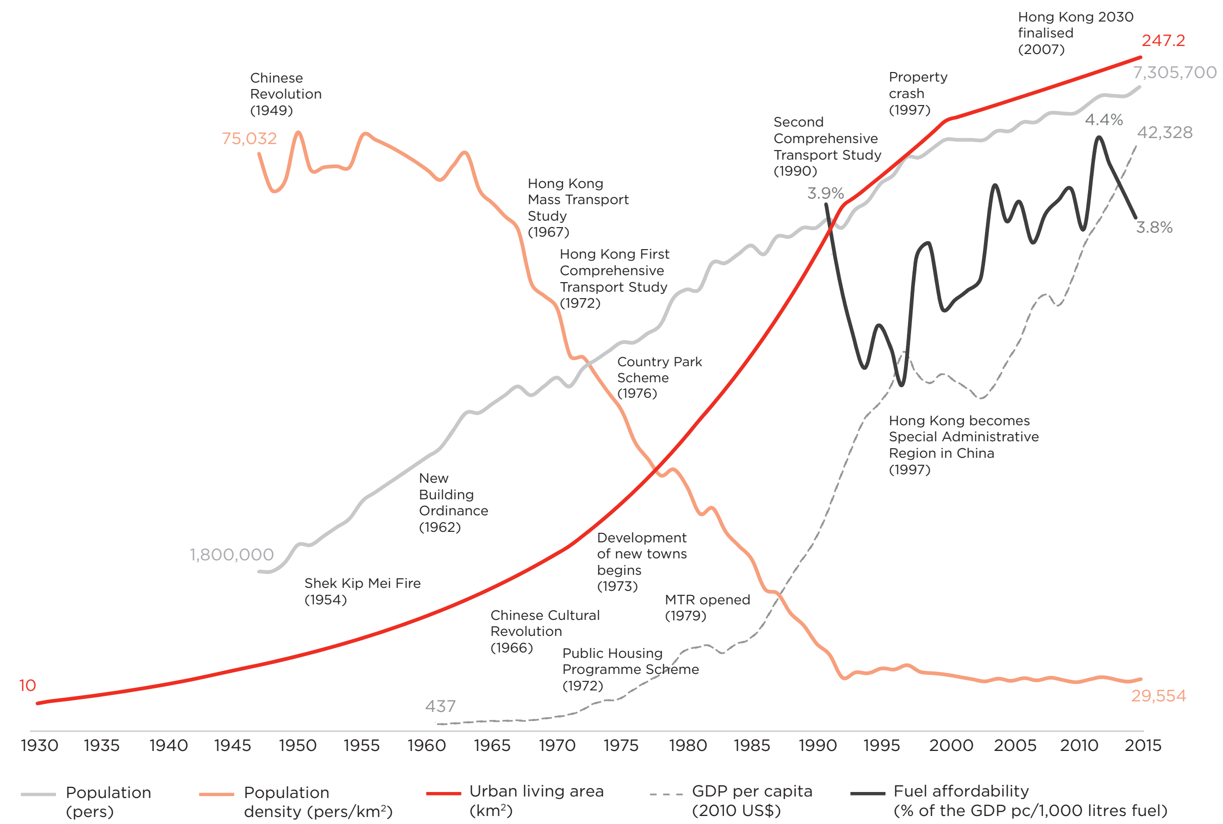
Singapore



Abu Dhabi



Hong Kong



2.3 How natural resources shape urban growth

As its starting point, this research was based on the assumption that natural resource availability and costs play a significant role in shaping urban built environments, and can help explain differences in urban development patterns across cities. This section examines this assumption more closely in the context of the four case study cities. Based on the evidence presented above, it first discusses the degree to which land availability may have influenced urban form in the four cities. Next, it presents the same argument in relation to energy availability and costs. This includes numerical tests, which use fuel price and fuel affordability as an indicator of energy costs, and urban expansion coefficient (UEC) as an indicator of urban growth. By doing so it tests whether, historically, energy costs have impacted urban growth in the four case study cities. To conclude, the section draws attention to some of the other key variables that have shaped urban growth in Kuwait, Abu Dhabi, Singapore and Hong Kong.

2.3.1 Land availability and urban growth

In Kuwait, Abu Dhabi, Singapore and Hong Kong, land availability appears to be one of the most important variables shaping the nature of urban growth. Simply in terms of total land area, Singapore's total territory (719 km^2) makes up four per cent of Kuwait's total territory (17,399 km^2), and a mere one per cent of Abu Dhabi's total territory (67,340 km^2). Similarly, Hong Kong's total territory (1,109 km^2) makes up six per cent of Kuwait and only two per cent of Abu Dhabi's total territories, limiting the space for urban growth and the type of development that can take place. It is important to note that while land constraints in each of the cities seemingly serve as disadvantages in terms of urban growth, they also serve as natural barriers to unfettered urban development, and to some degree help improve resource efficiency and the environment.

Land availability, however, is not simply a function of a territory's total land area, but also of physical constraints to development and population pressures. In Hong Kong and Singapore, urban development cannot take place on 52% and 41% of the total territory respectively primarily due to natural and other land-use constraints (see Exhibit A).

Adding to these differences in territory and land constraints, population levels in Hong Kong are nearly three times higher than Abu Dhabi and twice as high as Kuwait's, while population levels in Singapore are 1.3 times more than Kuwait and nearly three times more than Abu Dhabi. As a result, Singapore and Hong Kong face both greater population pressures than Kuwait and Abu Dhabi and have less land available for growth. Therefore, land availability on its own has necessitated the adoption of compact development policies including the development of high-rise apartments for public housing, controls on private vehicle ownership and the prioritisation of an extensive and well-functioning public transport network.[47] In addition, to support high population numbers, both Singapore and Hong Kong have also reclaimed land from the sea, primarily for industrial, housing and infrastructure purposes. Since 1960 Singapore has reclaimed 19 per cent of its total land area (DSS, 2017b), and Hong Kong has reclaimed six per cent of its total land area since 1887 (LD, 2017). To meet future needs, Singapore also aims to reclaim more land, develop some reserved land, recycle land with low-intensity use and intensify new developments (URA, 2013, p.4).

In contrast, land availability in Kuwait and Abu Dhabi has enabled their governments to distribute land and provide nationals with housing welfare in the form of large villas that are connected to the rest of the city through extensive road networks. Low-density housing, together with a single zoning system that segregates land use,[48] has led to even higher car dependency and urban sprawl over time. Overall, the availability of vast stretches of land has allowed both Kuwait and Abu Dhabi to meet their modernist aspirations, more specifically their desire to physically alter their cities 'in bold new forms' (Wall and Waterman, 2009) to improve living conditions for their national populations.

Although Singapore and Hong Kong face more land pressures than Kuwait and Abu Dhabi, the cost of land is high in all four cities. The key reason being that the welfare state in Kuwait and Abu Dhabi owns the majority of the land and, apart from providing citizens with land for free, or at minimum cost, for housing purposes (and some non-residential use in Abu Dhabi), supply of land into the private market is limited. This increases the cost of the available, non-stateowned land in the process. As a result, land availability and government policies and visions, as well as wealth from oil, rather than land costs on their own, have been influential in shaping Kuwait and Abu Dhabi's urban form.

In Singapore and Hong Kong, land scarcity has directly resulted in high land costs, which has incentivised developers to construct high-density buildings that provide more housing in less space, and allow them to maximise profits and returns on investment.[49] In Hong Kong, the high costs of land have also forced lower-income residents to live in extremely small spaces in poor living conditions. Here, land scarcity, government policies and high land costs together appear to have a more direct influence on urban form.

2.3.2 Energy affordability and urban growth

The availability of oil in Kuwait and Abu Dhabi is important insofar as it is the source of wealth through which large-scale urban development has taken place in the two cities. The discovery of oil in both cities created the perception that an 'endless' source of wealth could finance city growth, and allowed them to modernise and improve living conditions in a short period of time. With increasing oil revenues, both Kuwait and Abu Dhabi chose to subsidise energy for residential, commercial and transport purposes, making it more affordable for citizens to own a car, live in air-conditioned houses and adopt modern lifestyles, slowly

Figure 9: Fuel prices and urban expansion by decade

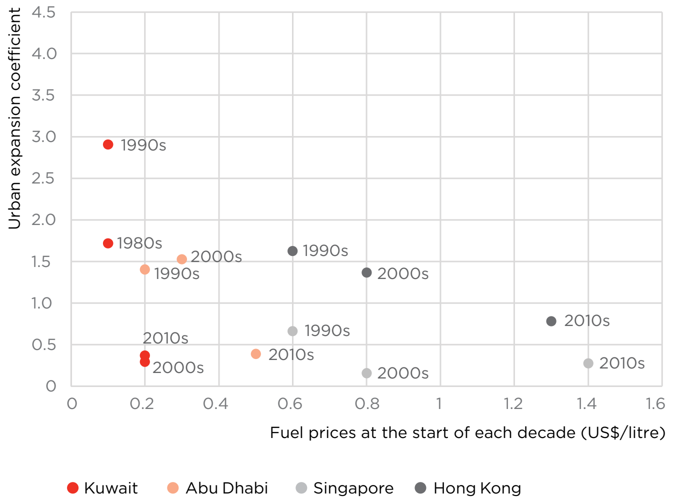
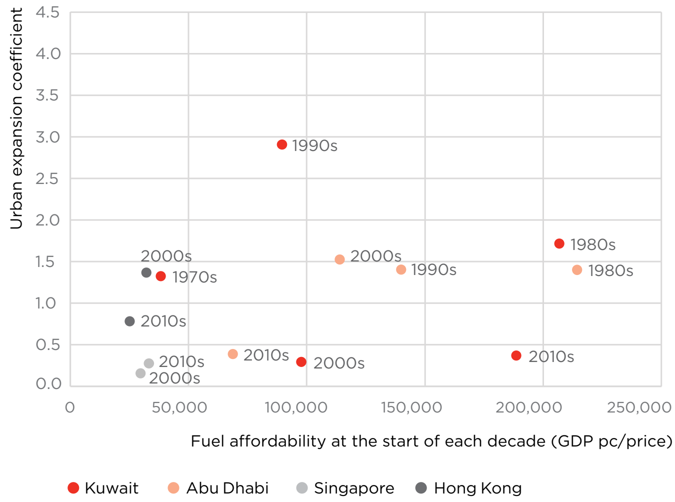


Figure 10: Fuel affordability and urban expansion by decade



changing the lived experiences and geographies of both cities. Energy availability, use and costs hence enabled, incentivised and supported the development of 'consumption cities' in Kuwait and Abu Dhabi. Yet, it is difficult to determine whether it is their natural resource endowment or their general economic wealth that has directly impacted urban form in both cities.

In Singapore and Hong Kong, the lack of sufficient indigenous energy sources has made it critical for both city states to secure a 'reliable and diversified supply of competitively priced energy' while devising ways to become more self-sufficient and efficient in this realm (EMA, 2015, p.11). As a result, when compared to Kuwait and Abu Dhabi, both have focused more closely on improving energy efficiency, designing various sustainability initiatives, particularly related to building design, improving international cooperation and simultaneously exploring alternative energy options that are suitable for the geography and climate. Singapore has set up its own oil refineries as a means to generate wealth and reduce dependency on imports. In terms of energy costs, the dependence on energy imports translates into high fuel and electricity prices, which, along with a range of other transport and land-use policies (see section 2.1), have allowed both governments to maintain low motorisation levels, and focus on improving pedestrian and public transport infrastructure.

To further assess the impact of fuel prices on densification patterns in each of the cities, Figure 9 explores the relationship between fuel price and urban expansion coefficient (UEC) over time. In line with recent research that suggests that fuel prices are linked to urban densities, the results show some correlation between fuel prices and densification patterns in the four case study cities. Higher fuel prices at the beginning of each decade tend to be associated with a lower UEC for the following ten-year period.

Of further interest is not only the absolute level of fuel prices but how fuel affordability is impacting on urban expansion (see Box 2); Figure 10 illustrates this relationship and suggests in this case a certain negative correlation between fuel affordability and the UEC). In both Abu Dhabi and Hong Kong, lower fuel affordability levels appear to be related to greater densification in the city. In Singapore, that relationship is not so evident but suggests that greater fuel affordability levels appear to be related to the city's de-densification. In Kuwait, however, it appears that fuel affordability has had no impact on changes in densification levels in the city. This may be due to the very low price of fuel relative to income.

To summarise, energy availability and costs have played a more integral role in shaping urban growth in Kuwait and Abu Dhabi, as compared to Singapore and Hong Kong where land constraints, government policies and other factors have influenced the way that the city has grown in a more direct way. In general, natural resource availability and costs have played a significant role in shaping urban built environments in the four case study cities, yet this research confirms that the way in which natural resources are used and extracted is also of key importance. Moreover, land as essentially a non-tradable natural resource appears to hold greater significance than the availability of other natural resources in influencing urban form.

2.3.3 Non-resource factors of urban growth

While this research explored the influence of land and energy on urban form, it is important to emphasise that differences in the built environment across the four case study cities also need to be understood as a result of other critical factors. Ultimately, it is the complex interplay of the above with other historical, economic and cultural factors that creates different outcomes and patterns of urban growth.

For the purpose of appreciating other key factors that influenced urban form in the four case study cities, it is important to return to the context within which relevant events unfolded. As shown before, during the 1940s and 1950s, Singapore and Hong Kong faced different geographic, demographic and economic challenges from Kuwait and Abu Dhabi. In short, the former were overcrowded cities that actively needed to achieve economic growth, create wealth and manage city growth, while the latter were sparsely populated settlements with a vast amount of resources and wealth brought by the discovery of oil. Further, in Singapore, the separation from Malaysia in 1965 made it imperative for it to become self-reliant, while in Hong Kong, the aftermath of the Second World War and the Chinese Cultural Revolution made it essential for the colonial government to respond to pressures of overcrowding and dissent. These conditions directly influenced subsequent policy choices taken by governments in each of the cities.

In Kuwait and Abu Dhabi, growing export revenues provided political leaders with the means with which they could implement their visions for their cities. Thus, Sheikh Abdullah and Sheikh Zayed respectively implemented welfare policies, set in motion their modernisation agendas and financed city growth and large-scale infrastructure development to mirror that of advanced industrialised economies. In Abu Dhabi, however, urban expansion was much more controlled due to Sheikh Zayed's influence in limiting sprawl while he was ruler. Overall, due to their reliance on oil revenues, urban development in Kuwait and Abu Dhabi depended heavily on global oil prices, accelerating and slowing down growth at different periods of time. In Singapore, the government under Prime Minister Lee Kuan Yew focused more closely on modernisation through employment creation, housing provision, export-oriented growth and actively controlled land management, aiming to make the city liveable, productive and attractive for 'foreign capital and workers' (Huat, 2011, p.42).

Despite the different circumstances faced by the GCC and East Asian cities, this research shows that there were a number of similarities in the ways in which Kuwait, Abu Dhabi, Singapore and Hong Kong approached infrastructure development and urban growth. First, with the partial exception of Hong Kong, all cities made use of master plans to guide development. Second, Kuwait and Singapore utilised land acquisition laws to closely follow the blueprints provided by the master plans and control land use. Third, all four cities adopted new building codes and standards to undertake certain forms of development. Finally, all four cities provided citizens with housing welfare. To some degree, all four governments were able to intervene in the city in a top-down manner as they tended to be insulated from popular political pressures.

However, there were multiple differences in the way that master plans, building codes, housing welfare and land acquisition laws were conceptualised and implemented. In Kuwait and Abu Dhabi, foreign experts were commissioned to design master plans. At times, the experts hired were unfamiliar with the local context and made recommendations in accordance with dominant western planning ideals and standards at the time, impacting the nature of urban growth. These were also in line with the modernist aspirations of political leaders and elites in both cities. In Kuwait and Abu Dhabi, new zoning regulations, typologies and building codes effectively segregated land use, prioritised the movement of motor vehicles and paid little attention to the local climate, social needs and existing neighbourhood organisation. While all cities provided housing for citizens, the nature of the housing differed significantly. In Kuwait and Abu Dhabi, citizens were provided with detached and semi-detached villa-type housing, while in Singapore and Hong Kong citizens were primarily provided with apartments. Aside from considerations related to land constraints, this may have also been the case as Emiratis and Kuwaitis prefer to live in detached houses that satisfy a desire for privacy, with clear boundaries between public and private spheres, whereas comparatively for Singaporeans and Hong Kongese, these boundaries are less distinct (Rowe, 2005, p.27, 118). In addition, while both Kuwait and Singapore used land acquisition laws to control land use and provide infrastructure, oil wealth allowed the Kuwaiti government to acquire land well above the market value, while the Singapore government offered market value only under certain circumstances – impacting the city's political economy and form of growth in the future (see sections 2.1.1 and 2.1.3).

Another key difference in policy choice relates to public transport provision. As mentioned earlier, due to high population pressures and land constraints, Singapore and Hong Kong prioritised public transport provision, investment in pedestrian infrastructure and policies to limit private motor vehicles. Kuwait and Abu Dhabi prioritised road building for car use, which was also a function and consequence of land use regulations, lack of pedestrian infrastructure, climatic conditions and planning ideals at the time.

While Kuwait and Abu Dhabi did not have the potential ridership numbers to justify investment in mass transit in the early decades after the discovery of oil, both have continued to find such an investment difficult despite an increase in population. The recent lack of investment in public transport is more closely related to policies and outlooks towards citizenship. In both Kuwait and Abu Dhabi, citizens refrain from using public transport due to

Kuwait
Kuwait residential villa types in NW Sulaibikhat neighbourhood, still partially under construction.
Photography: Alexandra Gomes

social norms around public transport usage. In addition, it is also less comfortable, convenient and reliable than car travel. As a result, public transport is used predominantly by non-citizens. Although non-citizens form the majority of the population, they are viewed as temporary residents for the benefit of whom such a large investment appears to be unwarranted. Non-citizens also face restrictions on car usage. In Kuwait, for instance – with some exceptions – a non-Kuwaiti can only obtain a driver's licence if they hold a college degree, have a minimum salary of 600KD (US$2,000) and have completed two years of residency. Partially as a result, nearly all Kuwaiti citizens use private vehicles for their travel needs, while most non-Kuwaitis, particularly those with low incomes, depend on walking, public buses and company-provided transport.

In both cities, with the exclusion of domestic workers, non-citizens also live in distinctly different neighbourhoods and housing typologies from citizens. However, in Kuwait, non-national residential areas are better integrated within the continuous urban fabric than in Abu Dhabi. In Abu Dhabi, many non-citizens live in workers' residential cities in industrial areas, some in isolated locations in the desert.

Aside from geographical factors and natural resource availability, differences in urban form between the GCC and East Asian case study cities are the direct result of deliberate policy choices that have determined the nature of city growth. Here, the structure of the economy, type of government, vision and incentive of political leaders, policy choices related to planning cultures and ideals, standards, codes, zoning regulations, master plans, land ownership patterns, land acquisition laws, cultural preferences around privacy and space requirements and climate are all important variables that explain differences in urban development patterns. These patterns themselves are reflections of historical processes that have shaped city growth over time.

3 Part B: From urbanisms to resources

Urban areas consume between 67 and 76 per cent of the world's energy and generate about 75 per cent of global greenhouse gas emissions (IPCC, 2014). But it is not cities per se that lead to their higher shares in energy demand compared to their population shares. It is above all their higher average wealth levels compared to non-urban places that determines their energy consumption. It is also the activities that take place in cities and their physical configuration that lead to considerable differences in energy consumption, even at similar wealth levels, as can be shown for the four high-income countries analysed here. In 2014, annual energy consumption per capita in Kuwait and the UAE was 375 GJ and 325 GJ respectively compared to 214 GJ in Singapore and 82 GJ in Hong Kong (World Bank, 2014). To a considerable degree, this difference may indeed be related to their respective urban forms as a large proportion of their energy demand stems from buildings and transport systems. In particular, the size and arrangement of buildings, and the degree of dependence on private motorised modes, directly impacts a city's energy requirements and resource consumption patterns.

Major factors influencing building energy demand, with heating and cooling energy needs being the biggest factors, include building design, climate, system efficiency and occupant behaviour. Based on current estimates, overall energy demand from buildings will continue to increase significantly in coming years, increasing the risks associated with climate change and resource depletion. In 2015, the residential sector, which contributes significantly to cooling energy demand, constituted 27 per cent of global electricity consumption. In Singapore and Hong Kong it contributed 27 per cent and 15 per cent respectively to their total electricity consumption. In Kuwait, however, the residential sector contributed to 65 per cent of total electricity consumption, particularly due to air-conditioning use in the summer months.[50] In the UAE, it contributed to 34 per cent of total electricity consumption.[51] Yet its share is likely to rise in the coming years; a recent study found that cooling energy use in contemporary buildings in Abu Dhabi is significantly higher than in traditional buildings, and limited actions have been taken to reduce their energy use (AboulNaga and Elsheshtawy, 2001).

Though still slightly lower than building energy use in absolute terms, transport energy demands are particularly relevant as they are the most rapidly growing. In 2014, transport comprised nearly 65 per cent of total global oil consumption – nearly 20 per cent more than in 1973 (IEA, 2016), and contributed to nearly 22 per cent of the world's energy-related greenhouse gas emissions (IPCC, 2014). As shown by Rode et al. (2012, p.5), 'of about ten billion trips that are made every day in urban areas around the world, a significant and increasing share is with carbon and energy intensive private motorised modes'. In the four case study cities, the share of transport energy demand of the total energy demand ranges from 23 per cent to 29 per cent (IEA, 2017).

This part of the report, Part B, looks at the way in which the spatial configuration of cities impacts on resource consumption and, given their substantial shares of overall energy consumption, specifically focuses on cooling and transport energy demand. Part B is divided into two sections. The first presents the cooling energy demand modelling based on urban morphology characteristics of selected neighbourhoods; the second discusses the transport energy demand that was calculated based on a metropolitan and micro accessibility analysis.

Both sections make use of empirical information from five areas within the each of the four cities. They were chosen based on the representativeness of their building typologies, which in turn were selected based on their distinctiveness.

The maps in Figure 12 illustrate the locations of the five sample dominant typologies in each city.

Al Reem Island, Abu Dhabi

Cities' activities, physical configuration and wealth, contribute to different levels of land and energy consumption.

Photography: Philipp Rode

Box 4: Global comparative perspective

Recent literature has confirmed that higher densities and compact urban form can reduce energy use in cities (Ahlfeldt and Pietrostefani, 2017; Creutzig et al., 2015; IPCC, 2014). To illustrate this, Figure 11 explores the relationship between metropolitan densities and energy use per capita for different countries. The analysis shows that a strong negative correlation exists between urban density and energy use, with lower urban density linked to higher energy use.

As seen in the graph, Kuwait and Abu Dhabi fall on one end of the spectrum with low urban densities and high energy use. Interestingly, Kuwait and Abu Dhabi's energy use is even higher than the already relatively low metropolitan density levels would suggest. This may be due to a range of factors including climate, wealth levels and housing policies that have differentiated between nationals and non-nationals, and have provided nationals with low-density housing and non-nationals with high-density housing (see Box 3). In addition, it is important to note that in both Kuwait and Abu Dhabi, aside from low urban density, high energy use is also likely to be driven by air-conditioning large homes and low energy prices.

At unusually high density levels, Singapore and Hong Kong have average levels of energy consumption but higher than the global relationships seem to suggest. In other words, they consume more energy than other countries with similar urban density levels. This is mostly a result of Singapore's and Hong Kong's significantly higher wealth levels compared to countries at similar urban densities. The industrial composition in Singapore may also play a role.

Figure 11: Energy use per capita and metropolitan density

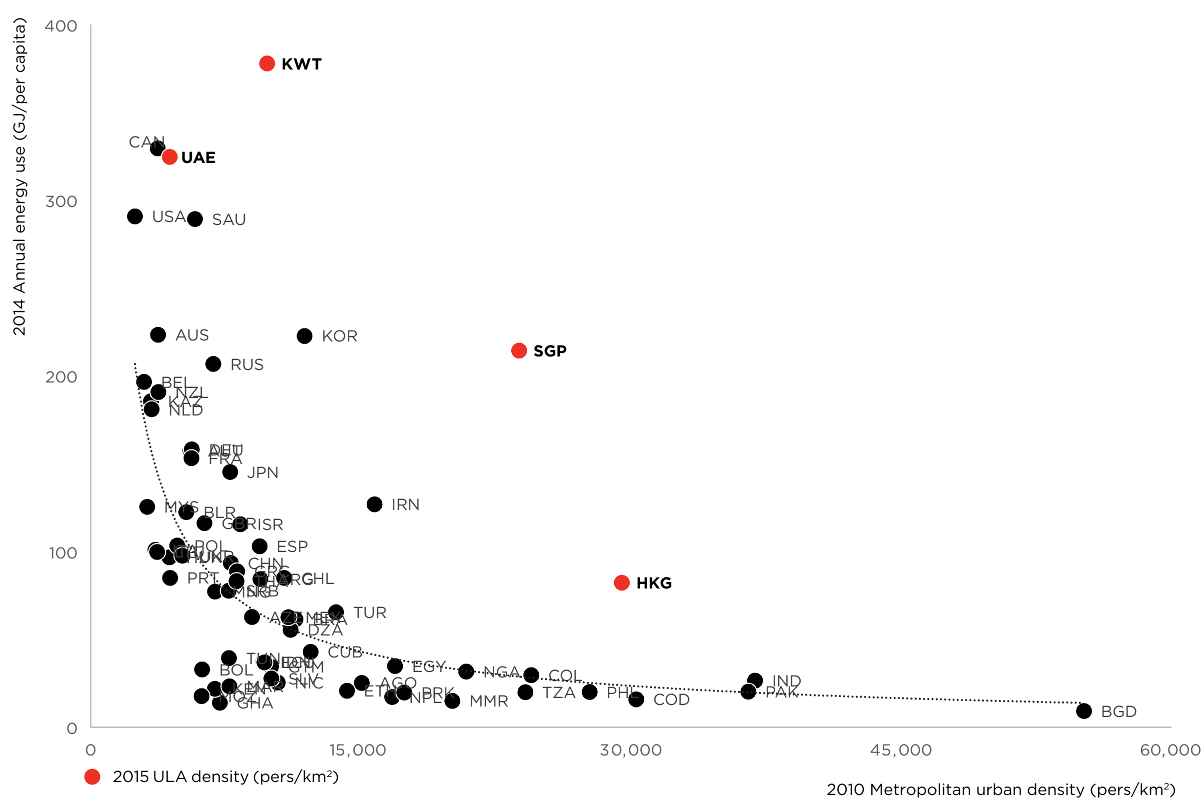
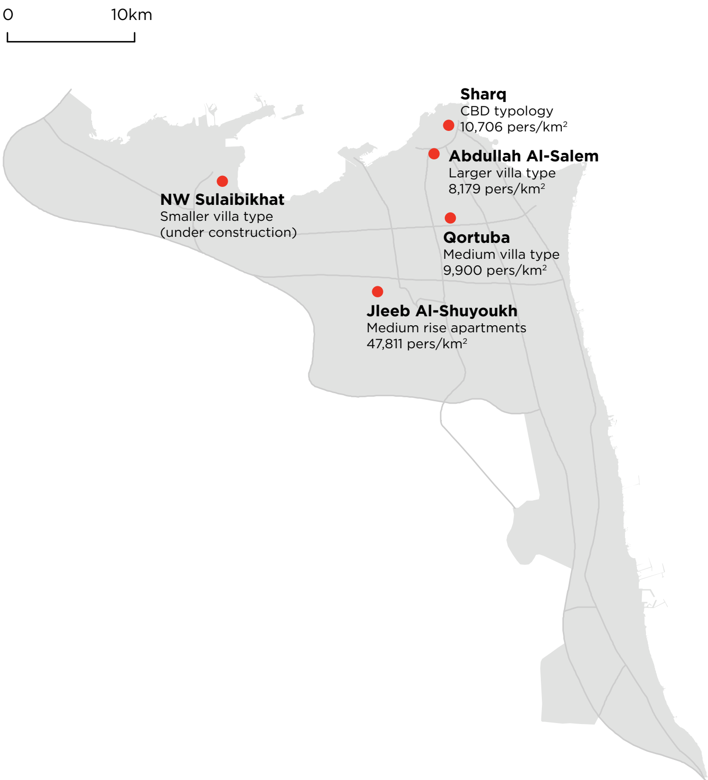
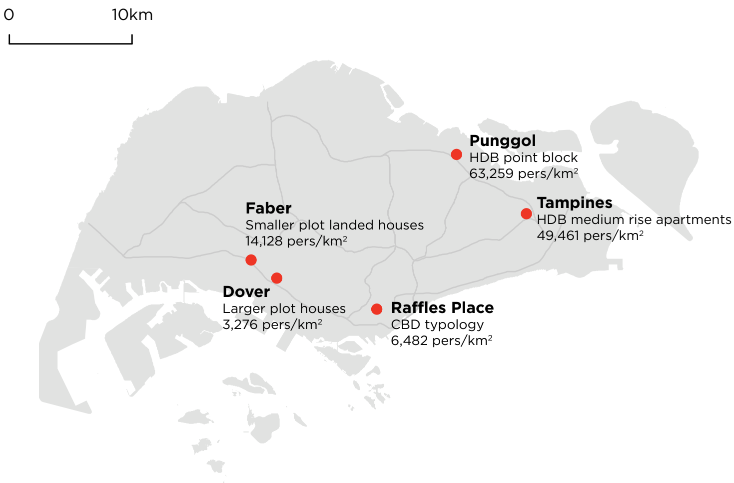


Figure 12: Location of the dominant typologies in the case study cities

Kuwait



Singapore



Abu Dhabi

Hong Kong

3.1 Cooling energy demand induced by urban morphologies

Three key factors are commonly used to explain differences in building energy demand: human behaviour, temperature expectations, and building technology and design (Baker and Steemers, 2000; Rode et al., 2014). Put together, these factors explain an up-to-twenty-fold difference that can be observed for energy demand in buildings (Ratti et al., 2005). Based on a study of heat energy demand in four European cities, Rode et al. (2014) have shown that urban-morphology-induced heat energy efficiency is significant and can lead to a difference in heat energy demand of up to a factor of six. Following this interest in the exclusive effects of design on heat energy demand, this section shifts to the cooling energy demand in buildings induced by building design and urban form. It is based on a cooling energy modelling analysis conducted by the project partner, the European Institute for Energy Research at the Karlsruhe Institute of Technology.

3.1.1 Introducing the urban morphologies samples

To establish the empirical basis for this analysis, the first step involved the identification of the most representative and distinctive building typologies (residential or including some level of housing) at the micro level in each of the four case study cities (see Exhibit D). The research then documented the urban morphologies of the most representative area for each typology at a scale of 500 by 500 metres with a focus on neighbourhood design, street and building configurations. Through this process, five distinct building types, which include a variety of detached housing/villas, mixed use/residential apartments and iconic towers – were identified in each city based on the most generic features of the building configurations (Exhibit F and G). Most of these samples allowed for an additional 'purification' of the morphological characteristics to ensure that the most prominent urban form in a given area expanded across the entire 500 by 500 metres samples. For each of the architectural types, data related to building footprint, building height and number of floors was collected, through institutional sources, expert surveys and open source websites.[52]

As a second step, monthly and yearly cooling energy demand of all 20 typologies was calculated using a deterministic model.[53] The model was based on four different types of input data: building geometry, building typology, weather condition and solar radiation. Building geometry data was used for the identification of individual walls, roofs and floor surfaces. Building typology data was used to input different building attributes including building type, age and insulation standard. Furthermore, while most buildings were assumed to have a window-to-wall ratio (WWR) of 25 per cent, high-rise/iconic towers were assumed to have a higher WWR of 50 per cent. Weather condition data was used to input monthly temperature and wind speed data. In addition, the average monthly solar radiation for each building surface was calculated using a solar radiation model, which takes the shading of the buildings into account. Insulation standards for all typologies were fixed to those of Kuwait. However, building geometry data and weather condition data was based on the local climate and 3D building characteristics of the four cities.

The results from the modelling exercise established the basis for analysing the effects of different urban morphologies through their morphological parameters (building density; surface-to-volume ratio; building height and surface coverage) on cooling energy demand. Results should be interpreted as being indicative of the relative differences between cooling energy demands of the different morphology types, and not as absolute values to be compared to real building cooling energy consumption.

EXHIBIT F: The urban morphology samples (key characteristics)

This section introduces the urban morphology samples that were identified for this study. For each city, five samples representing the most prominent building typologies (which include residential use) were selected. To provide a first overview of these building typologies, the table below provides a comparison of the five dominant types chosen for each city and introduces some of its key characteristics through short descriptions.

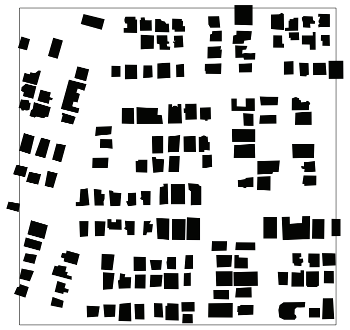
	LOW DENSITY DETACHED HOUSING	MEDIUM PLOT DETACHED HOUSING	SMALLER PLOT DETACHED HOUSING	MEDIUM RISE APARTMENT BLOCKS	MEDIUM RISE APARTMENTS	HIGH RISE APARTMENTS	ICONIC TOWERS
KUWAIT	**ABDULLAH AL-SALEM** **Larger villa type** Floor area ratio: 0.6 Building height range: 1-3 storeys Average building height: 2 storeys Abdullah Al-Salem is a non-governmental villa-type neighbourhood. In general, the plots are large – ranging between 750 and 1,000 m^2 each – and there are wider set-backs between the villas than in the higher-density villa-type areas. A supermarket, clinic, schools, mosques and other amenities exist within to serve the local community.	**QORTUBA** **Medium villa type** Floor area ratio: 0.9 Building height range: 1-4 storeys Average building height: 2 storeys Qortuba is a high-density non-governmental villa-type neighbourhood with a traditional configuration with 500 m^2 plots. Here, the housing has been designed and developed around a central community area that consists of a supermarket, mosques, schools and other amenities.	**NORTH WEST AL-SULAIBIKHAT** **Smaller villa type** Floor area ratio: 1.3 Building height range: 2-3 storeys Average building height: 2 storeys North West (NW) Sulaibikhat is a new public housing residential area with 400 m^2 plots promoted by the PAHW, and still partially under construction. This typology appears to be responding to the high demand for public housing as it utilises spaces more efficiently, in closer proximity to other buildings, thereby accommodating a larger number of buildings within the same area. A central commercial and services spine is built to serve the local community.		**JLEEB AL-SHUYOUKH** **Medium rise apartments** Floor area ratio: 2.0 Building height range: 1-13 storeys Average building height: 7 storeys Jleeb, the apartment typology neighbourhood, represents the type of housing targeting non-Kuwaiti low-income workers. Jleeb consists of medium-rise apartments and is predominantly residential, but has small shops attached to the apartments on the ground floor.		**SHARQ** **CBD typology** Floor area ratio: 2.0 Building height range: 1-62 storeys Average building height: 15 storeys The CBD typology of Kuwait, located in Sharq neighbourhood, has witnessed continuous demolitions and construction activities over the years, and it is characterised by the presence of large vacant plots. Today it mostly consists of commercial and office spaces, and hosts a mix of iconic and low-rise buildings.
ABU DHABI	**AL SHAMKHA NORTH** **Larger villa type** Floor area ratio: 0.3 Building height range: 2 storeys Average building height: 2 storeys Al Shamkha is an Emirati housing neighbourhood. This villa-type neighbourhood consists of housing built by nationals on individual plots (and with loans) provided by the government.		**AL-FALAH** **Smaller villa type** Floor area ratio: 0.3 Building height range: 1-2 storeys Average building height: 2 storeys Al-Falah is one of the most recently developed neighbourhoods and provides villa-style housing for Emiratis. Unlike most other Emirate housing projects, it is a development led by an urban development company. This neighbourhood is designed with several community centres that cater to residents, with small supermarkets, a mosque and a number of schools.	**MADINAT ZAYED BLOCK** **Medium rise apartments** Floor area ratio: 2 Building height range: 1-7 storeys Average building height: 6 storeys Also located in the city's CBD, close to the shopping centre with the same name, this is predominantly a mixed-use area, with vibrant and diverse retail shops (fresh vegetables, photographer, restaurants, shoe repairers, etc.) on the ground floors of the very characteristic medium-rise buildings. It mostly houses block-style buildings that are located along a grid.		**WORLD TRADE CENTRE SOUK** **CBD typology** Floor area ratio: 4.5 Building height range: 1-92 storeys Average building height: 17 storeys The CBD typology is within a mixed-use area located in the Central West area of the Island where the new souk shopping mall is located with its two high-rise iconic towers. The rest of the block is built up with 18-storey high-rise residential towers with commercial and retail use at ground-floor level.	**ETIHAD TOWERS** **Icon towers** Floor area ratio: 3.1 Building height range: 1-80 storeys Average building height: 27 storeys Etihad Towers represent the iconic towers typology in the south-west seaside area of Abu Dhabi Island that mostly consists of commercial centres and hotels. Some iconic buildings in this area are situated along empty plots and some green spaces.
SINGAPORE	**DOVER** **Larger plot houses** Floor area ratio: 0.1 Building height range: 1-2 storeys Average building height: 2 storeys Also located quite centrally in the southern area of the Island, Dover consists of larger-plot houses. Has low surface coverage, and represents low-density detached housing.		**FABER** **Smaller plot landed houses** Floor area ratio: 0.6 Building height range: 2-4 storeys Average building height: 2 storeys Faber has low surface coverage, and represents smaller-plot housing. Its location is quite central in the southern area of the Island.	**TAMPINES** **HDB medium rise apartments** Floor area ratio: 2.7 Building height range: 3-12 storeys Average building height: 10 storeys Tampines is a new town (planned as a large-scale self-contained satellite housing development). Located in the eastern area of Singapore, it is an example of medium-rise apartment blocks.		**PUNGGOL** **HDB point block** Floor area ratio: 3.6 Building height range: 1-17 storeys Average building height: 14 storeys Punggol is a point block HDB development designed around a green space with central parking space under it. Located in the north-east area of Singapore, this typology is an emerging example of high-rise areas in Singapore.	**RAFFLES PLACE** **CBD typology** Floor area ratio: 8.1 Building height range: 1-70 storeys Average building height: 10 storeys Raffles Place has the highest surface coverage of Singapore's typologies, and comprises of iconic towers with mixed-use typologies.
HONG KONG			**HONG LOK YUEN** **Smaller plot houses** Floor area ratio: 0.5 Building height range: 2 storeys Average building height: 2 storeys Hong Lok Yuen represents smaller-plot detached housing. It is a gated community, and has been selected as its morphological configuration is similar to villa typologies in the other case study cities.	**SHAM SHUI PO** **Shop house apartments** Floor area ratio: 4.2 Building height range: 1-30 storeys Average building height: 9 storeys Sham Shui Po serves as an example of shop houses that are incorporated within the Hong Kong grid. These medium-rise Tong Lau blocks of apartments are situated in many of the older areas of the city and generate a continuous active street frontage.	**TAIKOO** **Podium towers** Floor area ratio: 5.4 Building height range: 18-30 storeys Average building height: 26 storeys Taikoo represents medium-rise development (star-shaped) that mark the skyline of many central areas. Such towers are frequently clustered together and tend to be designed at ground level, leaving ample room for open spaces that have play and sport facilities for residents. This typology is located in the north-eastern area of Hong Kong Island.	**TAI KOK TSUI** **Podium tower estate** Floor area ratio: 3.1 Building height range: 1-44 storeys Average building height: 24 storeys Tai Kok Tsui is one of the most recent and largest private high-rise housing estates. Podium tower architecture consists of residential buildings supported by different podium structures that typically contain shopping and parking areas.	**CENTRAL** **CBD typology** Floor area ratio: 7.9 Building height range: 1-88 storeys Average building height: 15 storeys Central has the highest surface coverage of Hong Kong's typologies. It includes a mix of uses and morphologies including iconic towers.

Location map on previous page

EXHIBIT G: The urban morphology samples (figure grounds)

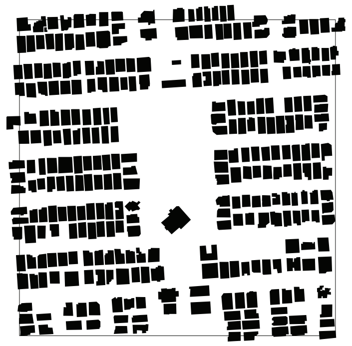
The figures below present the five urban morphology samples dominated by the building typologies introduced above. This is done for each city in a comparative way (from low-density detached housing to hyper-dense iconic towers). The morphology samples are presented as figure ground diagrams, two-dimensional maps where the building footprints are represented in black and open spaces (including roads, parks, empty plots, etc.) in white.

Kuwait



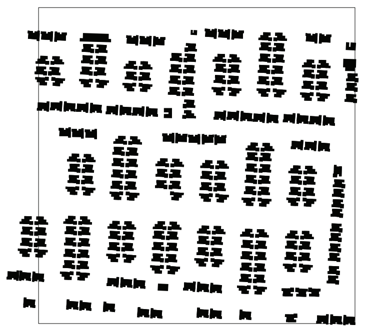
Larger villa type
Abdullah Al-Salem

Floor area ratio: 0.6
Average building height: 2 storeys



Medium villa type
Qortuba

Floor area ratio: 0.9
Average building height: 2 storeys

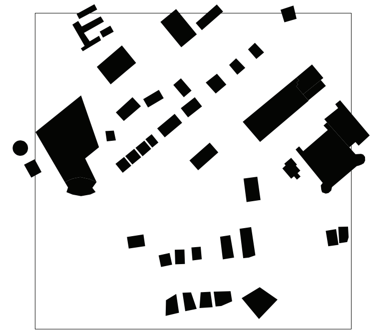


Smaller villa type
NW Sulaibikhat

Floor area ratio: 1.3
Average building height: 2 storeys

Medium rise apartments
Jleeb Al-Shuyoukh

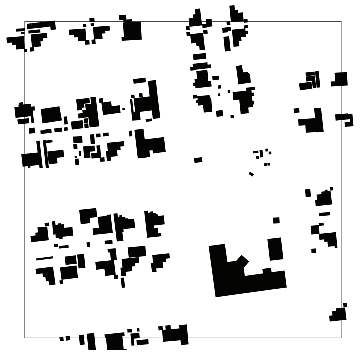
Floor area ratio: 2.0
Average building height: 7 storeys



CBD typology
Sharq

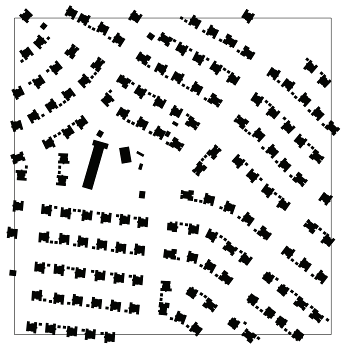
Floor area ratio: 2.0
Average building height: 15 storeys

Abu Dhabi



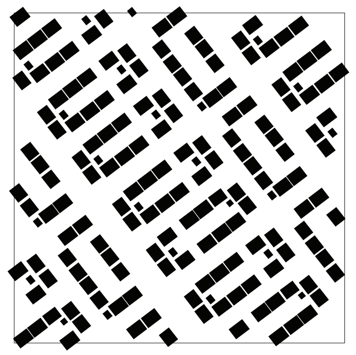
Larger villa type
Al-Shamkha North

Floor area ratio: 0.3
Average building height: 2 storeys



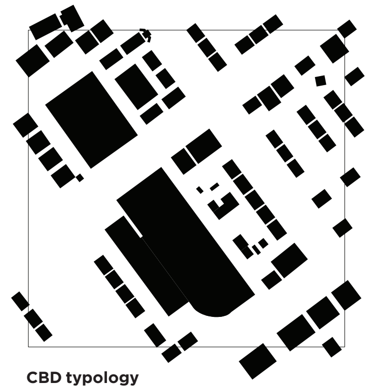
Smaller villa type
Al-Falah

Floor area ratio: 0.3
Average building height: 2 storeys



Medium rise apartments
Madinat Zayed Block

Floor area ratio: 2.0
Average building height: 6 storeys



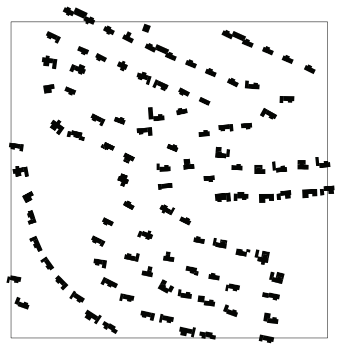
CBD typology
World Trade Centre Souk

Floor area ratio: 4.5
Average building height: 17 storeys

Icon towers
Ethiad Towers

Floor area ratio: 3.1
Average building height: 27 storeys

Singapore

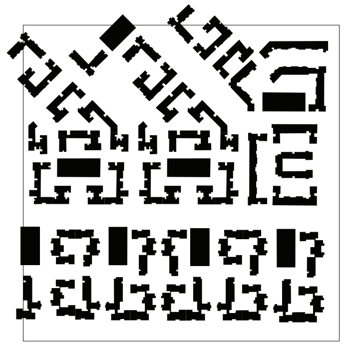


Larger plot houses
Dover

Floor area ratio: 0.1
Average building height: 2 storeys

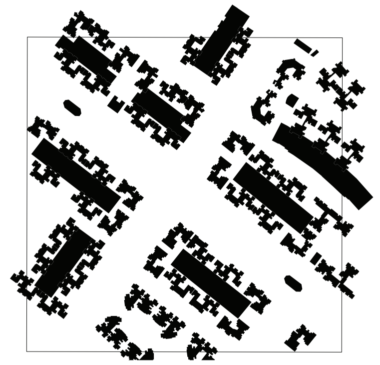
Smaller plot landed houses
Faber

Floor area ratio: 0.6
Average building height: 2 storeys



HDB medium rise apartments
Tampines

Floor area ratio: 2.7
Average building height: 10 storeys



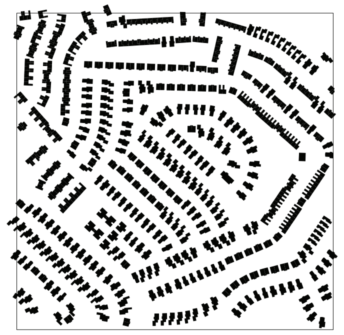
HDB point block
Punggol

Floor area ratio: 3.6
Average building height: 14 storeys

CBD typology
Raffles Place

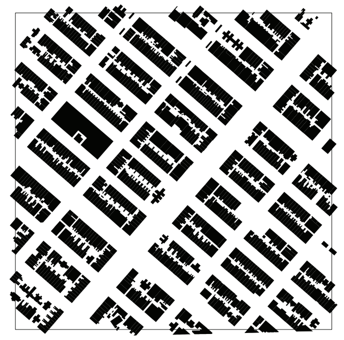
Floor area ratio: 8.1
Average building height: 10 storeys

Hong Kong



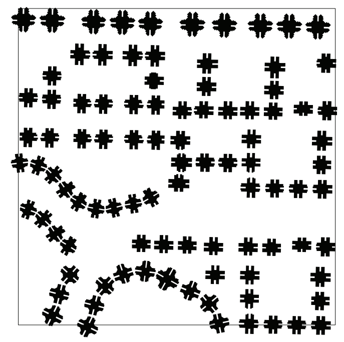
Smaller plot houses
Hong Lok Yuen

Floor area ratio: 0.5
Average building height: 2 storeys



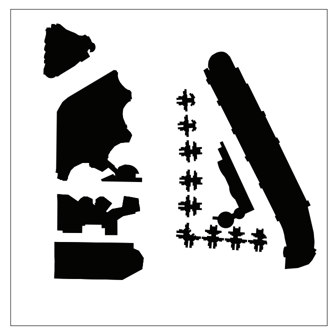
Shop house apartments
Sham Shui Po

Floor area ratio: 4.2
Average building height: 9 storeys



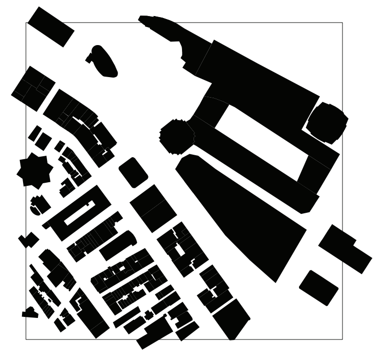
Podium towers
Taikoo

Floor area ratio: 5.4
Average building height: 26 storeys



Podium tower estate
Tai Kok Tsui

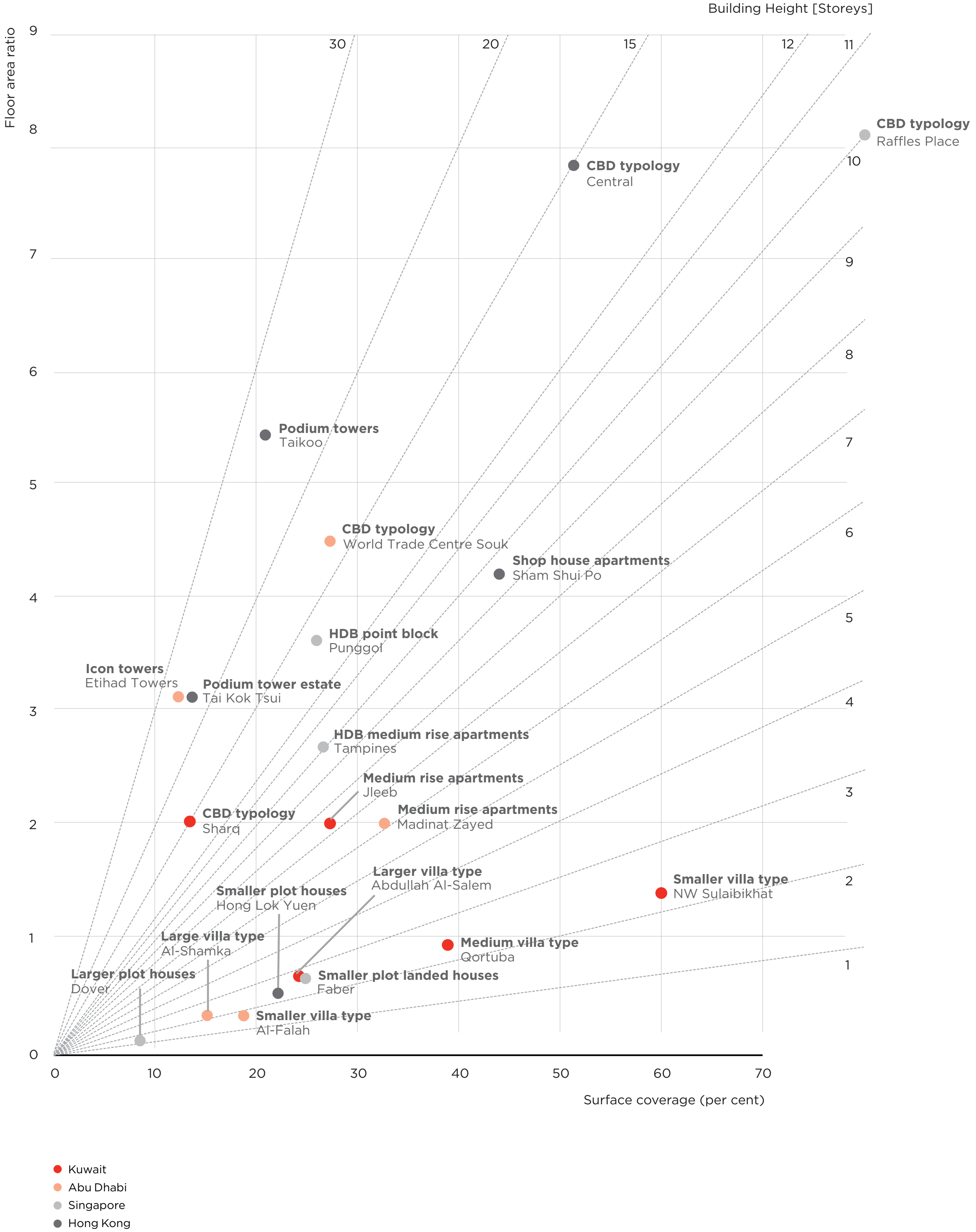
Floor area ratio: 3.1
Average building height: 24 storeys



CBD typology
Central

Floor area ratio: 7.9
Average building height: 15 storeys

Figure 13: Spacemate diagram



3.1.2 Comparing the urban morphologies samples

The typologies described in the sections above can be visualised and compared through Pont and Haupt's (2005) 'Spacemate' diagram. This diagram illustrates differences and similarities in floor area ratio (FAR), surface coverage, and building height . Floor area ratio, an indication of building density, is calculated using the total floor area for the whole building on every storey divided by the whole surface within the 500-by-500 metre frame. Surface coverage presents the ratio of the footprint area of buildings to the total land area. Figure 13 (spacemate diagram) shows the graphical relation of these indicators for five of the most traditional building typologies in each city.

The spacemate illustrates the spatial diversity of the urban morphology samples, with building density ranging from 0.1 in a Singapore larger plot housing typology to 8.1 in Singapore's CBD typology, average building height ranging from 2 in Abu Dhabi's villas typologies to 27 in its iconic towers typology, and surface coverage ranging from 9 per cent in Singapore's larger plot housing to 80 per cent in Singapore's CBD typology. While building height and FAR are clear differentiators between high-rise apartments and villa housing, surface coverage cannot be used to differentiate between the two.

Most typologies are within a middle field with mixed characteristics, with similar surface coverage of around 30 per cent and building density ranging from 0.6 in Kuwait (larger villa type) to 4.5 in Abu Dhabi (CBD typology).

Two clear clusters can be identified: low-density villas/ detached housing and hyper-dense apartments. These are two typological extremes. The lower-density housing includes typologies from the four cities that have similar FAR's (between 0.1 and 0.6) and building heights (two floors). The second cluster comprises the hyper-dense typologies of Singapore and Hong Kong, which have extreme FAR values (around 8), surface coverage between 50 and 80 per cent, and building heights of 10 and 15 floors. On the other hand, Kuwait and Abu Dhabi's highest-density typologies, with FAR values between 2 and three, and surface coverage between 12 and 13 per cent, are clustered together. It appears that empty plots and green areas of Kuwait and Abu Dhabi contrast with the proximity and compactness of Hong Kong and Singapore's surface coverage.

In Kuwait, only the smaller villa type typology (a public housing development area) has a surface coverage of 60. More than half of the typologies across all four cities (and all of the typologies in Kuwait) have a FAR of 2 or below. All of Abu Dhabi's typologies have a surface coverage below 32 per cent. FAR is higher in Singapore and Hong Kong, with three categories where the average building height is above 10 floors (and Hong Kong with two categories above 24). Of the four cities, Abu Dhabi has the highest average building height in the icon towers (Etihad Towers), an area where a number of iconic mixed-use buildings are emerging.

Figure 14: Annual cooling energy demand in the 20 typologies

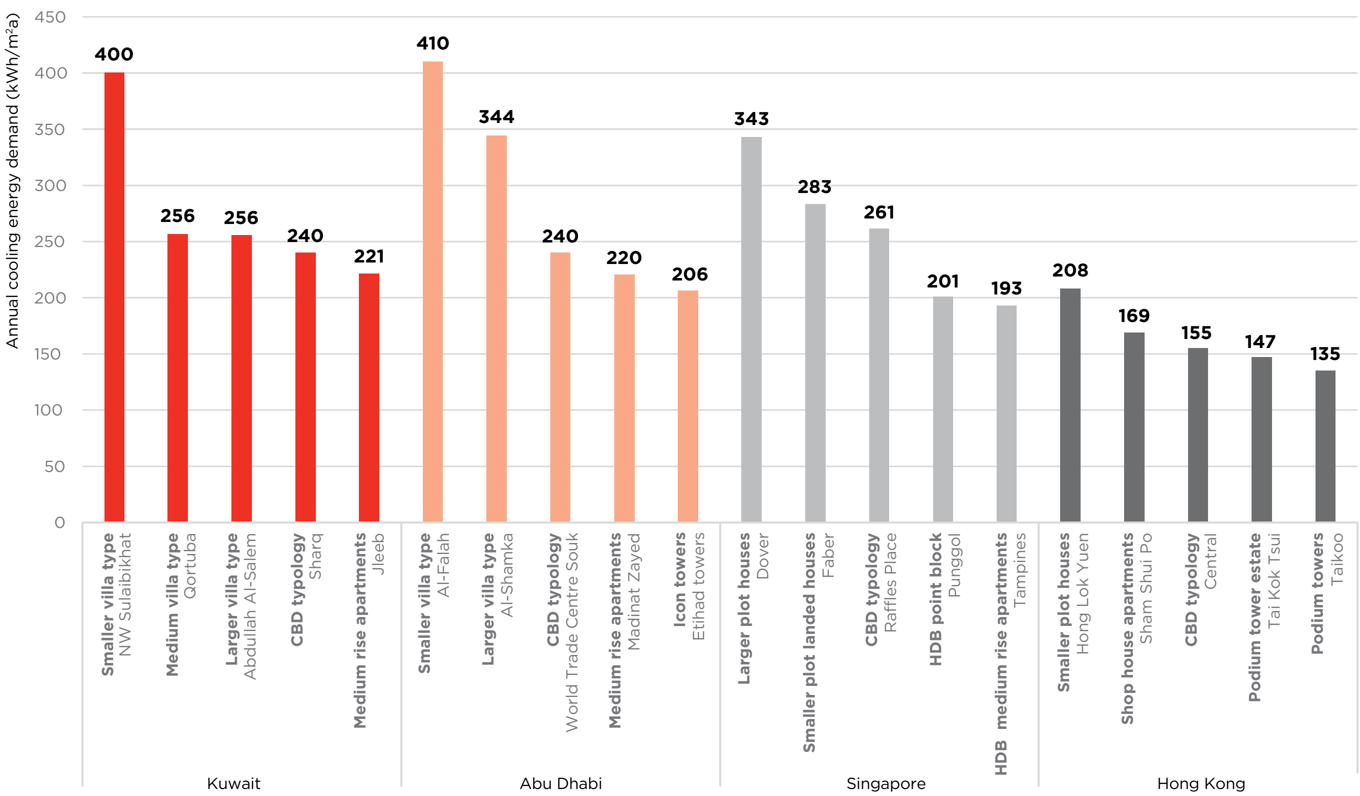


Figure 15: Density and cooling energy demand

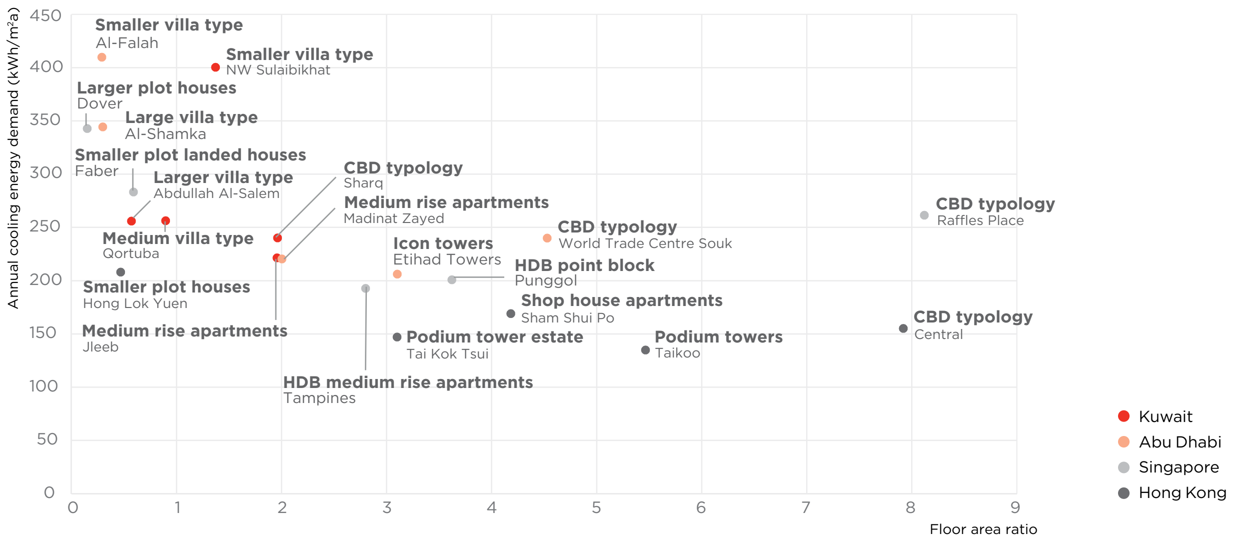


Figure 16: Building height and cooling energy demand

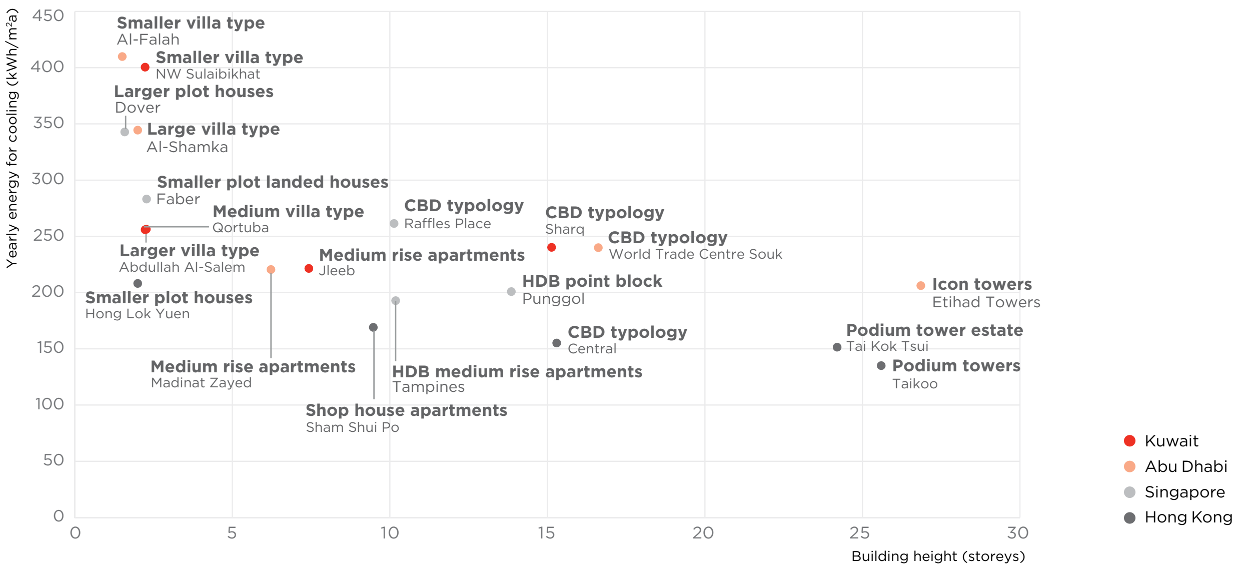
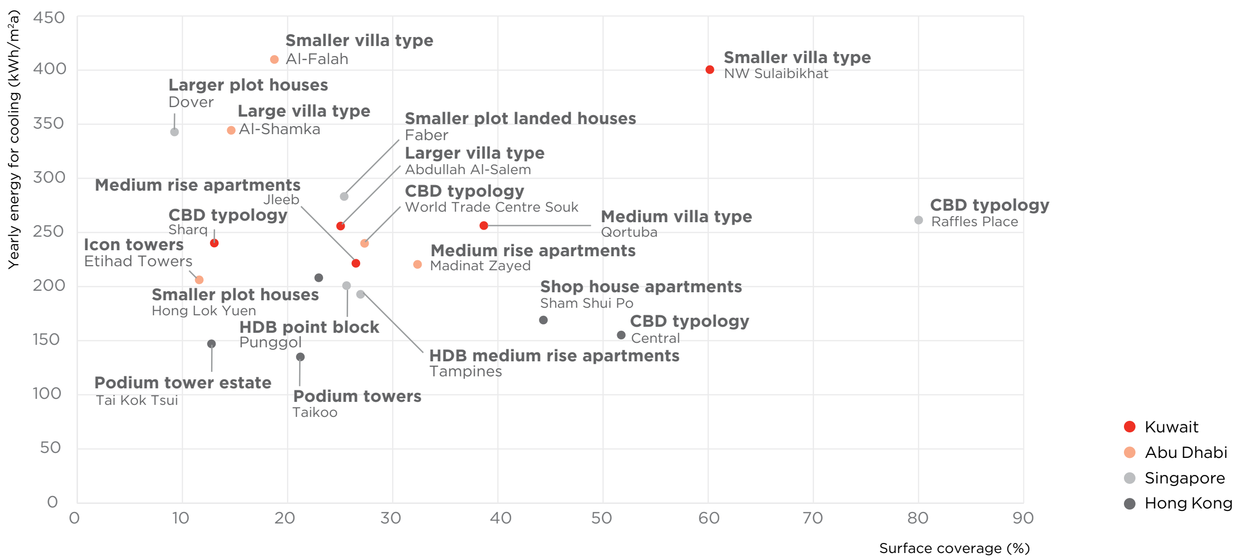


Figure 17: Surface coverage and cooling energy demand



3.1.3 Results of cooling energy simulation

Turning to the results of the cooling energy simulation, the modelling exercise identified considerable differences in the cooling energy demands across the urban morphology samples (Figure 14). A factor of three difference exists between the most energy-efficient typology, Hong Kong's Taikoo (podium towers) with 135 kWh/m² and Abu Dhabi's Al-Falah (smaller villa type) with 410 kWh/m². Overall, the Hong Kong samples feature significantly lower levels of cooling energy demands compared to the other three cities. With the exception of CBD samples and the icon towers (Etihad Towers) in Abu Dhabi (all cases where the WWR is higher and contributes to higher energy consumption) mid- and high-rise apartment typologies generally have lower cooling energy needs than low-density villas, which relatively consume the highest amount of cooling energy.

A closer examination of the relationship between cooling energy demand and urban morphology characteristics such as building density, building height and surface coverage confirms the initial observations above (Figure 15, 16 and 17). As shown in Figure 15, there is a negative correlation between cooling energy demand and building density (FAR), with lower densities associated with higher cooling energy demand. Particularly at density levels of below and around FAR 1, cooling energy demands are considerable higher, often twice the value compared to typologies with FAR 3 or more. Similarly, there is a negative correlation between average built height and cooling energy demand, with low-rise buildings requiring higher cooling energy than mid- and high-rise buildings. Above a height of five floors, however, the variation in cooling energy demand becomes considerably smaller, suggesting diminishing energy-efficiency returns with increased building height beyond this point. By contrast, the surface coverage of buildings reveals a less striking relationship with cooling energy demand.

A key factor driving the morphological impact on cooling energy demand is the surface-to-volume ratio. This is explored in Figure 18 for the case of Kuwait and its five urban morphology samples. The results show – with the exception of the CBD typology (Sharq) – that the higher the surface-to-volume ratio, the higher the cooling energy demand. The CBD typology stands out due to its higher window-to-wall ratio, compared to the other Kuwaiti typologies, which results in higher cooling energy requirements despite the low surface-to-volume ratio.

The Kuwait urban morphology samples are also of interest for analysing the impact of seasonal change, which is more pronounced here than in the other three cases. Figure 19 illustrates the monthly cooling energy requirements of the city's five samples. As one would expect, the graph shows that cooling energy needs increase substantially between March and September for all typologies, while the smaller villa type (NW Sulaibikhat) displays a significantly higher northern hemisphere summer peak compared to the other four. The annual cooling energy need in the medium

Figure 18: Annual cooling energy demand and surface-to-volume ratio in Kuwait typologies

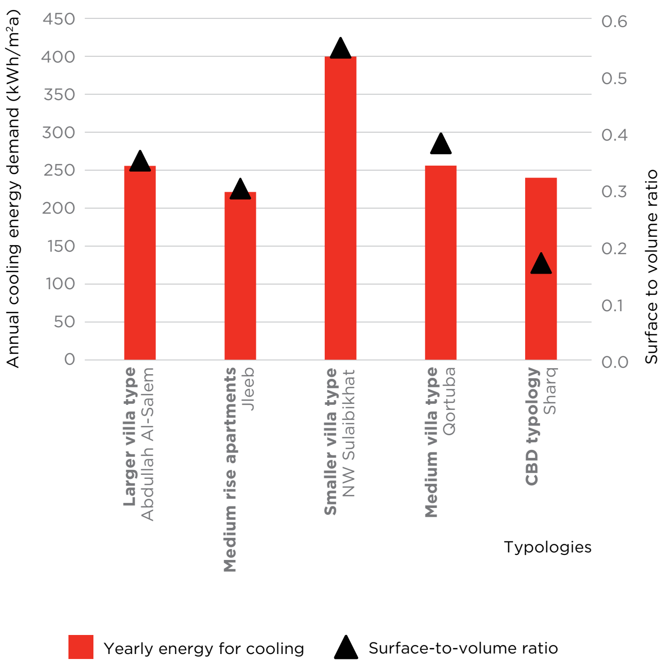
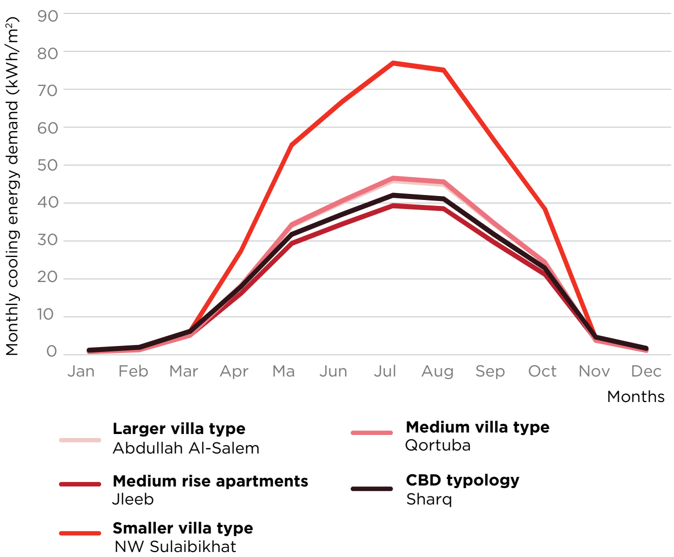


Figure 19: Monthly cooling energy demand in the five typologies in Kuwait



rise apartments (Jleeb) is around 221.42 kWh/m²a, with a minimum of 0.89 kWh/m² in January and a maximum of 39 kWh/m² in July.

It is important to note that the urban built environment often develops its own microclimate and, for example, higher building densities in certain climates can lead to urban heat island effects. At the same time, in desert cities such as Kuwait and Abu Dhabi, the reverse of urban heat island phenomena is observed (Lazzarini et al., 2013). Here, urban areas are cooler than suburban areas, which was also confirmed during an initial investigation of temperature data in the urban and sub-urban areas in Kuwait. The potential adverse effect of unmitigated urban heat islands on cooling energy demand in high-density areas of non-desert cities was quantified for the case of Singapore's CBD typology, indicating a potential increase of annual cooling energy demand of up to 40 per cent.

To conclude, this section shows that overall there is a negative correlation between building density and cooling energy demand. Low-rise, low-density buildings are likely to have higher cooling energy demand. Moreover, an increase in building density at lower density levels is likely to create the greatest impact in terms of a reduction in cooling energy.

3.2 Transport energy demand induced by urban accessibility

Transport energy demand in urban areas is typically calculated by taking a city's modal share into account, estimating the total distance covered by different motorised transport modes, and assessing each mode's standardised energy consumption. This simple calculation hints at the key components that impact the energy efficiency of urban transport systems: first, the travel intensity or total motorised kilometres required to ensure metropolitan-wide accessibility; second, the share of energy-efficient transport modes; and third, the energy demand of motorised vehicles in operation. Given this study's interest in the impact of urban form on resource consumption, it is the first element, the travel intensity of a metropolitan system, which is of interest. At the same time, urban form is also a central enabler for more energy-efficient transport modes such as public transport, walking and cycling.

The sections below will first present a comparative analysis of metropolitan accessibility in Kuwait and Hong Kong. They will then discuss job and micro accessibility for the selected sample neighbourhoods, and will conclude with a section that describes the results of transport energy analysis. Abu Dhabi and Singapore have been included for comparison in cases where data was available.

3.2.1 Metropolitan accessibility in Kuwait and Hong Kong

The functional integration or segregation of different land uses in cities is an important factor determining the 'need to travel' and overall levels of urban accessibility. For example, co-locating different uses within the same districts, neighbourhoods and even buildings can reduce travel distances between residential areas and areas with retail and leisure opportunities. Although more difficult to achieve, greater levels of mixed use also offer opportunities to reduce commuting distances between homes and jobs. Furthermore, greater proximity between urban functions is a prerequisite for more sustainable travel as it enables walking and cycling.

The analysis below follows three aspects of metropolitan accessibility in the cases of Kuwait and Hong Kong: first, the proximity between residential and employment areas; second, the levels of public transport accessibility in the two cities; and third, public transport accessibility of two different groups within Kuwait.

The proximity between residential and employment areas

As a starting point, the calculated average distance between residential and employment areas in Kuwait and Hong Kong can be understood by complementing the distribution of residential locations (see Exhibit A) with the distribution of job locations. Exhibit H illustrates the relationship between residential and employment locations in two ways: first, by juxtaposing residential densities and job densities; and second, by mapping the jobs-to-residents ratio across the metropolitan regions.

Residential densities in Kuwait are significantly lower than in Hong Kong. Kuwait's higher densities are also more concentrated in specific locations than Hong Kong's more pervasive high-density clusters. Job densities in Kuwait,

Table 3. Metropolitan accessibility for travel to work

	Jobs	Population	Metropolitan area (km²)	One-way commuting distance (km)	Traffic speed (km/hour)				One-way commuting time (mins)
					Car	Bus	Rail	Weighted mean	
Kuwait	1,703,145	4,178,572	852	17.8	24.2	16	N/A	21	51
Hong Kong	2,543,460	7,305,700	1,109	12.6	22.7	16	51	31	24

Notes: car speed: LSE Cities calculations based on Hong Kong local traffic speeds data and TomTom's traffic congestion values; bus speed: (Vasconcellos, 2014); rail speed: (MTR, 2017)

Singapore

Closer integration between different land uses and transport infrastructure in cities increases urban accessibility and effectively reduces travel time.

Photography: Philipp Rode

however, are high with almost 100,000 jobs/km² in its peak central area. While these are relatively high levels, they are nevertheless significantly lower than Hong Kong's peak densities of 160,000 jobs/km². The more important difference is the distribution of jobs, which are more concentrated in Kuwait, and more distributed in the case of Hong Kong.

In terms of the jobs-to-residents ratio, mixed use areas are considerably more prominent in Hong Kong than in Kuwait. While Kuwait features large and continuous mono-functional areas, either exclusively for housing or industrial purposes, the share of such areas in Hong Kong is low. Of further interest are mono-functional housing areas in Kuwait in relatively central locations. At the same time, higher levels of mixed use can be found across the metropolitan region in both cities even at considerable distances from the city centre.

With regard to the calculated travel intensity induced by each of the two cities' distribution of jobs and residents, a considerable difference can be observed (see Table 3). At 17.8 km, the average distance between residential and job locations in Kuwait is 41 per cent higher than Hong Kong's average distance of 12.6 km. An even greater difference exists when calculating the average commuting time. This takes the speed and share of different transport modes into consideration. With an average of 51 minutes, one-way commuting times in Kuwait are almost twice as high as Hong Kong's 24 minutes. While these findings may be in line with what one would expect given the efficiency of Hong Kong's urban form and transport systems, it is worth noting that these efficiencies are achieved in a considerably larger city fragmented by natural constraints, which tend to lead to longer commuting times and distances.

Public transport accessibility

In terms of public transport accessibility, Kuwait and Hong Kong are significantly different (Figure 20). This can be illustrated by analysing the percentage of residents and employees who have access to public transport, using a threshold of 500 metre distance to the next public transport station or stop. The proportion of the population that can conveniently access a bus stop in Kuwait (as Kuwait does not have a rail-based public transport system) is 31 per cent, compared to 73 per cent public transport access in Hong Kong. In fact, 38 per cent of the population in Hong Kong lives within 500 metres of a rail station, providing the city with higher levels of access to rail alone compared to Kuwait's overall public transport (bus) access.

Turning to workplace accessibility to public transport, which is higher in both cities, the analysis reveals convenient access for 48 per cent of all jobs in Kuwait and 79 per cent in Hong Kong. Again, the accessibility to rail alone in Hong Kong (54 per cent) is higher than Kuwait's overall job access to buses (48 per cent).

Figure 20: Residential and workplace accessibility to public transport

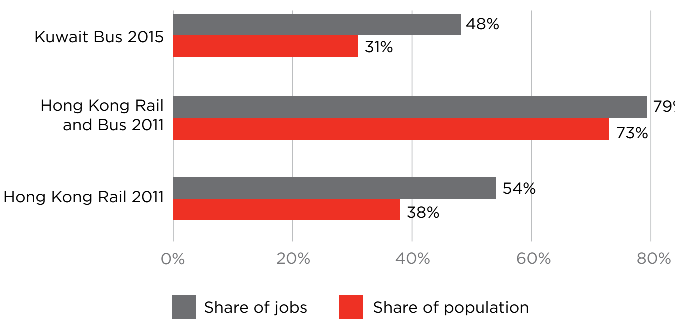
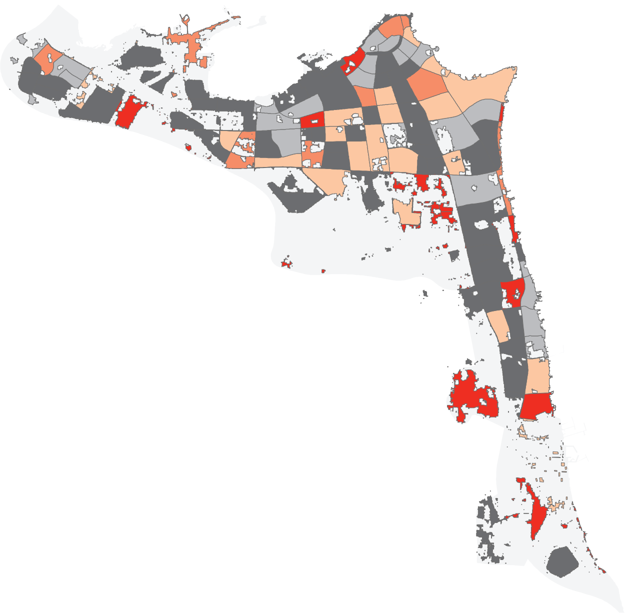


EXHIBIT H: Living/working ratios and residential vs employment densities

This exhibit illustrates the relationship between residential and employment locations in two ways: first, by mapping the jobs/residents ratios across the metropolitan regions; and second, by juxtaposing residential densities and job densities. Residential densities in Kuwait are significantly lower than in Hong Kong. The fewer higher density areas in Kuwait are also more concentrated in specific locations than Hong Kong's more pervasive high density clusters. Similarly, Kuwait's job densities are more concentrated in one area (the CBD). In Hong Kong, jobs are more evenly distributed across the city, although the CBD hosts the highest number of jobs. In terms of the jobs/residents ratio, areas of higher levels of mixed use are considerably more prominent in Hong Kong compared to Kuwait.

Kuwait



Mixed-use index (2015)

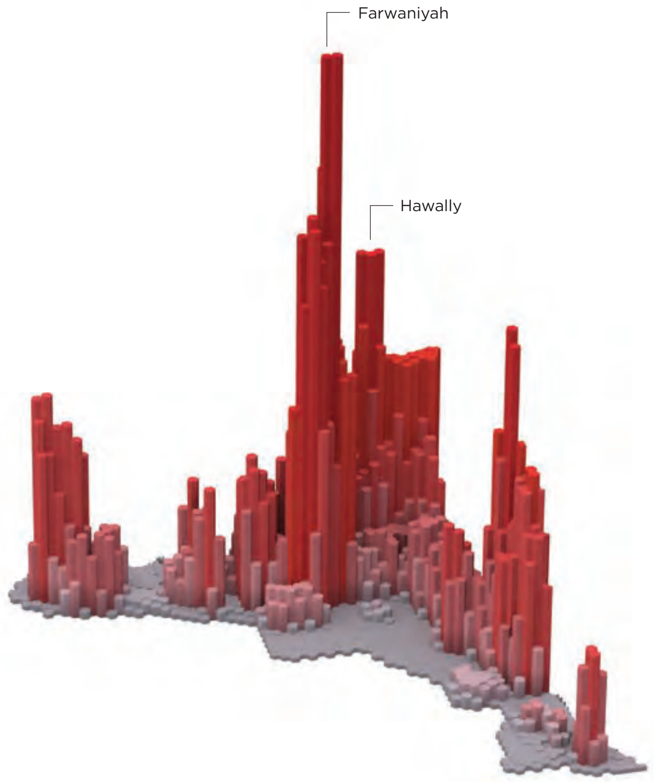
- 0 - 0.05 (lower mixed-use)
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.50
- 0.5 - 1 (higher mixed-use)

Metropolitan area

0 10km

Population (2015)

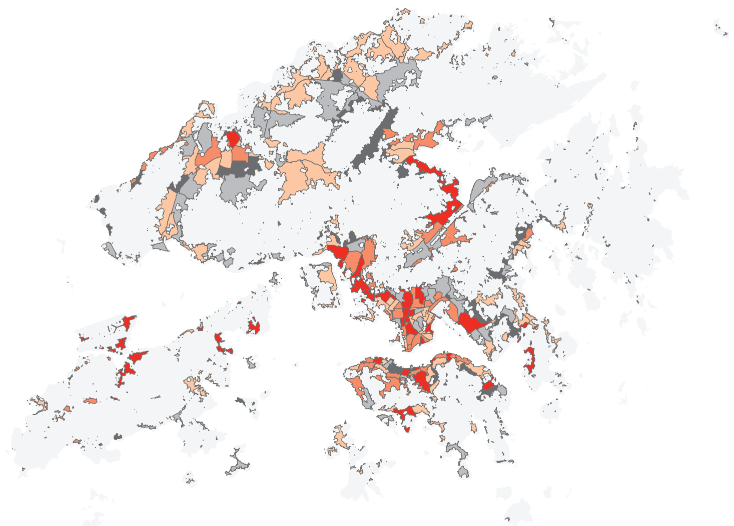
Urban living area density
9,848 pers/km²
Peak density
52,941 pers/km²



Jobs (2015)

Urban living area job density
4,014 jobs/km²
Peak job density
98,091 jobs/km²

Hong Kong



Mixed-use index (2011)

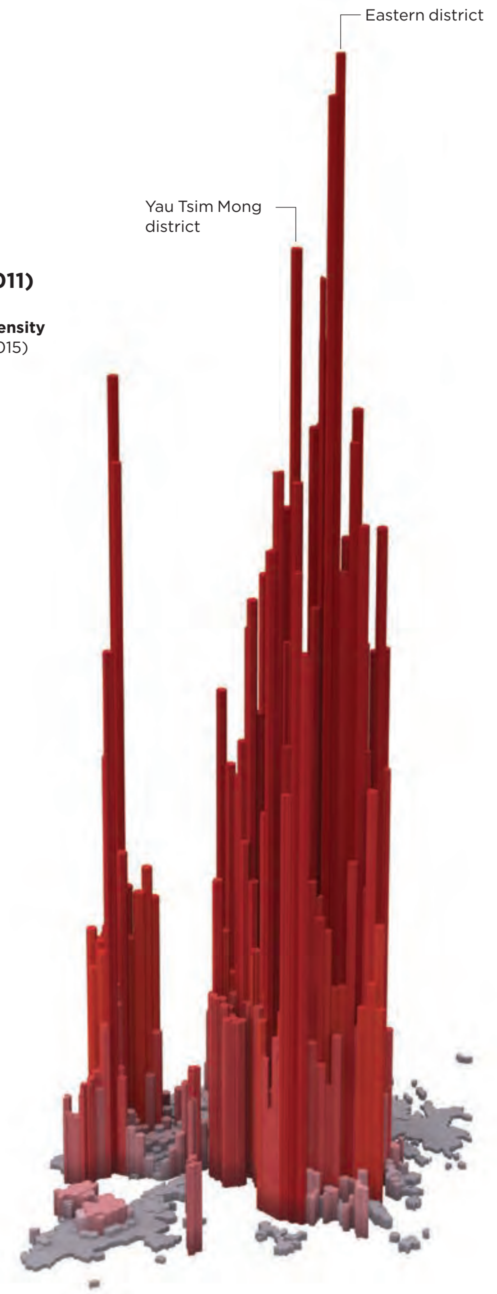
- 0 - 0.05 (lower mixed-use)
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.50
- 0.5 - 1 (higher mixed-use)

Metropolitan area

0 10km

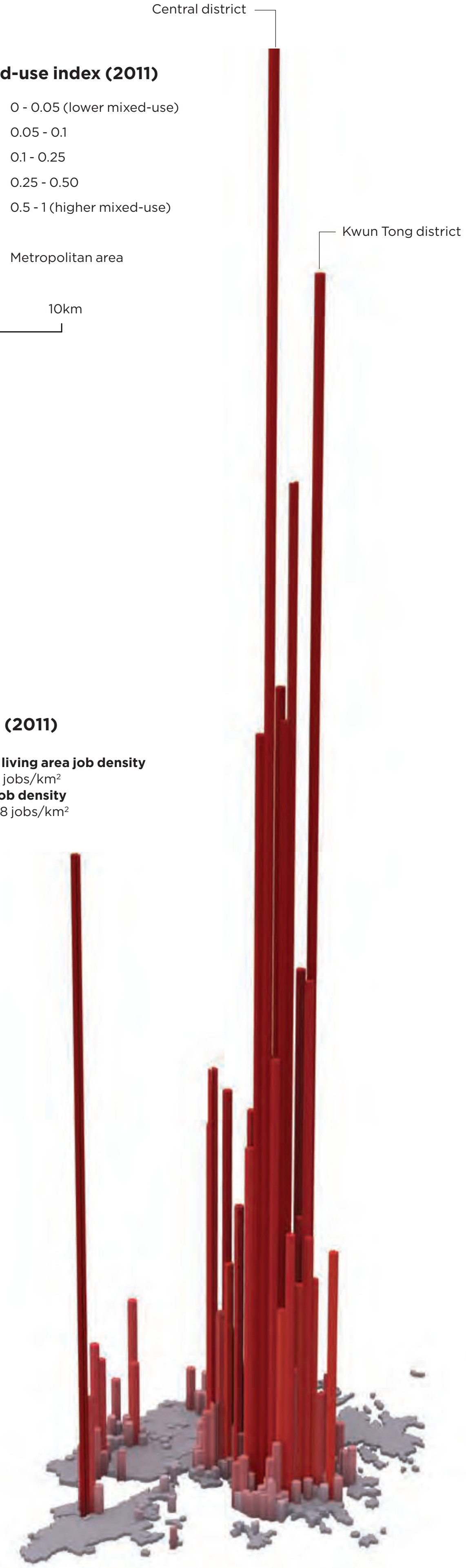
Population (2011)

Urban living area density
29,554 pers/km² (2015)
Peak density
112,941 pers/km²



Jobs (2011)

Urban living area job density
10,289 jobs/km²
Peak job density
160,678 jobs/km²



Kuwait's internal accessibility differences

Earlier sections emphasised considerable intra-urban differences that exist within each of the case study cities. For the case of Kuwait, Box 3 indicated considerable variation in urban living and mobility patterns of the Kuwaiti and non-Kuwaiti population. Figure 21 and 22 build on this finding and show residential and workplace proximity to bus stops by nationality status. The graphs show that 37 per cent of the non-Kuwaiti population lives less than 500 m from a bus stop, while only 16 per cent of the Kuwaiti population lives at a similar distance from a bus stop. Although Kuwaitis primarily use private vehicles for transport purposes, they can nevertheless access some bus stops close to their places of residence, as bus access is provided for non-Kuwaitis who work as domestic staff in Kuwaiti houses. However, it is important to note that not all bus stops directly serve Kuwaiti neighbourhoods close to their residences; some are located along major roads that are close to these neighbourhoods. Public transport access to and from work-places shows that Kuwaitis and non-Kuwaitis both have similar access as most workplaces are concentrated in the same area (CBD).

3.2.2 Access from and within selected neighbourhoods

In order to relate the overall metropolitan accessibility patterns above to less abstract conditions of specific neighbourhoods, a brief analysis follows of job accessibility and micro accessibility within the selected sample neighbourhoods of this study.

Job accessibility

Based on the same method used to analyse overall metropolitan accessibility, average distance to all jobs was calculated from five selected neighbourhoods in Kuwait and Hong Kong. This neighbourhood-specific metropolitan mobility analysis shows that overall, the selected Kuwaiti neighbourhood's exhibit significantly lower job accessibility compared to Hong Kong neighbourhoods, as the average distances to all jobs is greater than in Hong Kong (Figure 23). NW Sulaibikhat has the lowest accessibility levels with an average distance of 19.1 km to all jobs, while Abdullah Al-Salam has the highest accessibility levels with an average distance of 9.7 km to all jobs. In Hong Kong, the neighbourhood of Hong Lok Yuan displays the lowest accessibility levels of 16.8 km, while Tai Kok Tsui and Sham Shui Po have the best accessibility levels with an average distance of just 6.4 km to all jobs in the city.

Figure 21: Kuwait residential accessibility to bus stops by nationality, 2015

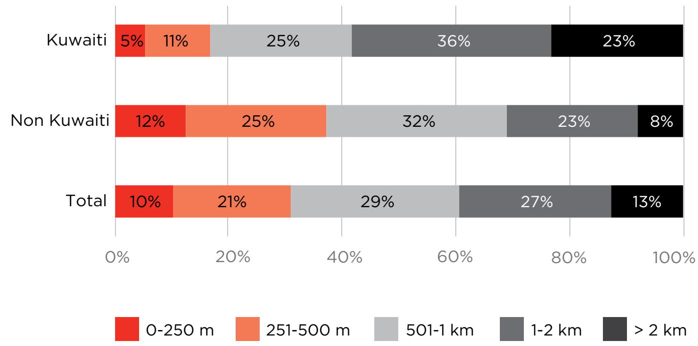


Figure 22: Kuwait workplace accessibility to bus stops by nationality, 2015

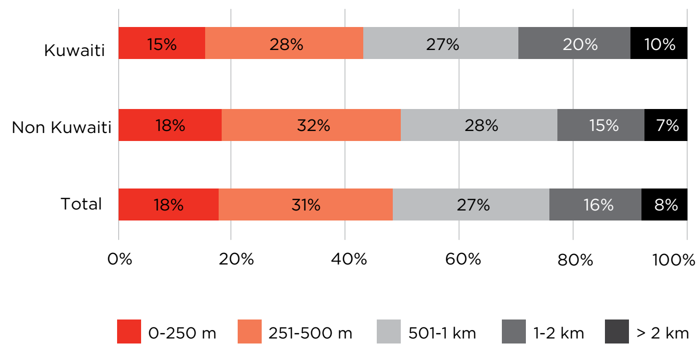
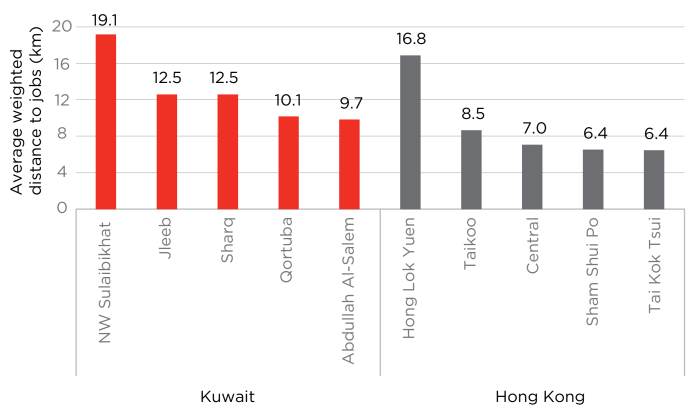


Figure 23: Average weighted distance to all jobs in the selected neighbourhoods



Singapore

The provision of public transport is closely synchronised and at times fully integrated with urban projects and property development.

Photography: Philipp Rode

An important factor determining average job accessibility from each of the neighbourhoods is its location in relation to the city centre, which represents the main hub of employment in both cities. As shown in Figure 24, a clear positive relationship exists between the two variables across both cities. Overall, the selected neighbourhoods in Hong Kong exhibit shorter distances for both variables, and with the exception of Hong Lok Yuan, lie closely on the graph, showing smaller within-city variation in accessibility levels. The selected neighbourhoods in Kuwait exhibit greater distances, and are reflective of lower accessibility levels. There is also greater variation in accessibility levels within the city as compared to Hong Kong. In Kuwait, Sharq is an outlier case which is located in close proximity to the city centre, yet has relatively long commuting distances to all jobs. Given the importance of location, the selection of representative neighbourhoods in each of the cities is another significant factor that explains the accessibility variance beyond what has been identified as an overall pattern for Hong Kong and Kuwait in the section above.

As there exists a strong relationship between location and density in the selected neighbourhoods, it is likely that a strong relationship could exist between density and job accessibility. Figure 25 confirms that this is so. It shows that there is a positive relationship between density and work-related accessibility in Hong Kong as its metropolitan job accessibility gradually increases with rising population density. On the other hand, this relationship is less clear in Kuwait where higher job accessibility exists in relatively low-density neighbourhoods.

Figure 24: Average distance to city centre and distance to all jobs

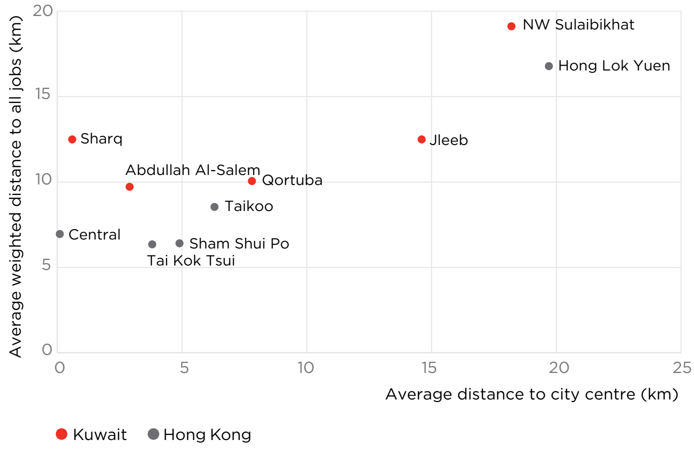


Figure 25: Density and average distance to all jobs

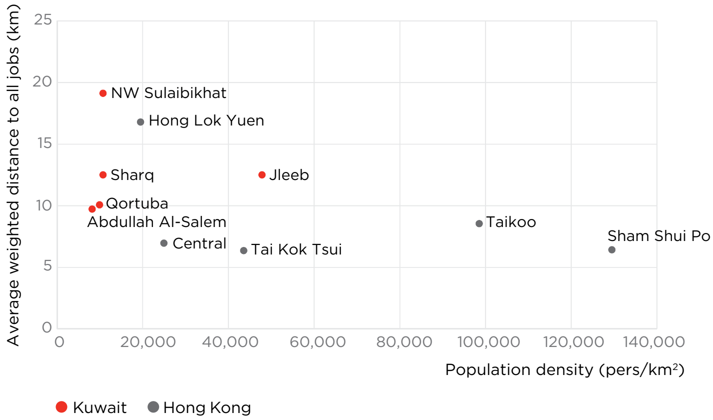


Figure 26: Horizontal and vertical micro mobility for selected neighbourhoods

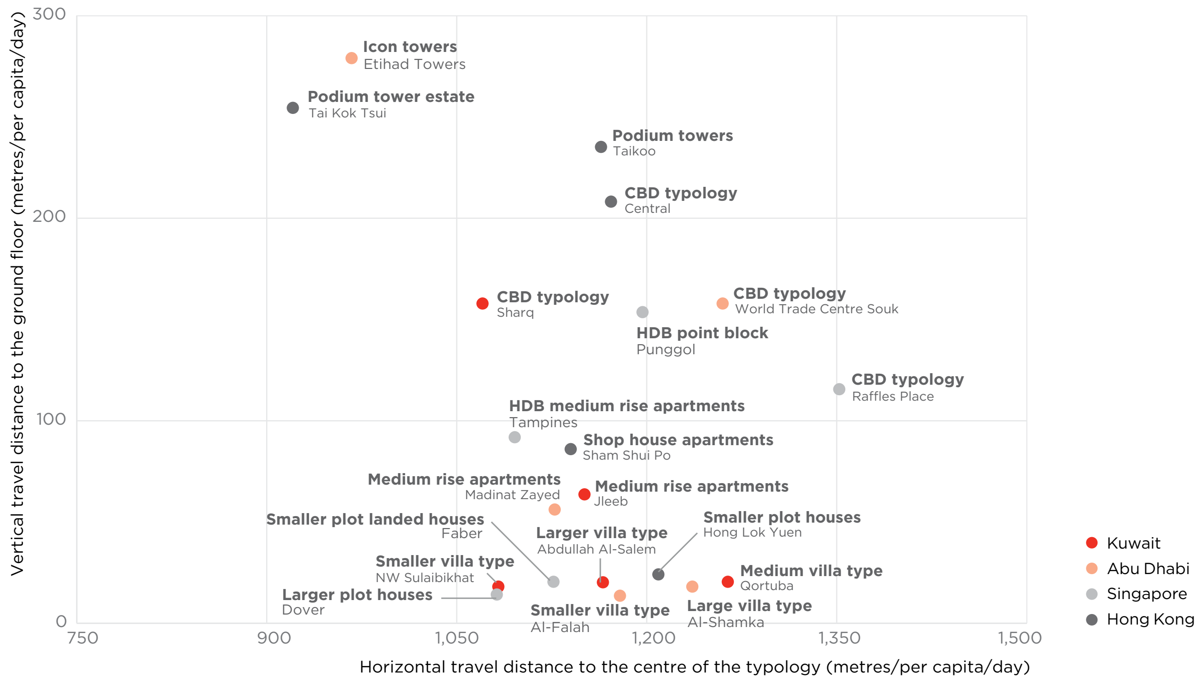


Table 4: Mode share and standardised energy consumption in Kuwait and Hong Kong

	Mode share (per cent)		Standardised energy consumption (MJ/passenger km)		
Mode	Kuwait	Hong Kong	Kuwait	Hong Kong	Source
Private car	55	8	2.6	2.3	Newman and Kenworthy (2011)
Buses	39	45	0.7	0.5	Kenworthy (2003)
Rail	0	36	N/A	0.2	Kenworthy (2008)
Weighted average			1.8	0.5	LSE Cities

Micro accessibility

To complement the job accessibility analysis, which considers travel beyond the selected neighbourhoods, movement patterns linked to micro accessibility within each of the neighbourhoods were calculated. This is based on an analysis of horizontal and vertical micro mobility within a 500 by 500 metre area. Horizontal micro mobility measures the average daily distance a person travels to reach the centre of the typology, based on a constant daily trip rate of three trips per resident. GIS analysis shows that these distances vary from about 920 metres in Hong Kong's Tai Kok Tsui (Podium tower estate) to 1,350 metres in Singapore's Raffles Place (CBD typology). These differences are mainly due to the distribution of buildings within the 500 by 500m frame, the use of central areas for buildings or open spaces, and the presence of large buildings which have central entrances that can accommodate a large number of residents. While micro accessibility differences are relatively minor in terms of metres travelled, more significant are the differences in whether these last or first metres within the neighbourhoods are walking or driving trips.

Vertical micro mobility represents the average daily vertical distance per capita covered to reach the ground floor in each typology. It multiplies the average height of a building in a typology, with a constant trip rate of three trips per person per day. The results show that, excluding CBD areas, the daily per capita vertical mobility distances in Kuwait's residential typologies are relatively lower (31 metres) than the daily per capita vertical mobility distances in Hong Kong's residential typologies (150 metres). This is reflective of the nature of buildings in the GCC cities and the East Asian cities, the former predominantly of a low-rise nature, and the latter of a high-rise nature. Figure 26 compares horizontal and vertical mobility within each of the samples, and shows that a clear relationship between horizontal and vertical mobility does not exist.

3.2.3 Results of transport energy calculation

Based on the above accessibility analysis, this final section presents calculations of total transport energy demand at the metropolitan (macro) and neighbourhood (micro) level. It first examines macro and micro energy demands separately, and then concludes with a discussion of the combined results.

Metropolitan mobility energy demand

The analysis below calculates the total energy consumed by each passenger in Kuwait and Hong Kong when commuting for work, and is based on the calculated average distance to work, mode share, and standard energy consumption values from official statistics and scientific literature. The analysis is based on 261 working days per calendar year. Table 4 presents mode share and standard energy consumption values in megajoules (MJ) per passenger kilometre for both Kuwait and Hong Kong. Based on local statistics, this analysis also assumes that in Kuwait, 55 per cent of workers travel by car or taxi, and only 39 per cent use buses to travel to work. Similarly in Hong Kong, it assumes that eight per cent of workers travel by car or taxi, 44.5 per cent travel by bus, and 35.9 per cent travel by rail. Literature on energy consumption in Asian cities, based on research by Kenworthy (2003, 2008), states that, on average, car-based travel consumes approximately three to four times more energy than bus-based travel, and 11 times more energy than rail-based travel. Based on actual mode share data from both cities, it is estimated that, for each passenger kilometre travelled, energy consumption in Kuwait is about 1.82 MJ, which is roughly 3.4 times higher than for Hong Kong (0.53 MJ).

Using the standardised energy consumption values shown above, Figure 27 shows the annual per capita energy demand for work journeys in Kuwait and Hong Kong. On average, in Kuwait, the calculated annual energy demand for commuting is 15.8 GJ per person, five times the commuting energy demand in Hong Kong (3.1 GJ). If all trips were made by car, annual commuting would consume 23.8 GJ per person in Kuwait, and 15.3 GJ in Hong Kong.

Similarly, bus-only commuting would require 6.9 GJ in Kuwait and 3.2 GJ in Hong Kong per commuter per year. Rail-only commuting in Hong Kong would be the most energy-efficient motorised mode, with 1.2 GJ per commuter per annum. This simple calculation suggests that lower levels of workplace accessibility and high car dependence play a central role in shaping high transport energy demand in Kuwait as compared to Hong Kong. These differences are substantial and lead to an absolute annual energy demand for travel to work of about 26,849 terajoules (TJ) in Kuwait metropolitan area, and only 7,833 TJ in Hong Kong. Assuming that commuting-related travel typically only accounts for about 20 per cent of kilometres travelled in a city, the total difference in transport energy demand between the two cities may be as high as 95,080 TJ. For comparison, an average nuclear power station with an installed capacity of 1,000 kW produces about 31,500 TJ of electricity per year. To meet Kuwait's high transport energy demand, the city requires the equivalent of three average nuclear power plants.

Figure 28 presents the annual energy demand share of each transport mode in the two cities. In Kuwait, car-based travel comprises 83 per cent of commuting energy demand (22,282 TJ), while bus-based travel comprises merely 17 per cent (4,567 TJ) of commuting energy demand. In Hong Kong, car-based travel comprises nearly 40 per cent (3,118 TJ) of total commuting energy demand, bus-based travel 46 per cent (3,573 TJ), and rail-based travel only 15 per cent (1,141 TJ).

The observed differences in commuting energy demand in the two cities not only have environmental but also economic consequences. Figure 29 compares fuel costs for work journeys in Kuwait and Hong Kong based on the average calculated trip length, mode of travel, and pump price for petrol (gasoline) for the year 2014 (US$0.2 and $2.06 for one litre of petrol in Kuwait and Hong Kong respectively). To allow for comparison, the energy demand of Hong Kong's rail system – which is currently partially electricity based – has also been converted to fuel costs. Figure 29 also shows a high-price scenario for Kuwait by adjusting its current prices to Hong Kong prices.

Based on actual fuel prices in the two cities, total annual fuel costs for commuting in Kuwait are US$149.2 million, and US$357.2 million in Hong Kong. Adjusting fuel prices to Hong Kong levels would increase Kuwait's average commuting costs to US$1.2 billion, which is more than three times the average commuting costs in Hong Kong.

Figure 27: Annual per capita energy demand for work journeys in Kuwait and Hong Kong

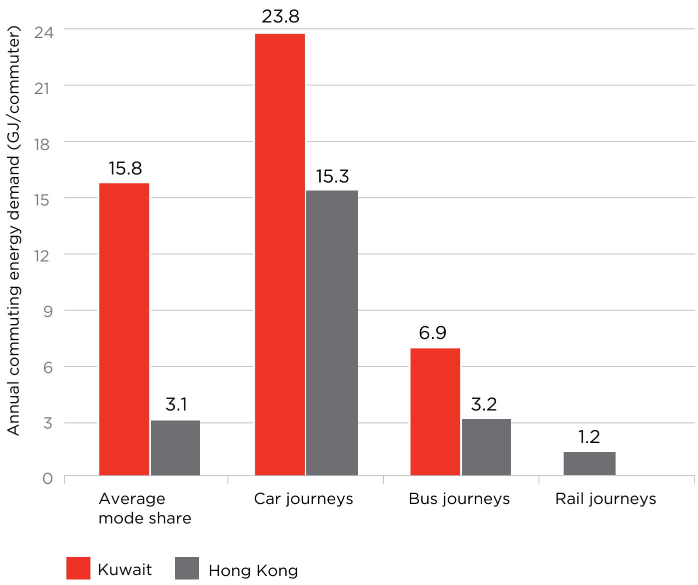
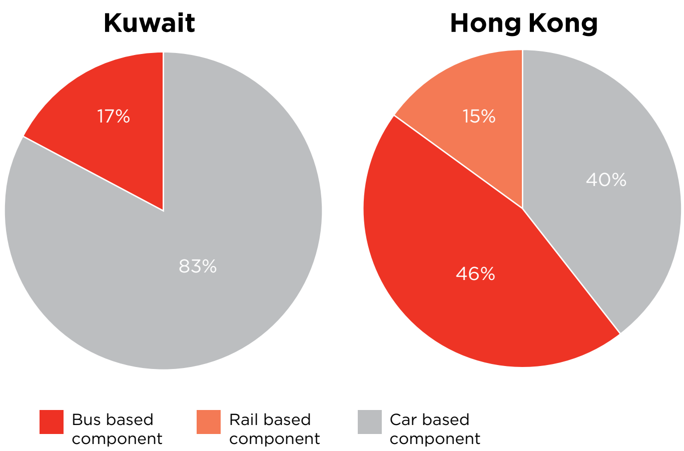


Figure 28: Energy composition of work journeys based on average mode share



Micro mobility energy demand

The calculated energy consumption linked to micro mobility within each of the selected neighbourhoods was calculated based on the horizontal and vertical movements established earlier. Only two types of energy use were considered and assigned to each neighbourhood: energy related to car use for horizontal movement and energy related to elevator use for vertical movement. Both of these are based on their physical structures. The analysis reveals that annual energy consumption per person for micro mobility lies between 0.07 GJ and 1.2 GJ and is mostly determined by car-use for horizontal movement rather than by lift-generated vertical movement (Figure 30). Low-density neighbourhoods with fewer than three floors per building do not have lifts and hence only show automobile energy consumption (horizontal mobility values). Similarly, daily mobility within medium- and high-density neighbourhoods is often based on a mix of walking and car use. It can also be entirely based on walking, resulting in a decrease in their annual energy use.

Figure 29: Total annual fuel costs for commuting in Kuwait and Hong Kong (local and HK fuel prices)

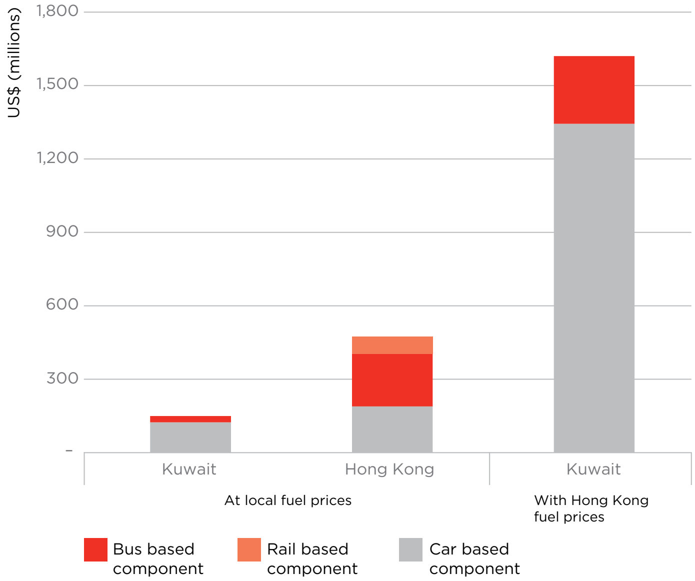
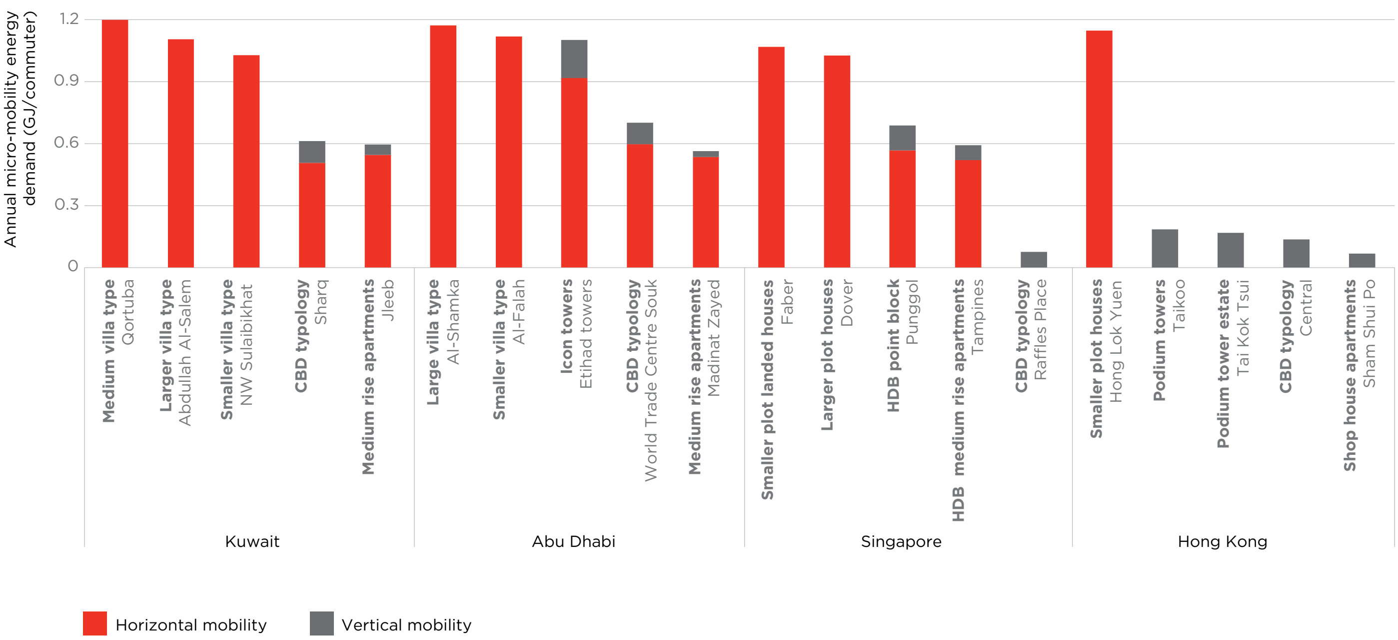
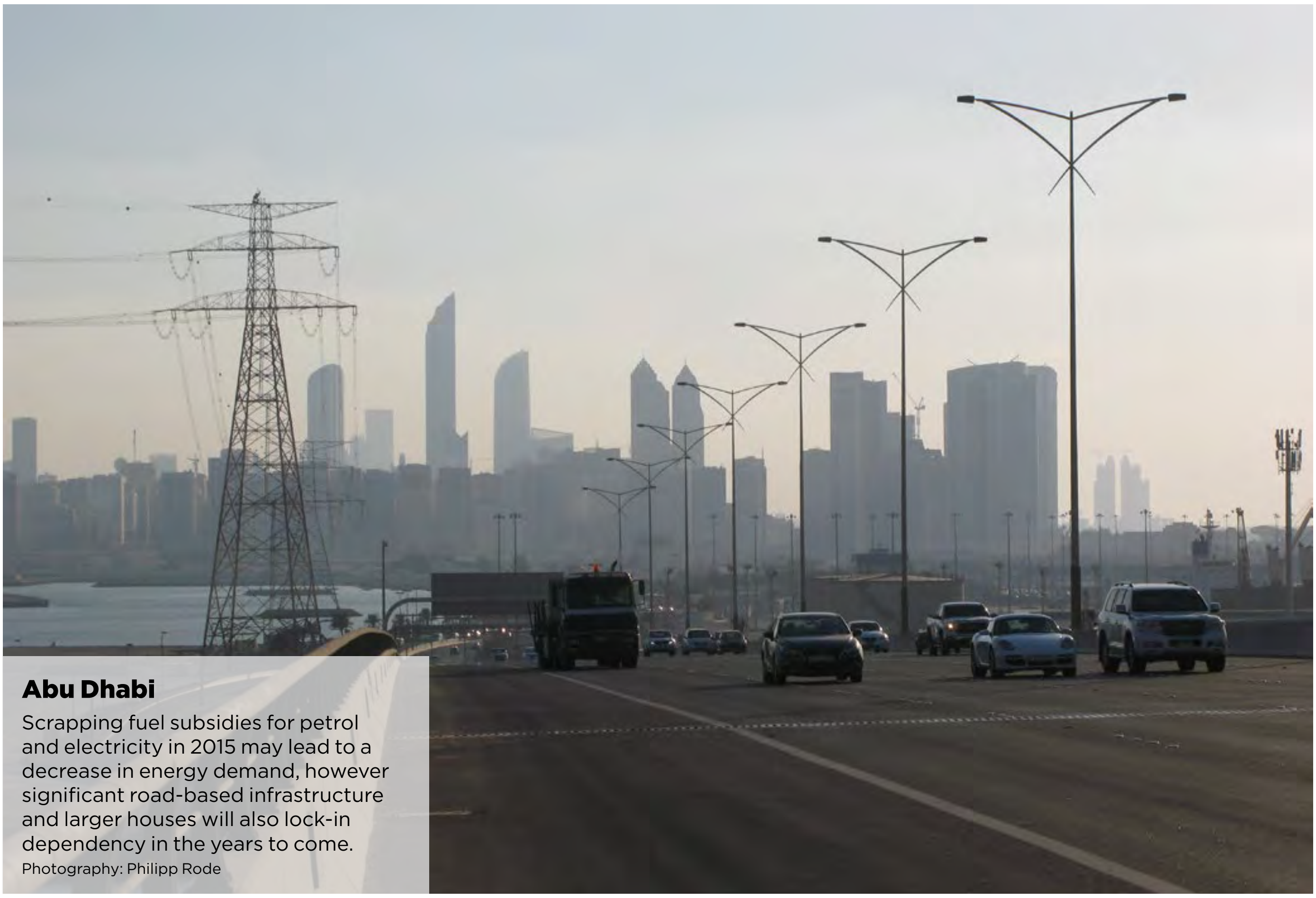


Figure 30: Energy demand for micro mobility within neighbourhoods





Abu Dhabi

Scrapping fuel subsidies for petrol and electricity in 2015 may lead to a decrease in energy demand, however significant road-based infrastructure and larger houses will also lock-in dependency in the years to come.

Photography: Philipp Rode

Figure 31: Micro mobility energy demand and density

Figure 31 explores the relationship between micro mobility energy demand and building density within the 20 neighborhoods across the four cities. It illustrates a relatively clear association between higher building densities and lower annual energy demand for micro-mobility, primarily as a result of lower car dependence in higher density areas.

Combined energy demand for macro and micro mobility

Analysis of total energy consumption for macro and micro mobility reveals the overall limited role of transport energy demand within the neighbourhoods compared to metropolitan-wide transport energy needs (Figure 32). Typically, the latter accounts for between 82 and 97 per cent of total transport energy demand. Depending on typology, annual per capita energy demand for horizontal and vertical mobility varies significantly within cities, and ranges between 11 and 22 GJ/year for Kuwait and 2 and 6.4 GJ/year for Hong Kong.

Finally, figure 33 explores the relationship between total transport energy use and the building density of each neighborhood. It shows that in both cities, higher-density typologies tend to be more energy-efficient mainly as a result of lower automobile use. In this case, however, it is car-based commuting beyond the neighbourhood that accounts for the main differences.

To conclude the second part of this report, it is important to re-emphasise the considerable degree of evidence this study has presented on the strong relationships between urban form and energy demand. For both key aspects analysed here, the cooling and transport energy demand, factors related to urban form such as urban density, building density, distribution of functions and transport infrastructure were repeatedly found to be strong predictors of energy needs. In the context of cooling energy demand, the study established a factor of three between the most and least energy-efficient urban morphology sample. The difference calculated for transport energy demands is even more pronounced and calculations indicated a factor of five difference of transport energy needs as a result of the different spatial configurations of Hong Kong and Kuwait.

Figure 32: Total automobile and lift energy consumption of selected neighbourhoods within metropolitan areas

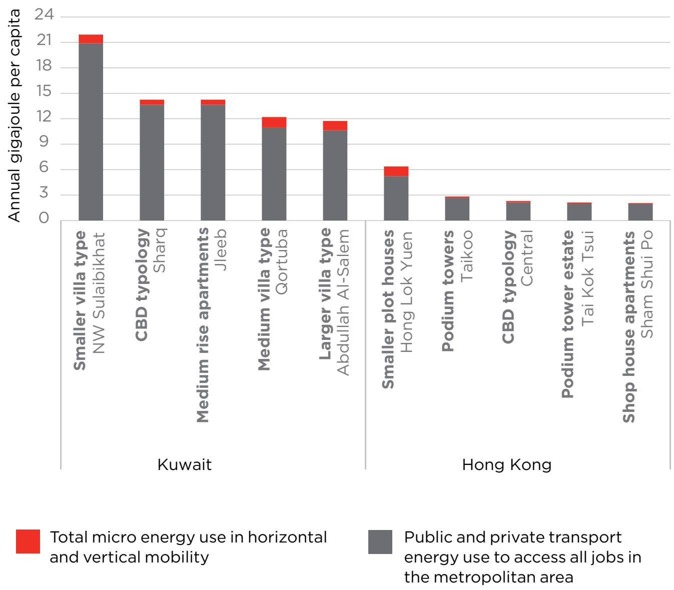
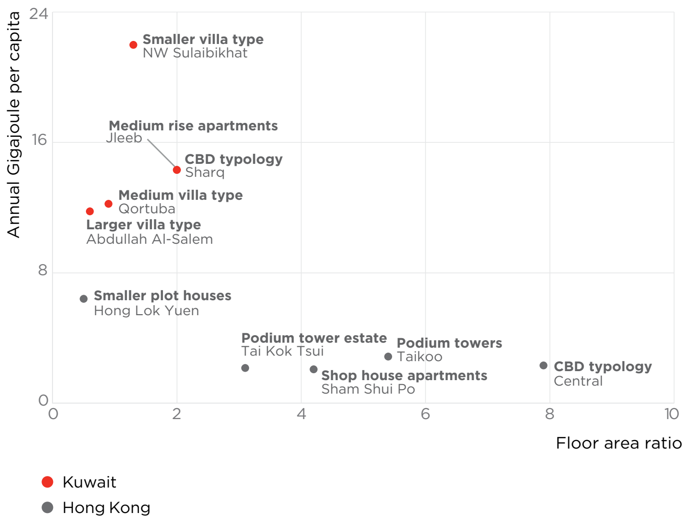


Figure 33: Total energy use, at the micro (lift to ground, automobile to centre) and macro (access to all jobs) levels in Kuwait and Hong Kong



4 Conclusion

The *Resource Urbanisms* report investigated the impact of natural resource availability and costs on urban form, and explored the extent to which differences in urban form lead to differences in resource use and consumption. This analysis, based on urban development patterns in Kuwait, Abu Dhabi, Singapore and Hong Kong, confirmed a range of established assumptions and generated several new findings.

In terms of building on an established understanding of urban growth factors, this study confirmed that natural resources and, above all, land, as a scarce, non-tradable and non-substitutable natural resource, plays an integral role in shaping urban form at the macro and micro scale. Unlike other natural resources, land area, with by and large locally fixed supply, is one of the most important variables explaining differences in city growth. In the cases of Singapore and Hong Kong, land constraints and population pressures are central to understanding the adoption of compact growth policies, whereas in the cases of Kuwait and Abu Dhabi, land availability and lower population levels are key in explaining the adoption of low-density housing welfare initiatives and car-centric city planning.

At the same time, the research re-emphasised other factors of urban growth. Aside from geographical factors and natural resources, urban development in the case study cities was clearly shaped by a confluence of critical and complex physical, historical, economic and cultural factors. Although not directly addressed by this study, the evidence collected in each of the case study cities suggests that key non-resource factors of urban development need to be considered alongside the analysed land and energy conditions as well as other natural resources such as water.

In the context of the two Gulf cities, intra-urban differences of the built environment cannot be understood without a comprehensive understanding of citizenship. In Kuwait, for instance, nationals primarily live in villas and commute using private vehicles while non-nationals live in apartments and commute by public transport. Although nationals and non-nationals occupy different types of residential units in both Kuwait and Abu Dhabi, non-nationals in Kuwait are more integrated within the urban fabric of the city than they are in Abu Dhabi.

In terms of expanding the existing evidence, more specific findings were established in relation to the impact of energy prices and oil endowments on urban form, and the impact of urban form on cooling and transport energy demands. This research finds that fuel prices are associated with periods of densification and de-densification in the case study cities. However, recorded relationships are generally more nuanced compared to the impact of land availability, and the recorded sample size did not allow for statistically credible generalisations. In Kuwait, Abu Dhabi, Singapore and Hong Kong, the established patterns suggest a possible correlation between fuel prices and densification patterns, with higher prices linked to more compact patterns of development. Electricity prices may have a more indirect relationship as they increase. Recent price increases recorded in Abu Dhabi may render cooling energy costs for larger houses less affordable, thus reducing the demand for such housing typologies.

At the same time, the study found limited evidence that oil endowment directly impacts physical urban form, specifically densities and modes of transport, over and above a country's economic wealth levels. Global evidence suggests that wealth itself is a more accurate predictor of urban living area densities, with the source of wealth having a more limited role in shaping densities.

By contrast, considerable evidence was presented in relation to the impact of urban form on cooling and transport energy demand. Overall, this research confirms that the shape and physical configuration of cities directly impacts energy requirements and resource efficiency, making urban morphologies a critical factor for global sustainability, particularly as infrastructure investments result in considerable time lags and lock-in effects. Cooling energy demand modelling conducted for 20 different urban morphology samples in five distinctive building typologies in each city shows that there is a factor of three difference between the most energy-efficient sample and the least energy-efficient sample simply due to building design and morphology. In addition, the modelling confirmed a negative correlation between compact morphologies and cooling energy demand, with higher densities and building heights resulting in lower energy demand.

Transport energy efficiency also depends on urban form and above all the combination of density, mixed land use and public transport. Calculations of the average distances between living and working in Kuwait and Hong Kong, as well as job and micro accessibility analysis for the 20 sample neighbourhoods, show that there is a considerable difference in city access and transport energy demand: a factor of five difference per capita in annual transport energy demand for journeys to work in Kuwait and Hong Kong, and a factor of 18 difference across the transport energy demand of the 20 sample neighbourhoods.

Overall, this research suggests that there are important insights from the comparison between all four case study cities, as well as the observed differences within each city, which can support strategic choices for urban development. Above all, these insights support the emerging view that more compact, mixed-use city structures at the metropolitan and neighbourhood scale can facilitate greater energy efficiency and sustainability.

At the same time, this study also implies that there are key opportunities for future research on the relationship between urban development and natural resources. Most importantly, the analysis can be expanded to also investigate water, food and other material resources and their impact on urban form. Given the overwhelming importance of land availability in this regard, future research could also bridge the extensive amount of existing work on land economics, tenure and real estate, and land as critical natural capital.

Considering the much greater diversity of urbanisms internal to each case study city than expected, and related intra-urban differences in resource use, future research could also zoom in further and develop a deeper understanding of relevant dynamics at the local scale. Such work may also address wider impacts of urbanisms on liveability, use and access to public space, as well as health and well-being.

To conclude, the research presented in this report, as well as the many prior studies that informed it, all demonstrate the centrality of urban form in influencing resource use and consumption. The research also shows that policymaking decisions related to urban form and infrastructure in cities such as Kuwait, Abu Dhabi, Singapore and Hong Kong will play a critical role in shaping urban futures and global sustainability goals.

CBD, Abu Dhabi
Aside from the CBD and some other high-density blocks, the Emirati capital primarily comprises of low-density developments and limited public spaces.
Photography: Alexandra Gomes

Bibliography

AboulNaga, M.M., Elsheshtawy, Y.H., 2001. Environmental sustainability assessment of buildings in hot climates: the case of the UAE. Renew. Energy 24, 553–563. doi:10.1016/S0960-1481(01)00041-6

Abu Dhabi Housing Authority (ADHA), 2014. Abu Dhabi National Housing Guidelines for Integrated Communities: Lessons Learnt Report

Acemoglu, D., Johnson, S., Robinson, J.A., 2002. Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution. Q. J. Econ. 117, 1231–1294

Addae-Dapaah, K., 1999. Utilization of urban residential land: a case study of Singapore. Cities 16, 93–101. doi:10.1016/S0264-2751(99)00004-9

Ahlfeldt, G., Pietrostefani, E., 2017. Demystifying Compact Urban Growth: Evidence from 300 Studies From Across the World (Working Paper). Coalition for Urban Transitions, NCE and OECD, London and Washington, D.C.

Aktins, 2010. Public Transport Study in Kuwait Town, Urban Areas and New Towns. Kuwait Municipality

Al-Nakib, F., 2013. Kuwait's Modern Spectacle Oil Wealth and the Making of a New Capital City, 1950–90. Comp. Stud. South Asia Afr. Middle East 33, 7–25. doi:10.1215/1089201X-2072694

Al-Nakib, F., 2016. Kuwait Transformed: A History of Oil and Urban Life. Stanford University Press, Stanford, California

Alissa, R., 2013. The Oil Town of Ahmadi since 1946 From Colonial Town to Nostalgic City. Comp. Stud. South Asia Afr. Middle East 33, 41–58. doi:10.1215/1089201X-2072712

Al-Mutairi, H., Dewsbury, J., Lane-Serff, G.F., 2011. Energy and the implication of residential cooling in hot climates: Case study for developing effective solution for residential cooling demand in Kuwait. Presented at the Energy and Sustainability 2011

Al-Rashedi, Y., 2011. The Impacts and Viability of Urban Revitalization in the City (Masters Thesis). Paris Sorbonne University d'Abu Dhabi

AlShalfan, S., 2013. The Right to Housing in Kuwait: An Urban Injustice in a Socially Just System

Auty, R.M., 2001. Resource Abundance and Economic Development. OUP Oxford

Baker, N., Steemers, K., 2000. Energy and Environment in Architecture: A Technical Design Guide. E & FN Spon

Bertinelli, L., Black, D., 2004. Urbanization and growth. J. Urban Econ. 56, 80–96. doi:10.1016/j.jue.2004.03.003

Bet-Shlimon, A., 2013. The Politics and Ideology of Urban Development in Iraq's Oil City Kirkuk, 1946–58. Comp. Stud. South Asia Afr. Middle East 33, 26–40. doi:10.1215/1089201X-2072703

Bjorvatn, K., Farzanegan, M.R., Schneider, F., 2012. Resource Curse and Power Balance: Evidence from Oil-Rich Countries. World Dev. 40, 1308–1316. doi:10.1016/j.worlddev.2012.03.003

Blake, H.A., 1900. Appendix IX to Sir Henry Blakes Report to Mr J Chamberlain HK (Hong Kong Sessional Papers)

Buchanan, C., 1969. Studies for a National Physical Plan for the State of Kuwait and Master Plan for the Urban Areas: Housing in Kuwait

Carlino, G.A., 2011. Three Keys to the City: Resources, Agglomeration Economies, and Sorting

Cartier, C., 1999. The state, property development and symbolic landscape in high- rise Hong Kong. Landsc. Res. 24, 185–208. doi:10.1080/01426399908706558

Census and Statistics Department (CSD), 2016a. Hong Kong Annual Digest of Statistics

Census and Statistics Department (CSD), 2016b. Hong Kong Energy Statistics Annual Report | Census and Statistics Department

Census and Statistics Department (CSD), 2016c. Geography and Climate: Land Area of Hong Kong

Central Statistical Bureau (CSB), 1990. Statistical Abstract in 25 Years

Centre for Liveable Cities (CLC), 2014. Urban Systems Studies: Land Acquisition and Resettlement - Securing Resources for Development

Chaudhry, K.A., 1994. Economic Liberalization and the Lineages of the Rentier State. Comp. Polit. 27, 1–25. doi:10.2307/422215

Cho, I.S., Križnik, B., 2017. Community-Based Urban Development, Advances in 21st Century Human Settlements. Springer Singapore, Singapore. doi:10.1007/978-981-10-1987-6

Creutzig, F., 2014. How fuel prices determine public transport infrastructure, modal shares and urban form. Urban Clim. 10, 63–76. doi:10.1016/j.uclim.2014.09.003

Creutzig, F., Baiocchi, G., Bierkandt, R., Pichler, P.-P., Seto, K.C., 2015. Global typology of urban energy use and potentials for an urbanization mitigation wedge. Proc. Natl. Acad. Sci. 112, 6283–6288. doi:10.1073/pnas.1315545112

Crinson, M., 1997. Abadan: planning and architecture under the Anglo-Iranian Oil Company. Plan. Perspect. 12, 341–359. doi:10.1080/026654397364681

Cullinane, S., Cullinane, K., 2003. Hong Kong city profile. Cities 20, 279–288. doi:10.1016/S0264-2751(03)00027-1

Damluji, M., 2013. The Oil City in Focus The Cinematic Spaces of Abadan in the Anglo-Iranian Oil Company's Persian Story. Comp. Stud. South Asia Afr. Middle East 33, 75–88. doi:10.1215/1089201X-2072730

Davis, G.A., 1995. Learning to love the Dutch disease: Evidence from the mineral economies. World Dev. 23, 1765–1779. doi:10.1016/0305-750X(95)00071-J

Davis, J.C., Henderson, J.V., 2003. Evidence on the political economy of the urbanization process. J. Urban Econ. 53, 98–125

Dempsey, M.C., 2014. Castles in the Sand: A City Planner in Abu Dhabi. McFarland, Jefferson, North Carolina

Department of Statistics Singapore (DSS), 2017a. Population Trends. http://www.singstat.gov.sg/statistics/browse-by-theme/geographic-distribution

Department of Statistics Singapore (DSS), 2017b. M890151 - Land Area (As At December), Annual. http://www.tablebuilder.singstat.gov.sg/publicfacing/createDataTable.action?refId=2775

Dimitriou, H.T., Cook, A., 1998. Land-use/transport Planning in Hong Kong: The End of an Era : a Review of Principles and Practices. Ashgate

Elsheshtawy, Y., 2008. Cities of Sand and Fog: Abu Dhabi's Global Ambitions, in: Elsheshtawy, Y. (Ed.), The Evolving Arab City: Tradition, Modernity and Urban Development. Routledge, New York, pp. 258–304

Energy Market Authority (EMA), 2015. Singapore Energy Statistics

Environment Agency (EA) Abu Dhabi, 2008. Terrestrial Environment of Abu Dhabi Emirate, United Arab Emirates

Environment Bureau, Development Bureau, Transport and Housing Bureau, 2015. Energy Saving Plan for Hong Kong's Built Environment 2015 -2025

Fay, M., Opal, C., 1999. Urbanization without Growth: A Not-So-Uncommon Phenomenon, Policy Research Working Papers. The World Bank. doi:10.1596/1813-9450-2412

Findlay, R., Lundahl, M., 2001. Natural Resources and Economic Development: The 1870-1914 Experience, in: Auty, R.M. (Ed.), Resource Abundance and Economic Development. Oxford University Press, New York

Frankel, J.A., 2010. The Natural Resource Curse: A Survey (Working Paper No. 15836). National Bureau of Economic Research. doi:10.3386/w15836

Freeman, O.W., 1945. Natural Resources and Urban Development. Ann. Am. Acad. Pol. Soc. Sci. 242, 30–45

Fuccaro, N., 2013a. Introduction Histories of Oil and Urban Modernity in the Middle East. Comp. Stud. South Asia Afr. Middle East 33, 1–6. doi:10.1215/1089201X-2020327

Fuccaro, N., 2013b. Shaping the Urban Life of Oil in Bahrain Consumerism, Leisure, and Public Communication in Manama and in the Oil Camps, 1932–1960s. Comp. Stud. South Asia Afr. Middle East 33, 59–74. doi:10.1215/1089201X-2072721

Fuccaro, N., 2009. Histories of City and State in the Persian Gulf: Manama since 1800. Cambridge University Press, Cambridge

Gharibi, H.A., 2016. Urbanisation and Changing Life-Style Patterns in Muscat, in: Nebel, S., Richthofen, A.V. (Eds.), Urban Oman: Trends and Perspectives of Urbanisation in Muscat Capital Area, HABITAT - INTERNATIONAL: Schriften Zur Internationalen Stadtentwicklung.Gilbert, A., Healey, P., 1985. The Political Economy of Land: the State and Urban Development in Venezuela. Gower Publishing Company, Aldershot, England

Glaeser, E.L., 2013. A World of Cities: The Causes and Consequences of Urbanization in Poorer Countries (Working Paper No. 19745). National Bureau of Economic Research. doi:10.3386/w19745

Gollin, D., Jedwab, R., Vollrath, D., 2016. Urbanization with and without industrialization. J. Econ. Growth 21, 35–70. doi:10.1007/s10887-015-9121-4

Hashim, A.R.B., 2016. The History of Planning Residential Neighborhoods in Abu Dhabi: 1961-1990, in: Transformations: The Emirati National House. National Pavillion United Arab Emirates la Biennale di Venezia, UAE

Henderson, J.V., 2004. Urbanization and Growth

Herb, M., 2014. The Wages of Oil: Parliaments and Economic Development in Kuwait and the UAE. Cornell University Press

Herb, M., 2005. No Representation without Taxation? Rents, Development, and Democracy. Comp. Polit. 37, 297–316. doi:10.2307/20072891

Hertog, S., 2010. The Sociology of the Gulf Rentier Systems: Societies of Intermediaries. Comp. Stud. Soc. Hist. 52, 282. doi:10.1017/S0010417510000058

Hertog, S., Luciani, G., 2012. Energy and sustainability policies in the Gulf states, in: Held, D., Ulrichsen, K. (Eds.), The Transformation of the Gulf: Politics, Economics and the Global Order. Routledge, New York

Hong Kong Government, 1957. Hong Kong Annual Report, Colonial reports. H.M. Stationery Office

Huat, C.B., 2011. Singapore as Model: Planning Innovations, Knowledge Experts, in: Roy, A., Ong, A. (Eds.), Worlding Cities: Asian Experiments and the Art of Being Global. Wiley-Blackwell, Oxford, UK, pp. 27–54. doi:10.1002/9781444346800.ch1

Intergovernmental Panel on Climate Change (IPCC), 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, United Kingdom and New York, USA NY

Interional Energy Agency (IEA), 2016. Key World Energy Statistics

International Energy Agency (IEA), 2017. Energy Statistics. https://www.iea.org/statistics/statisticssearch/

Jedwab, R., 2013. Urbanization without structural transformation: Evidence from consumption cities in Africa (Working Paper - George Washington University, Washington, DC. Processed). George Washington University, Washington D.C.

Jedwab, R., Vollrath, D., 2015. Urbanization without growth in historical perspective. Explor. Econ. Hist. 58, 1–21. doi:10.1016/j.eeh.2015.09.002

Kandt, J., 2011. Mapping Social Determinants, in: Hong Kong: Cities, Health and Well-Being. LSE Cities

Katiri, L.E., Fattouh, B., Segal, P., 2012. Anatomy of an oil-based welfare state: rent distribution in Kuwait, in: Held, D., Ulrichsen, K. (Eds.), The Transformation of the Gulf: Politics, Economics and the Global Order. Routledge, New York

Kenworthy, J.R., 2008. Energy Use and CO2 Production in the Urban Passenger Transport Systems of 84 International Cities: Findings and Policy Implications, in: Droege, P. (Ed.), Urban Energy Transition: From Fossil Fuels to Renewable Power. Elsevier, Oxford, UK

Kenworthy, J.R. (2003) Transport Energy Use and Greenhouse Gases in Urban Passenger Transport Systems: A Study of 84 Global Cities. In: International Sustainability Conference, 17 - 19 September, Fremantle, Western Australia. Presented at the International Sustainability Conference, Fremantle, Western Australia. http://Researchrepository.murdoch.edu.au/View/Author/Kenworthy, Jeffrey.html

Kostof, S., 1991. The City Shaped: Urban Patterns and Meanings Through History. Little, Brown and Company, New York

Krane, J., 2013. Stability versus Sustainability: Energy Policy in the Gulf Monarchies (EPRG Working Paper 1302)

Land Transport Authority (LTA), 2016. Annual Vehicle Statistics

Lands Department (LD), 2017. Reclamation Area (Since 1887). http://www.landsd.gov.hk/mapping/en/publications/reclamation.htm

Lawless, R.I., Seccombe, I.J., 1993. Impact of the Oil Industry on Urbanization in the Persian Gulf Region, in: Amirahmadi, H., Shakhs, S.S.E. (Eds.), Urban Development in the Muslim World. Center for Urban Policy Research, New Brunswick, New Jersey

Lazzarini, M., Marpu, P.R., Ghedira, H., 2013. Temperature-land cover interactions: The inversion of urban heat island phenomenon in desert city areas. Remote Sens. Environ. 130, 136–152. doi:10.1016/j.rse.2012.11.007

Lim, W.S.W., Motha, P., 1980. Land Policy in Singapore. Habitat Int. 4, 499–504

Logan, J.R., Molotch, H., 1987. Urban Fortunes: The Political Economy of Place. University of California Press, Berkeley and Los Angeles, California

Mass Transit Railway (MTR), 2017. Business Overview

Ministry of Energy (MOE), 2015a. UAE State of Energy Report

Ministry of Energy (MOE), 2015b. Fuel Prices to be Deregulated with effect from 1 August, 2015. https://www.moenr.gov.ae/en/media-centre/news.aspx

Ministry of the Environment and Water Resources (MEWR), Ministry of National Development (MND), 2014. Sustainable Singapore Blueprint 2015

Ministry of Trade and Industry (MTI), 2007. National Energy Policy Report - Energy for Growth

Minoprio, Spencely and F.W. Macfarlane, 1951. Plan for the Town of Kuwait: Report to His Highness Shaikh Abdullah Assalim Assubah, C.I.E., The Amir of Kuwait

Murshed, M.S., 2001. Short-Run Models of Contrasting Natural Resource Endowments, in: Auty, R.M. (Ed.), Resource Abundance and Economic Development. Oxford University Press, New York

Newman, P., Kenworthy, J.R., 2011. Evaluating the Transport Sector's Contribution to Greenhouse Gas Emissions and Energy Consumption, in: Salter, R., Dhar, S., Newman, P. (Eds.), Technologies for Climate Change Mitigation: Transport Sector, TNA Guidebook Series, UNEP & DTU. Magnum Custom Publishing, New Delhi, India

Organisation for Economic Co-operation and Development (OECD), 2012. Compact City Policies: A Comparative Assessment, Green Growth Studies. OECD

Organization of the Petroleum Exporting Countries (OPEC), 2017. Kuwait Facts and Figures. http://www.opec.org/opec_web/en/about_us/165.htm

Organization of the Petroleum Exporting Countries (OPEC), 2015. Annual Statistical Bulletin 2015

Oxford Business Group (OBG), 2013. The Report: Abu Dhabi 2013

Palasciuc, I., 2016. Striving for energy efficiency in the UAE

Phang, S.Y., 2007. The Singapore Model of Housing and the Welfare State, in: Groves, R., Murie, A., Watson, C.J. (Eds.), Housing and the New Welfare State: Perspectives from East Asia and Europe. Ashgate, Aldershot, pp. 15–44

Phang, S.Y., Kim, K., 2011. Singapore's Housing Policies: 1960-2013. Front. Dev. Policy Innov. Dev. Case Stud. 123–153

Pistor, K., Schutter, O.D. (Eds.), 2015. Governing Access to Essential Resources. Columbia University Press, New York

Planning Department (PD), 2016. Hong Kong 2030+: Our City, Zooming in Hong Kong. http://www.hk2030plus.hk/about_b.htm

Planning Department (PD), 2007. Hong Kong 2030, Towards a Planning Vision and Strategy Transcending 2030. Development Bureau and Planning Department

Pont, M.B., Haupt, P., 2005. The Spacemate - Density and the Typomorphology of the Urban Fabric. NA 18

Rappaport, J., Sachs, J.D., 2003. The United States as a Coastal Nation. J. Econ. Growth 8, 5–46. doi:10.1023/A:1022870216673

Ratti, C., Baker, N., Steemers, K., 2005. Energy consumption and urban texture. Energy Build. 37, 762–776. doi:10.1016/j.enbuild.2004.10.010

Rode, P., Keim, C., Robazza, G., Viejo, P., Schofield, J., 2014. Cities and Energy: Urban Morphology and Residential Heat-Energy Demand. Environ. Plan. B Plan. Des. 41, 138–162. doi:10.1068/b39065

Rode, P., Stern, N., Zenghelis, D., 2012. Electric City. Presented at the Urban Age Electric City Conference, LSE Cities, London, p. 5.

Rowe, P.G., 2005. East Asia Modern: Shaping the Contemporary City. Reaktion Books.

Shelton, B., Karakiewicz, J., Kvan, T., 2011. The Making of Hong Kong: From Vertical to Volumetric. Routledge.

Shiber, S.G., 1964. The Kuwait Urbanization - Being an Urbanistic Case-Study of a Developing Country - Documentation, Analysis, Critique. Kuwait Government Printing Press, Kuwait.

Singapore Land Authority (SLA), 2017. Utilisation Rate of State Land. Data.gov.sg. https://data.gov.sg/search?q=Utilisation+Rate+of+State+Land

Statistic Centre Abu Dhabi (SCAD), 2015. Statistical Yearbook of Abu Dhabi 2015

Statistics Centre Abu Dhabi (SCAD), 2016. Abu Dhabi Statistical Yearbook

Teoalida, 2017. Singapore HDB Statistics, facts & figures. http://www.teoalida.com/singapore/hdbstatistics/

The Global Commission on the Economy and Climate (GCEC), 2014. Better Growth, Better Climate: The New Climate Economy Report

Transport and Housing Bureau (THB), 2017. Public Transport Strategy Study Final Report

Transport Department (TD), 2015. Vehicle Licensing during 2005 - 2014, Annual Transport Digest 2015

Urban Redevelopment Authority (URA), 2013. A High Quality Environment for All Singaporeans: Land Use Plan to Support Singapore's Future Population

Urban Redevelopment Authority (URA), 2012. Designing Our City: Planning for a Sustainable Singapore

Urban Redevelopment Authority (URA), 2011. Concept Plan 2011 and MND's Land Use Plan

Urban Redevelopment Authority (URA), 1991. Concept Plan 1991: Living the Next Lap - Towards a Tropical City of Excellence

Vasconcellos, E.A. de, 2014. Urban Transport, Environment, and Equity: The Case for Developing Countries. Routledge

Wall, E., Waterman, T., 2009. Basics Landscape Architecture 01: Urban Design. AVA Publishing.

Walton, J., 1993. Urban Sociology: The Contribution and Limits of Political Economy. Annu. Rev. Sociol. 19, 301–320

Wickramasekara, P., 2016. South Asian Gulf migration to the Gulf: a safety valve or a development strategy? Migr. Dev. 5, 99–129

World Atlas, 2017. The World's Largest Oil Reserves By Country - WorldAtlas.com. http://www.worldatlas.com/articles/the-world-s-largest-oil-reserves-by-country.html

World Bank, 2017. GDP per capita (current US$) | Data. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=KW&view=chart

World Bank, 2014. Energy use (kg of oil equivalent per capita) | Data. https://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE

Zhang, X.Q., 2000. High-Rise and High-Density Compact Urban Form: The Development of Hong Kong, in: Jenks, M., Burgess, R. (Eds.), Compact Cities: Sustainable Urban Forms for Developing Countries. Taylor & Francis

Figure data sources

Data matrix: LSE Cities 2017, based on data from World Bank Open Data, International Energy Agency, World Health Organization, Institutional local data and LSE Cities analysis

Figure 1: LSE Cities 2017, based on data from LandScan TM 2010 High Resolution Global Population Data Set

Figure 3: LSE Cities 2017, based on data from DIVA GIS, EMISK Kuwait, UPC Abu Dhabi, Singstat Singapore and Censtatd Hong Kong

Exhibit A: LSE Cities 2017; 3D residential densities based on data from PACI and EMISK Kuwait, UPC and DOT Abu Dhabi, DASL and Singstat Singapore and Censtatd Hong Kong; Mode share based on data from Kuwait municipality, UITP, Singstat Singapore and Censtatd Hong Kong; Land availability and housing typology based on data from EarthExplorer Landsat Program, Google Maps, Open Street Maps, PACI and Emisk Kuwait, UPC Abu Dhabi, URA, DASL and Singstat Singapore and Censtatd Hong Kong

Figure 4 and 5: LSE Cities 2017, based on data from the World Bank Open Data and UN World Urbanization Prospects

Figure 2: LSE Cities 2017, based on data from EarthExplorer Landsat Program, Google Maps, DIVA GIS, UPC Abu Dhabi, EMISK Kuwait, Singstat Singapore and Censtatd Hong Kong

Figure 6: LSE Cities 2017, based on data from EarthExplorer Landsat Program and Google Maps

Figure 7: LSE Cities 2017, based on data from EarthExplorer Landsat Program, Google Maps, CSB and PACI Kuwait, SCAD Abu Dhabi, Singstat Singapore and Censtatd Hong Kong

Exhibit B: LSE Cities 2017, based on data from EarthExplorer Landsat Program, Google Maps, DIVA GIS, CSB, PACI and EMISK Kuwait, SCAD and UPC Abu Dhabi, Singstat Singapore and Censtatd Hong Kong and other supporting data

Exhibit C: LSE Cities 2017, based on EarthExplorer Landsat Program, Google Maps, Open Street Maps, DIVA GIS, EMISK Kuwait, DoT Abu Dhabi, LTA Singapore, TD Hong Kong and other supporting data

Exhibit D: LSE Cities 2017, based on data from EarthExplorer Landsat Program, Google Maps, DIVA GIS, EMISK Kuwait, UPC Abu Dhabi, Singstat Singapore and Censtatd Hong Kong

Figure 8: LSE Cities 2017; 3D densities based on data from PACI and EMISK Kuwait; Mode share based on data from Kuwait Municipality

Exhibit E: LSE Cities 2017, based on data from the World Bank Open Data, EarthExplorer Landsat Program, CSB, PACI and EMISK Kuwait, SCAD and UPC Abu Dhabi, Singstat Singapore and Censtatd Hong Kong and other supporting data

Figure 9 and 10: LSE Cities 2017, based on data from World Bank Open Data, EarthExplorer Landsat Program, Google Maps, CSB and PACI Kuwait, SCAD Abu Dhabi, Singstat Singapore and Censtatd Hong Kong

Figure 11: LSE Cities 2017, based on data from World Bank Open Data and Atlas of Urban Expansion Lincoln Institute

Figure 12: LSE Cities 2017, based on data from Google Earth, DIVA GIS, PACI and EMISK Kuwait, UPC Abu Dhabi, Singstat Singapore and Censtatd Hong Kong

Exhibit F and G and Figure 13: LSE Cities 2017, based on data from Google Maps, google street view, Bing maps, Open Street Maps, PACI and Baladia Kuwait, Geoportal Abu Dhabi, Street directory, HDB and URA Singapore, Emporis, Centadata and buildingmgt Hong Kong and other supporting data

Figure 14 to 19: LSE Cities 2017, based on data from EIFER

Exhibit H: LSE Cities 2017; 3D densities based on data from PACI and EMISK Kuwait, and Censtatd Hong Kong; Mix use ratio based on data from PACI and EMISK Kuwait and Censtatd Hong Kong.

Figure 20 to 33: LSE Cities 2017, based on data from Google Maps, Open Street Map, PACI and EMISK Kuwait and Censtatd Hong Kong and other supporting data

Endnotes

1. See Resource Urbanisms website for description of research challenges: https://lsecities.net/objects/research-projects/resource-urbanisms

2. Technical methodology papers on each of the components described here are available at https://lsecities.net/objects/research-projects/resource-urbanisms. Journal articles will also be forthcoming.

3. See Resource Urbanisms website for a detailed description of the process used to calculate urban living area: https://lsecities.net/objects/research-projects/resource-urbanisms

4. The percentage of the population living in low-density housing also includes domestic staff. In some instances, the number of people living in low-density housing may have been overestimated as the methodology used associated each block in the metropolitan area with its dominant typology, and was limited in its ability to disaggregate further.

5. National urban density is based on administrative boundaries and hence differs from actual built-up land densities.

6. World Atlas (2017). See: http://www.worldatlas.com/articles/the-world-s-largest-oil-reserves-by-country.html

7. A few plots were above 1,000

8. These were a combination of detached and semi-detached homes that were distributed within new neighbourhood units, as described by Shiber (1964, p.224).

9. The second master plan was finalised in 1970, the first revision of the master plan took place in 1977 and the second revision took place in 1983. In 1997, the third master plan was finalised and was revised in 2005.

10. Primarily in the shape of desalination plants. These desalination plants are powered by crude oil, heavy oil, gas oil and natural gas. For more details see: http://mew.gov.kw

11. The state owns approximately 90% of the total land area of Kuwait. See Herb (2014).

12. It is now known as the Public Authority for Housing Welfare.

13. The 1980s and 1990s, however, were a period of financial and political instability for Kuwait. The crash of the stock market, known as Al-Manakh Crisis, caused the government to bail out many citizens; followed by the Iraq–Iran war and a failed assassination of the Amir of Kuwait. In 1990, Kuwait was invaded by Iraq, resulting in further political turmoil and a slowing-down of development for the next decade, as it recovered from war. Only since the capture of Saddam Hussein in 2003 has confidence been on the rise.

14. According to Herb (2014), this is because the state plays a leading role in developing land. According to (Al-Nakib, 2016), land prices consistently increased in Kuwait after the discovery of oil due to speculation that the state's land acquisition encouraged. Changes in floor area ratios in the city centre also contributed to rising land values. It is important to note here that with few exceptions, non-Kuwaitis (excluding GCC nationals) do not have the right to own land in Kuwait. Foreign investors can only lease land in the Free Trade Zone, or through joint ventures with Kuwait companies or citizens (Herb, 2014).

15. In July 2017, the average global price of petrol was $1.02 whereas it was $0.34 in Kuwait. See: http://www.globalpetrolprices.com/gasoline_prices/

16. There are also strict restrictions that prevent non-Kuwaitis from holding drivers' licences, which contributes to this division. More specifically, Kuwaitis have to be physically fit, pass the driving test and be at least 18 years of age. Non-Kuwaitis have to comply with the following additional conditions: a) have a valid residency and have completed at least two years as a resident, b) have a minimum salary of 600KD (US$2000), c) be a college graduate. Some exceptions exist for certain professions.

17. As per Kuwait's Building Code 2009, the Public Authority for Housing Welfare (PAHW) in Kuwait provides citizens 400 m^2 plots, on which people are allowed to build three floors plus a basement.

18. In the first two years of his rule, Sheikh Zayed hired ARABICON to develop a town plan for Abu Dhabi. Under the supervision of an Egyptian planner, Abd al-Rahman Makhlouf, they were also required to review and modify the Halcrow plan (which had been finalised in 1962) (Elsheshtawy, 2008; Hashim, 2016).

19. The plan primarily modified the 1962 Halcrow Plan.

20. For private and industrial use.

21. John Elliott of ARABICON, which was a civil engineering firm hired to develop a plan for Abu Dhabi, and Egyptian planner Abdul Rahman Makhlouf, Abu Dhabi's Chief Town Planner until 1976.

22. Today the Khalifa Committee no longer exists and some of its functions have been transferred into a government agency called Department of Social Services & Commercial Buildings (DSSCB).

23. See also global fuel prices at: http://www.globalpetrolprices.com/gasoline_prices/

24. When Singapore achieved internal self-governing status under colonial rule.

25. Nearly 76% of the country's electricity is generated through piped natural gas (PNG) from Malaysia and Indonesia. See MTI (2007).

26. If a land owner had declared the value of the land for official purposes prior to the acquisition (to pay tax or duties), that value was taken as the market value. In addition, if an area had burnt down, the land-owner received 1/3rd of the compensation. See Lim and Motha (1980).

27. HDB public housing scheme was established in the year 1960. It is supported by a series of policy instruments such as the Central Pension Fund (CPF) and the Land Acquisition Act.

28. See: https://tradingeconomics.com/country-list/gasoline-prices?continent=asia

29. See: https://data.worldbank.org/indicator/EP.PMP.SGAS.CD

30. The service sector comprises 92.5% of GDP. Hong Kong's manufacturing output rose by 275% between 1960 and 1970. See: Dimitriou and Cook (1998, p. 42).

31. Numbers are based on a 2016 survey, and are used for comparison in this case.

32. Partially due to rapid industrial development: 'The accelerated rate of industrial development since the war was due in part to the arrival in the Colony of capital and skilled labour from the Chinese mainland. The population having increased so rapidly from 1945 and 1948, manufacturers had not only a large reservoir of efficient and willing labour to draw upon, but also a considerable local market for certain of their products. Many of the new industries which have grown up since the war have catered particularly for the large markets of South East Asia.' See Hong Kong Annual Report (1957), chapter on 'Production and Marketing'.

33. In a proclamation dated 7 April 1899, made just before taking over what were to be the New Territories, Governor Blake, of the British Colony of Hong Kong, announced: 'Within the leased area all fields, land, houses, graves, local customs and usages will remain unchanged, only if land is required for public offices, fortifications, or the like official purposes, it shall be bought at a fair price,' (Blake, 1900, p.280).

34. Severe water rationing with four hours of supply every four days (1963–64) led to a Second Agreement with Guangdong authorities for incremental water supplies from Guangdong, China (1965).

35. Under these reforms, government spending focused on housing infrastructure, new town development, public transport improvement and social services.

36. Many areas chosen were hilly sites or highlands that were unoccupied. Many of these sites were declared Crown Land and property in 1892 and served as water catchments for reservoirs, which had previously been protected under the Waterworks Ordinance, or as areas that were targets for post-war afforestation. Both types of land use became obsolete with the development of the port and better access to recourses.

37. Some of the most important tunnels include: Victoria to Kowloon Cross Harbour Tunnel 1972, Kowloon to Sha Tin Lion Rock 1974, Kowloon to Sha Tin twin tunnel, Aberdeen Tunnel 1982. See: Shelton et al. (2011).

38. 'According to a study conducted by the Land Transport Authority of Singapore in November 2014, public transport usage rate in Hong Kong was the highest of 27 major cities. For other major cities, the public transport usage rate was around 60% in Singapore, 70% in Seoul, 50% in Tokyo, 30% in London and New York,' (THB, 2017, p.1).

39. Hong Kong figures calculated based on data from TD (2015), Singapore figures calculated based on data from LTA (2016).

40. The Urban Heat Island effect suggests that cities are warmer than their surrounding areas, with certain exceptions.

41. 'One country, two systems' is a constitutional principle formulated by Deng Xiaoping for the reunification of China during the early 1980s.

42. Due to data constraints, it was not possible to capture boundary changes resulting from land reclamations.

43. To map dominant urban typologies across each of our case study cities, typologies were identified and analysed at the block level in Kuwait and Abu Dhabi, subzone level in Singapore and Tertiary Planning Unit (TPU) level in Hong Kong. Blocks, subzones or TPUs that were less than 25% occupied were excluded. Through this process, a list of the most traditional typologies was developed for each city, which included their spatial location and total area (km^2). Non-residential uses were mapped if they included housing accommodation for a large proportion of the population.

44. This was calculated by overlaying the dominant typologies in each city with the historical expansion of the ULA. It is important to note here that it was not possible to observe the replacement of different typologies over time as the methodology is based on remote sensing, which only captures horizontal expansion. This may limit the accuracy of the analysis, particularly in Hong Kong and Singapore's central areas.

45. Active modes such as walking and cycling were not considered in the survey that was used to collect this data, and therefore have not been presented in these graphics.

46. Note that some data was not available for that period.

47. Singapore's 2013 Land Use Plan states: 'In Singapore, travel needs must be met largely by public transport as it is the most space-efficient way of transporting large numbers of people. Our limited land supply also does not allow us to build ever more roads and other facilities for private transport in an unrestrained way. We aim to achieve a public transport mode share of 70% of journeys during the morning peak hours by 2020, and 75% by 2030, (p.41).

48. This was the dominant mode of planning adopted by western planners in the 1950s-1970s, and was also used by foreign consultants who designed Kuwait's master plans.

49. According to Rowe (2005), developers compete with each other to construct taller buildings, particularly when rents are high and property values are rising (pp.94–95).

50. According to Al-Mutairi et al. (2011), 'residential air conditioners consume 58.4% of the total electricity delivered by power plants at peak usage time on a hot summer day in Kuwait,' (p.863).

51. Residential contribution to total electricity consumption from IEA 2015 Stats. See: https://www.iea.org/statistics/statisticssearch/

52. Due to data constraints most of the typologies were drawn by hand. Hence there may be some differences in the granularity of each typology, which may have also affected the analysis and results.

53. See Resource Urbanisms website for technical paper on methods used: https://lsecities.net/objects/research-projects/resource-urbanisms

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www.eifer.org/

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