Chapter 3
Climate and Urbanization

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Abstract Urbanization is a major factor across Asia and the Pacific, and so the scope of this chapter is somewhat restricted. There is a focus on larger urban areas, as the small communities of rural areas are discussed in other chapters. The breadth of the topic of urbanization also means that reports by government agencies and NGOs (grey literature) are cited, as well as the formal academic literature. The six sections of the present Chapter systematically review literature in the field. In the first section we overview urbanization trends in the region. In the second section we review the history of urbanization in the region. The third section examines urbanization and climate in Asia and the Pacific. The fourth section describes the risks in urban areas due to climate change-related hazards. The fifth section overviews mitigation and adaptation measures in the region. The final section concludes with the needs for resilient cities and addresses uncertainties, research gaps and policy measures.

Future predictions suggest that large cities will not hold most of the region's total urban population. In 1990, cities of larger than one million held almost 35.1 % of the total urban population and by 2025 the UN predicts that cities of one million or more will hold 41.2 % of the total urban population. The share of those living in

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M.J. Manton and L.A. Stevenson (eds.), *Climate in Asia and the Pacific: Security, Society and Sustainability*, Advances in Global Change Research 56,
DOI 10.1007/978-94-007-7338-7_3,

mega-cities is expected to increase from 8.9 % of the total urban population to 12.8 % during the same period. While expectations are for an increase in share, there still remains 58.2 % of the urban population living in settlements smaller than one million. This fact is all the more impressive given the large population that is expected to move into cities in the region between 2010 and 2025 (over 549 million in 15 years, or over 36 million people a year).

Climate resilient cities are those that can withstand climate effects and not change dramatically. They include biophysical and socio-economic sub-systems that can withstand various climate impacts and continue to develop in a fairly predictable manner. Cities that are not resilient change dramatically to new states with new relationships emerging both within the socio-economic sub-system and between the socio-economic and biophysical sub-systems. Resilient cities are sustainable cities. Resilience can be achieved when urban areas move along a more sustainable pathway. The goal of policy makers and stakeholders for their individual urban centres, urban regions as well as nations in the face of climate change is to enhance resilience. In the present review of cities in the Asia-Pacific region, we identify some important aspects that impinge on this goal. Addressing uncertainties, research gaps and policy needs related to climate change and urbanization will help make cities in the region more resilient.

Keywords GHG emissions • Climate hazards • Mega-cities • Urbanization • Climate vulnerabilities

3.1 Introduction

The present chapter reviews literature on trends of urban development and their relationships between this development and climate at the local, regional and global levels in Asia and the Pacific. It includes an examination of the vulnerabilities of urban cities and its residents to climate-related hazards. We also briefly outline and sample urban mitigation and adaptation strategies currently being formulated or implemented.

Chapter 3 has six sections that systematically review literature in the field. In the first section we overview urbanization trends in the region. In the second section we review the history of urbanization in the region. The third section examines urbanization and climate in Asia and the Pacific. The fourth section describes the risks in urban areas due to climate change-related hazards. The fifth section overviews mitigation and adaptation measures in the region. The final section concludes with the needs for resilient cities and addresses uncertainties, research gaps and policy measures.

Urbanization is a major factor across Asia and the Pacific, and so the scope of this chapter must be somewhat restricted; for example, information on cities of small island developing states on the Pacific is covered elsewhere in the present volume. Moreover, there is a focus on larger urban areas, as the small communities of rural areas are discussed in other chapters. The breadth of the topic of urbanization also means that reports by government agencies and NGOs (grey literature) are cited, as well as the formal academic literature.

3.2 Urbanization Trends in Asia and the Pacific

The story of contemporary Asia and the Pacific urbanization is underpinned by the growing strength and complexity of globalization processes operating in the region. During the second half of the twentieth century, Japanese-led growth gave way to an increasing development of the international division of labour, trade, foreign direct investment (FDI) flows, and movements of people, information and resources into and between the four Tigers, the ASEAN-4, and most recently in China, India and Viet Nam. The "flying geese" model of development with Japan as the lead goose (Akamatsu 1962; Bernard and Ravenhill 1995; Hatch and Yamamura 1996; Kojima 2000) complemented by institutional and regulatory policies (Amsden 1989; Rowan 1998) that influence economic forces (Dicken 1992) set the context for changes that are now manifested across the region.

Given the strength and importance of regional urban integration processes operating across Asia and the Pacific, some have predicted convergence in form and function (Cohen 1996; Dick and Rimmer 1998; Hack 2000). This notion has not proven true as cities across the region continue diverging in important characteristics. For example, different transportation-related development trajectories have been identified for Asian cities. This is also true of the relationship between cities and climate. For example, current estimates of greenhouse gas (GHG) emissions from urban areas across the region suggest that they vary with population size, density, wealth and climate, implicating diversity in mitigation and adaptation strategies (Marcotullio et al. 2012). Diversity among uniqueness is an important aspect of urbanization within the region.

Another notable aspect of urbanization in the region is the emergence of mega-cities (populations over ten million). Much research has focused on these cities (Douglass 2000; McGee and Robinson 1995; Laquian 2005; Stubbs and Clarke 1996; UN-Habitat 2011a). The emphasis on these cities (Tokyo, Shanghai, Jabotabek, Manila, Bangkok, Jakarta, Mumbai, etc.) is understandable given their rise in number and economic importance.

Future predictions suggest that large cities, while increasing in importance, will not hold most of the region's total urban population. In 1990, cities of larger than one million held almost 35.1 % of the total urban population and by 2025 the UN predicts that cities of one million or more with hold 41.2 % of the total urban population. The share of those living in mega-cities is expected to increase from 8.9 % of the total urban population to 12.8 % during the same period. While expectations are for an increase in share, there still remains 58.2 % of the urban population living in settlements smaller than one million. This fact is all the more impressive given the large population that is expected to move into cities in the region between 2010 and 2025 (over 549 million in 15 years, or over 36 million people a year).

3.2.1 Contemporary History and Future Predictions

The trends in urbanization in Asia and the Pacific follow uneven growth over both time and space and, in the present section, we divide the history of urbanization into three eras: 1950–1990, 1990–2010 and 2010–2050.

3.2.1.1 1950–1990 Trends

The early post-War period finds much of the region largely rural, but urbanizing rapidly. This apparent contradiction was due to rapidly increasing rural and urban populations (Drakakis-Smith 1992). Underpinning this dynamic was a changing age structure of the population. During 1960–2007, the proportion of Asia's population in the 15–24 age bracket increased from 17 % in 1960 to 21 % in 1985, before beginning to decline (18 % in 2007) (UN-Habitat 2011a).

Besides the city-states and developed countries in Oceania, most nations had shares of urban populations of a third or less of the total populations (Table 3.1). The urban share for all of Asia increased from approximately 16 % in 1950 to 29.5 % in 1990. The economies that urbanized the most rapidly include the four Tigers of East Asia (Hong Kong, Singapore, Taiwan and Republic of Korea) and the Association of Southeast Asian Nations (ASEAN)-4 (Malaysia, Indonesia, Philippines and Thailand). For example, during this 40-year period, the Republic of Korea urbanization level increased from 21.4 % to 74 %.

Rapid urbanization led to dense settlements in the period 1950–1990. In the region the population increases ranged from 211 million to over 870 million, averaging 3.6 % per year. The four Tigers experienced an average growth rate of 4.6 % while ASEAN-4 urban population grew by 4.4 %. Other rapid urbanization in this period occurred in Mongolia, Bhutan, Bangladesh, Nepal, Lao People's Democratic Republic and some of the small island states in the Pacific, but these were related to population growth and not economic growth. The populous economies of South Asia also retained strong population growth, particularly in India and Pakistan, each growing by 3.2 % and 4.1 %, respectively (Table 3.2).

For many developing economies, the 1980s was an era of economic slow-down, particularly, as the world economy responded to a global recession. During the 1980s, urbanization in the region continued and, in fact, urban growth rates increased across much of the region. In some countries, such as India and the Philippines, growth slowed during the decade, but urbanization and urban growth continued.

During the 1980s, China began to enter a phase of rapid urban growth, particularly around coastal areas. At this time, Chinese national development policy prioritized the implementation of six special economic zones, which were later expanded to include another 14 cities all of which were along the eastern coast. This shift to a more open market-based policy changed the country. In South Asia, urban population growth was strong (2.4 % per year), but the sub-region remained largely rural. By 1990, most developing nations in the Asia-Pacific region were less than 30 % urban (Table 3.2).

Table 3.1 Asia and the Pacific urbanization levels, 1950–1990 (percent)

	1950	1970	1990	Absolute Percent Change (1950–1990)	Average Annual Percent Change (1950–1990)
World	**28.83**	**36.08**	**42.62**	**13.78**	**0.981**
Asia and the Pacific	**15.99**	**21.58**	**29.47**	**13.48**	**1.540**
Eastern Asia	**15.51**	**22.88**	**32.21**	**16.70**	**1.843**
China	11.80	17.40	26.44	14.64	2.037
China, Hong Kong SAR	85.20	87.73	99.52	14.32	0.389
China, Macao SAR	96.89	97.03	99.76	2.87	0.073
Dem. People's Republic of Korea	31.00	54.20	58.38	27.38	1.595
Japan	34.85	53.20	63.09	28.24	1.495
Mongolia	20.00	45.05	57.03	37.03	2.654
Republic of Korea	21.35	40.70	73.84	52.49	3.150
Taiwan[a]	–	60.19	75.76	15.57	1.545
Southern Asia	15.94	18.88	25.14	6.26	1.929
Bangladesh	4.28	7.59	19.81	15.53	3.904
Bhutan	2.10	6.09	16.39	14.29	5.271
India	17.04	19.76	25.55	8.51	1.017
Maldives	10.61	11.89	25.84	15.23	2.250
Nepal	2.68	3.96	8.85	6.18	3.036
Pakistan	17.52	24.82	30.58	13.06	1.402
Sri Lanka	15.33	21.89	18.61	3.28	0.486
South-Eastern Asia	**15.48**	**21.50**	**31.62**	**16.14**	**1.802**
Brunei Darussalam	26.76	61.68	65.83	39.08	2.276
Cambodia	10.20	15.97	12.60	2.40	0.530
Indonesia	12.40	17.07	30.58	18.18	2.283
Lao People's Democratic Republic	7.24	9.63	15.44	8.20	1.911
Malaysia	20.36	33.45	49.79	29.43	2.261
Myanmar	16.16	22.83	24.71	8.55	1.068
Philippines	27.14	32.98	48.59	21.46	1.467
Singapore	99.45	100.00	100.00	0.56	0.014
Thailand	16.48	20.89	29.42	12.95	1.460
Timor-Leste	9.89	12.89	20.84	10.95	1.881
Viet Nam	11.64	18.30	20.26	8.61	1.394
Oceania	**62.00**	**70.80**	**70.70**	**8.70**	**0.329**
Australia/New Zealand	**76.16**	**84.51**	**85.29**	**9.13**	**0.284**
Australia	77.00	85.27	85.40	8.40	0.259
New Zealand	72.52	81.11	84.74	12.22	0.390
Melanesia	**5.44**	**14.88**	**19.92**	**14.48**	**3.299**
Fiji	24.35	34.76	41.61	17.26	1.348
New Caledonia	24.59	51.23	59.54	34.95	2.235
Papua New Guinea	1.70	9.80	14.99	13.29	5.593
Solomon Islands	3.80	8.92	13.68	9.88	3.254
Vanuatu	8.75	12.33	18.72	9.96	1.918

(continued)

Table 3.1 (continued)

	1950	1970	1990	Absolute Percent Change (1950–1990)	Average Annual Percent Change (1950–1990)
Micronesia	**31.62**	**46.28**	**62.60**	**30.98**	**1.722**
Guam	41.30	61.92	90.80	49.50	1.989
Kiribati	11.00	24.09	34.99	23.99	2.935
Marshall Islands	23.34	53.49	65.05	41.72	2.596
Micronesia (Fed. States of)	20.00	24.81	25.82	5.82	0.640
Nauru	100.00	100.00	100.00	–	0.000
Northern Mariana Islands	42.00	70.06	89.73	47.73	1.916
Palau	53.88	59.72	69.59	15.71	0.642
Polynesia	**23.24**	**33.89**	**40.07**	**16.83**	**1.372**
American Samoa	61.77	70.38	80.95	19.18	0.678
Cook Islands	38.03	53.29	57.72	19.69	1.048
French Polynesia	34.09	55.25	55.86	21.78	1.243
Niue	21.50	21.10	30.90	9.40	0.910
Pitcairn	–	–	–	–	–
Samoa	12.89	20.35	21.20	8.31	1.252
Tokelau	–	–	–	–	–
Tonga	12.89	20.19	22.70	9.82	1.426
Tuvalu	11.19	22.08	40.66	29.47	3.278
Wallis and Futuna Islands	–	–	–	–	–

Source: Data from UN DESA 2009 World Urbanization Prospects: The 2009 Revision, File 2 Percentage of Population Residing in Urban Areas by Major Area, Region and Country, 1950–2050, POP/DB/WUP/Rev.2009/1/F2

[a]Taiwan: CEPD, 1975–2011, Urban and Regional Development Statistics, Taiwan, 1970 data are for 1975

One striking feature of Asian urbanization is the concentration of the urban population in large cities, in particular, mega-cities. In 1950, there was one mega-city in Asia (Tokyo), compared to five mega-cities in 1990 (Tokyo, Mumbai, Osaka-Kobe, Kolkata and Seoul) in the region (Table 3.2). Moreover, during this period, the share of the urban population residing in cities of over one million increased from 27.3 % to 35.1 %. The number of those living in mega-cities increased from 11.2 million to 77.3 million. By 1990, 8.9 % of the total urban population resided in mega-cities.

3.2.1.2 1990–2010 Trends

During the first half of this era, economic expansion and urbanization continued. Rapid and prolonged wealth creation for nations prompted some to call Asian development a “miracle” (World Bank 1993). Economic indicators alone, however, did not capture the social transformations experienced in the region. It was

Table 3.2 Asia and the Pacific distribution of urban population and urban agglomeration by size, 1950–1990 (population in thousands)

Asia and the Pacific distribution of urban population and urban agglomeration by size, 1950–1990 (population in thousands)

Urban agglomeration size	1950	1970	1990	Percent Total 1990	Absolute Change (1950–1990)	Percent Total Change (1950–1990)
Ten million and larger						
Number	1	1	5	5.2	4	5.7
Population	11,275	23,298	77,306	8.9	66,032	10.0
Five million to less than ten million						
Number	0	5	10	10.3	10	14.3
Population	0	33,493	71,156	8.2	71,156	10.8
One million to less than five million						
Number	26	43	82	84.5	56	80.0
Population	46,453	87,954	157,827	18.1	111,374	16.9
Less than one million						
Population	153,711	285,479	565,900	64.9	412,189	62.4
Total number urban agglomeration over one million	27	49	97		70	
Total urban population	211,439	430,224	872,189		660,750	

Source: Data from World Urbanization Prospects: The 2009 Revision, File 12
Population of Urban Agglomerations with 750,000 Inhabitants or More in 2009, by Country, 1950–2025, POP/DB/WUP/Rev.2009/2/F12

not only wealth that increased, but also the quality of life dramatically improved with reductions in poverty levels, longer life expectancy, reductions in birth mortality, increases in access to basic services and greater literacy (Deolalikar et al. 2002; UN-Habitat 2011a).

During the later 1990s, as economic development spread to more locations, global patterns shifted and the numbers of those in poverty dropped worldwide. The world total number of those in poverty (less than US$ 1 a day) decreased from 1.248 billion in 1990 to 969 million in 2004. Asia and the Pacific's share of the global poor, however, shrunk faster than that for the world. In 1990, there were approximately 955.4 million in poverty throughout the region accounting for 77 % of the global poverty. By 2004, this number shrank to 615.3 million, which accounted for 64 % of the total. Most of those escaping poverty were from East and Southeast Asia, but numbers in South Asia also decreased. Moreover, Asia and the Pacific's share of the ultra-poor (living on less than US$0.5 a day) dropped even more dramatically. In 1990, of the 1.248 billion that were poor, 193 million were ultra-poor. During this year Asia and the Pacific housed 93.4 million (48 % of the world's ultra-poor population). By 2005, the number of ultra-poor throughout the world dropped to 162 million. In the Asia-Pacific region, however, the number dropped to 28.5 million, i.e. 17 % of the world's ultra-poor (Ahmed et al. 2007). One of the main features of Asia's success was the social transformation and poverty reduction that accompanied the region's rapid economic growth and urbanization (Deolalikar et al. 2002; UN-Habitat 2011c).

During this period, the region has undergone rapid demographic transition. The United Nations Development Programme's (UNDP) "human development index" trends confirmed that there have been significant social and economic advances over the last three to four decades. While these figures portray the aggregate human development experienced in some countries within the region, there is great diversity in, among and within nations. Initial conditions, before rapid growth, may be primarily responsible for the more egalitarian experience of Northeast Asia, and there is less clear evidence that growth has been directed to more equitable income distributions elsewhere (Jomo 1998).

From late 1997 and most of 1998, several countries in Asia suffered severe economic contractions and the region as a whole suffered dwarfing what was experienced in the 1980s. The speed and intensity with which the crisis mounted within country after country surprised the world. Some commented that during this period, globalization took a step backwards (Asian Development Bank 1999). However, at the end of 1998, the crises were contained in most countries.

The reprieve of rapid growth facilitated the examination of its costs. The crisis itself intensified and re-focused attention on social tensions (Daniere 1996; Schmidt 1998). Concerns also emerged over environmental conditions including pollution levels that have increased faster than GDP even during the most rapid growth periods (Asian Development Bank 1997; Dua and Esty 1997; Brandon 1994; Setchell 1995). These trends facilitated a questioning of the future viability of globalization-driven growth strategies. By the end of the era, sustainable urban development, pro-poor growth and green buildings, economies and cities had become buzzwords.

Over the 20 years between 1990 and 2010, the urban residential population in Asia and the Pacific expanded by 670 million growing from 872 million to 1.54 billion people compared to the pervious era's increase of 449 million over 40 years (Table 3.3). Asian urbanization continued to include the growth of large cities. During this era large cities become the predominant form of urbanization throughout the region. The number of mega-cities increased from five to ten, including Tokyo, Delhi, Mumbai, Shanghai, Kolkata, Dhaka, Karachi, Beijing, Manila and Osaka-Kobe. Moreover the share of the urban population living in cities over one million increased from 35.1 % to 40.6 %. The population in mega-cities reached approximately 174 million or 11.3 % of the total dwellers in urban areas.

At the end of this era, there remained places with low urbanization levels; Sri Lanka, Bangladesh, Bhutan, Nepal, Papua New Guinea and some of the Small Island States. Most economies, however, reached levels of 30 % or more.

Table 3.3 Asia and the Pacific urbanization levels, 1990–2010 (percent)

Major area, region, economy	1990	2000	2010	Absolute Percent Change (1990–2010)	Average Annual Percent Change (1990–2010)
World	**42.62**	**46.40**	**50.46**	**7.85**	**0.849**
Asia and the Pacific	**29.47**	**34.81**	**40.56**	**11.09**	**1.610**
East Asia	**32.21**	**40.39**	**50.17**	**17.96**	**2.241**
China	26.44	35.76	46.96	20.51	2.913
China, Hong Kong SAR	99.52	100.00	100.00	0.48	0.024
China, Macao SAR	99.76	100.00	100.00	0.24	0.012
Dem. People's Republic of Korea	58.38	59.41	60.22	1.83	0.155
Japan	63.09	65.22	66.83	3.74	0.288
Mongolia	57.03	56.86	62.03	4.99	0.420
Republic of Korea	73.84	79.62	82.96	9.11	0.584
Taiwan	75.76	77.71	79.80	4.04	0.260
South Asia	**21.54**		**30.38**		
Bangladesh	19.81	23.59	28.07	8.26	1.757
Bhutan	16.39	25.42	34.71	18.32	3.823
India	25.55	27.67	30.01	4.46	0.808
Maldives	25.84	27.71	40.10	14.26	2.222
Nepal	8.85	13.43	18.62	9.77	3.787
Pakistan	30.58	33.14	35.90	5.32	0.805
Sri Lanka	18.61	15.83	14.31	–4.30	–1.304
Southeast Asia	**31.62**	**38.16**	**41.84**	**10.22**	**1.410**
Brunei Darussalam	65.83	71.15	75.65	9.82	0.698
Cambodia	12.60	16.91	20.11	7.51	2.365
Indonesia	30.58	42.00	44.28	13.70	1.868
Lao People's Democratic Republic	15.44	21.98	33.18	17.75	3.901
Malaysia	49.79	61.98	72.17	22.38	1.873
Myanmar	24.71	27.80	33.65	8.94	1.556
Philippines	48.59	47.99	48.90	0.31	0.032
Singapore	100.00	100.00	100.00	–	0.000
Thailand	29.42	31.14	33.96	4.54	0.720
Timor-Leste	20.84	24.26	28.12	7.28	1.509
Viet Nam	20.26	24.49	30.38	10.12	2.047
Oceania	**70.70**	**70.39**	**70.22**	**–0.48**	**–0.034**
Australia/New Zealand	**85.29**	**86.91**	**88.62**	**3.33**	**0.192**
Australia	85.40	87.17	89.11	3.71	0.213
New Zealand	84.74	85.68	86.20	1.46	0.085
Melanesia	**19.92**	**18.96**	**18.38**	**–1.53**	**–0.400**
Fiji	41.61	47.91	51.86	10.25	1.107
New Caledonia	59.54	59.20	57.36	–2.18	–0.186
Papua New Guinea	14.99	13.20	12.53	–2.47	–0.895
Solomon Islands	13.68	15.71	18.55	4.87	1.536
Vanuatu	18.72	21.70	25.56	6.85	1.571

(continued)

Table 3.3 (continued)

Major area, region, economy	1990	2000	2010	Absolute Percent Change (1990–2010)	Average Annual Percent Change (1990–2010)
Micronesia	**62.60**	**65.60**	**68.06**	**5.46**	**0.419**
Guam	90.80	93.10	93.17	2.37	0.129
Kiribati	34.99	42.96	43.90	8.91	1.141
Marshall Islands	65.05	68.36	71.76	6.71	0.492
Micronesia (Fed. States of)	25.82	22.33	22.66	–3.16	–0.650
Nauru	100.00	100.00	100.00	–	0.000
Northern Mariana Islands	89.73	90.16	91.34	1.61	0.089
Palau	69.59	69.96	83.39	13.79	0.908
Polynesia	**40.07**	**41.16**	**42.40**	**2.33**	**0.283**
American Samoa	80.95	88.77	92.97	12.03	0.695
Cook Islands	57.72	65.19	75.31	17.59	1.339
French Polynesia	55.86	52.38	51.44	–4.42	–0.411
Niue	30.90	33.07	37.54	6.65	0.979
Pitcairn	–	–	–	–	–
Samoa	21.20	21.98	20.23	–0.97	–0.234
Tokelau	–	–	–	–	–
Tonga	22.70	23.01	23.43	0.72	0.157
Tuvalu	40.66	46.02	50.39	9.73	1.079
Wallis and Futuna Islands	–	–	–	–	–

Source: Data from UN DESA 2009 World Urbanization Prospects: The 2009 Revision, File 2 Percentage of Population Residing in Urban Areas by Major Area, Region and Country, 1950–2050, POP/DB/WUP/Rev.2009/1/F2

3.2.1.3 2010–2050 and Beyond

In the future we expect globalization-driven growth to continue as the region's urbanization and urban population growth rates continue to decrease, but we also expect a doubling of the already large urban population size. The urban share for Asia will grow from 42.2 % in 2010 to 64.6 % in 2050 (Table 3.4). During this period, the Asia-Pacific urban population will grow from 1.54 billion to 2.9 billion people (reference from table). By 2050, urban populations in India, Pakistan and Bangladesh combined (1.2 billion) will become 15 % larger than that of China (1.03 billion).

We will see almost all nations in the region reaching urbanization levels of over 50 % with the average for the region at 64.9 %. The most urbanized regions are expected to be in East Asia (over 74 %), Australia and New Zealand (over 93 %) and Micronesia (over 80 %). South Asia is predicted to reach an urbanized level of more than 55 % and for Southeast Asia more than 65 % will live in dense settlements.

The growth of large cities is expected to continue, although the percentage of populations living in these cities is expected to decrease. From 2010 to 2025, the number

Table 3.4 Asia and the Pacific urbanization levels, 2010–2050 (percent)

Major area, region, economy	2010	2030	2050	Absolute Percent Change (2010–2050)	Average Annual Percent Change (2010–2050)
World	**50.46**	**58.97**	**68.70**	**18.24**	**0.774**
Asia and the Pacific	**40.56**	**52.02**	**64.93**	**24.37**	**1.183**
East Asia	**50.17**	**63.73**	**74.34**	**24.16**	**0.988**
China	46.96	61.91	73.23	26.28	1.117
China, Hong Kong SAR	100.00	100.00	100.00	–	0.000
China, Macao SAR	100.00	100.00	100.00	–	0.000
Dem. People's Republic of Korea	60.22	65.74	74.53	14.32	0.535
Japan	66.83	72.98	80.08	13.24	0.453
Mongolia	62.03	71.56	79.53	17.50	0.623
Republic of Korea	82.96	87.67	90.83	7.88	0.227
Taiwan	–	–	–	–	–
South Asia	**30.38**	**40.55**	**55.14**	**24.75**	**1.501**
Bangladesh	28.07	41.04	56.41	28.34	1.760
Bhutan	34.71	49.97	64.17	29.46	1.548
India	30.01	39.75	54.23	24.22	1.490
Maldives	40.10	60.06	73.12	33.01	1.513
Nepal	18.62	31.74	47.56	28.94	2.372
Pakistan	35.90	45.62	59.37	23.48	1.266
Sri Lanka	14.31	19.55	31.34	17.03	1.979
Southeast Asia	**41.84**	**52.85**	**65.44**	**23.59**	**1.124**
Brunei Darussalam	75.65	82.33	87.21	11.56	0.356
Cambodia	20.11	29.20	43.83	23.72	1.967
Indonesia	44.28	53.70	65.95	21.67	1.001
Lao People's Democratic Republic	33.18	53.07	68.03	34.85	1.811
Malaysia	72.17	82.21	87.85	15.68	0.493
Myanmar	33.65	48.09	62.87	29.22	1.575
Philippines	48.90	58.33	69.36	20.46	0.877
Singapore	100.00	100.00	100.00	–	0.000
Thailand	33.96	45.77	59.96	25.99	1.431
Timor-Leste	28.12	39.89	54.92	26.80	1.687
Viet Nam	30.38	44.18	58.99	28.61	1.673
Oceania	**70.22**	**71.38**	**74.81**	**4.58**	**0.158**
Australia/New Zealand	**88.62**	**91.25**	**93.37**	**4.75**	**0.131**
Australia	89.11	91.86	93.84	4.73	0.129
New Zealand	86.20	88.14	90.88	4.68	0.132
Melanesia	**18.38**	**23.81**	**34.87**	**16.49**	**1.613**
Fiji	51.86	61.66	72.20	20.34	0.831
New Caledonia	57.36	62.68	71.95	14.59	0.568
Papua New Guinea	12.53	18.18	29.75	17.23	2.186
Solomon Islands	18.55	29.20	44.31	25.76	2.200
Vanuatu	25.56	38.01	53.48	27.92	1.863

(continued)

Table 3.4 (continued)

Major area, region, economy	2010	2030	2050	Absolute Percent Change (2010–2050)	Average Annual Percent Change (2010–2050)
Micronesia	**68.06**	**73.27**	**80.03**	**11.97**	**0.406**
Guam	93.17	94.20	95.45	2.28	0.061
Kiribati	43.90	51.66	63.91	20.01	0.943
Marshall Islands	71.76	78.77	84.62	12.86	0.413
Micronesia (Fed. States of)	22.66	30.27	44.43	21.77	1.697
Nauru	100.00	100.00	100.00	–	0.000
Northern Mariana Islands	91.34	93.33	94.89	3.55	0.095
Palau	83.39	92.01	94.49	11.11	0.313
Polynesia	**42.40**	**48.82**	**59.90**	**17.49**	**0.867**
American Samoa	92.97	95.62	96.81	3.83	0.101
Cook Islands	75.31	84.94	89.32	14.02	0.428
French Polynesia	51.44	56.62	67.42	15.98	0.678
Niue	37.54	49.43	63.06	25.52	1.305
Pitcairn	–	–	–	–	–
Samoa	20.23	23.96	36.64	16.41	1.496
Tokelau	–	–	–	–	–
Tonga	23.43	30.40	44.50	21.07	1.617
Tuvalu	50.39	61.48	72.45	22.05	0.912
Wallis and Futuna Islands	–	–	–	–	–

Source: Data from UN DESA 2009 World Urbanization Prospects: The 2009 Revision, File 2 Percentage of Population Residing in Urban Areas by Major Area, Region and Country, 1950–2050, POP/DB/WUP/Rev.2009/1/F2
There are no predictions for urban population increases for these periods

of mega-cities will increase to 15 (Table 3.5), however, the share of the total urban population living in large cities will increase only slightly from 40.6 % to 41.2 %. By 2025, approximately 58.8 % of the region's urban population will live in cities of less than one million. Approximately 12.8 % of the total urban population will live in mega-cities. This trend is important as currently much research and policy attention is devoted to the larger cities, but those that are less than one million will be the locations where the lion's share of the Asia-Pacific urban population is predicted to live.

3.3 Urbanization and Climate in Asia and the Pacific

The growth of cities in Asia and the Pacific has implications for land and energy use, and climate. Generally, the trends include greater urban land usage, more energy and changes in local and region climates. While these are negative trends as measured against a sustainable trajectory, final conclusions must include two

Table 3.5 Asia and the Pacific distribution of urban population and urban agglomeration by size, 2010–2025 (population in thousands)

Urban agglomeration size	2010	2020	2025	Percent Total 2025	Absolute Change (2010–2025)	Percent Total Change (2010–2025)
Ten million and larger						
Number	10	14	15	5.9	5	7.9
Population	174,117	241,151	266,889	12.8	92,772	16.9
Larger than five million and less than ten million						
Number	18	22	22	8.7	4	6.3
Population	131,930	156,950	163,402	7.8	31,472	5.7
Larger than one million and less than five million						
Number	163	210	217	85.4	54	85.7
Population	320,134	432,193	432,193	20.7	112,059	20.4
Less than one million						
Population	916,154	1,072,254	1,229,178	58.8	313,024	57.0
Total number urban agglomeration over one million	191	246	254		63	
Total urban population	1,542,335	1,902,548	2,091,662		549,327	

Source: Data from World Urbanization Prospects: The 2009 Revision, File 12
Population of Urban Agglomerations with 750,000 Inhabitants or More in 2009, by Country, 1950–2025, POP/DB/WUP/Rev.2009/2/F12

qualifications. First, the trends we present would potentially be worse if the populations were not concentrated in dense settlements. That is, land use change would be more dramatic, energy use higher and contributions to global climate change more spectacular if the same populations were spread out evenly over the landscape. Second, the trends observed need not necessarily continue. Given more sensitive urban design and other mitigation measures, evidence suggests that the climate impacts of urban living can be lowered.

3.3.1 Urbanization and Land and Energy Use

According to a recent estimate the combined trends of increasing populations in dense settlements along with decreasing densities indicates that the developing world will triple the urban land taken by cities with more than 100,000 by 2030 (Angel et al. 2005). Of these, urban land use changes in China and India are growing at the fastest rates (Seto et al. 2011).

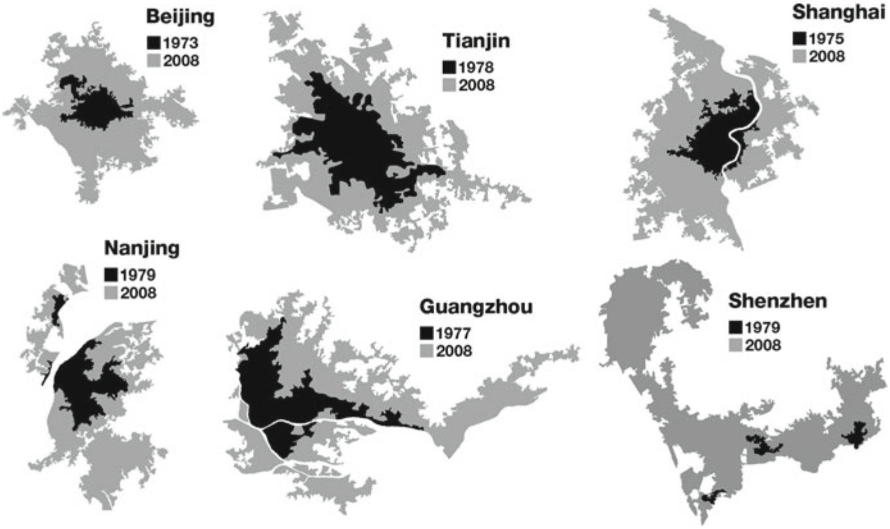

Fig. 3.1 Examples of growth in Chinese cities, 1970s–2008 (Source: Zhang et al. 2012)

Examples of rapidly expanding individual urban areas have been identified in China. Between 1973 and 2008, the average increase in urban land in a sample of 60 cities (4 municipalities, 28 provincial capitals, 2 special administrative regions and 26 other well-known cities) throughout the country was approximately 2.5 times (Wen 2010). Some cities (such as Shenzhen & Houkou) underwent spectacular growth multiplying their land area by more than a factor of 20. From the 1980s to 2005, the urban lands of Beijing-Tianjin-Tangshan Region, Yangtze River Delta City Region and the Pearl River Delta City Region grew by factors of 1.15, 1.04 and 2.63, respectively (Liu 2011) (Fig. 3.1).

The development of land use and building changes has accompanied increases in energy consumption. To meet this need, total energy production in Asia increased by 125 % from 1971 to 1990 and by 90 % from 1990 to 2007. These increases were higher than any other region. Energy production has been largely driven by growth in China, which was approximately 125 % and 105 % during the above periods, respectively. By 2007, China was producing 1.8 billion tonnes oil equivalent, while the rest of Asia was producing 1.2 billion tonnes oil equivalent (OECD 2010). Moreover, energy production in China exceeded that of the Middle East and the Former Soviet Union.

Much of this energy is related to urbanization. As cities grow in size and complexity the energy demands to keep them running smoothly increase. Many large cities appropriate energy in the form of electricity. The growth of urban Asia and the Pacific accompanied growth in electricity consumption. In 2009, Asia included two of the four highest non-OECD consumers of electricity; China and India. Among these four nations, China held the largest share of electricity consumption at 39.4 %. This share reflects rapid increases in electricity provisioning in the country. Between

1973 and 2009, electricity consumption in China increased at an average annual growth rate of 9 % (IEA 2011). Most electricity consumption, particularly in developing countries, occurs in cities. For example, in India, the country's urban residents consume 87 % of the nation's electricity (Sawin and Hughes 2007).

Moreover, urban areas also facilitate the use of motor vehicles. Vehicle usage has increased dramatically in Asia, but not equally amongst nations. East, South and Southeast Asia's share of global automobiles on the road increased from 12.7 % in 1985 to 21.8 % in 2009 (an increase from 62.1 to 210.4 billion vehicles). Car ownership rates in China have been growing at 12 % per annum and in India at 9 % per annum; and include two- and three-wheeled vehicles. Asia produces 95 % of global two- and three-wheeled vehicles, which constitutes 75 % of the world's stocks and China is the fastest growing market for these vehicles (World Energy Council 2011).

Transportation fuel consumption patterns over time suggest that different Asian nations are following distinctive paths (Barter 1999) with Hong Kong, Singapore and Japan on a low consumption path, Republic of Korea and Taiwan at the intermediate level, and Thailand and Malaysia following a more Western, high transport fuel consumption, trajectory (Marcotullio and Marshall 2007).

The largest and most recent industrializing nations to embrace the automobile may follow the high transport fuel consumption trend. From 2005 to 2009, India increased the number of cars on the road by 25 % and the number of motor vehicles in China doubled. In 2009, car sales in China exceeded those in the USA (Ward's 2010). Some estimates suggest that by 2040, future automobile consumption in India and China alone will double the total number of vehicles currently on the road, i.e., adding an additional 800 million automobiles to the global car population (The Economist 2006; Wilson et al. 2004).

3.3.2 Urban Climate

Changes in land to urban uses and increases in energy demand help to change local climate. Atmospheric scientists, such as Landsberg (1981), observed that urban climatic conditions include lower radiation, more cloudiness, higher precipitation, higher temperatures and more particulates, gaseous admixtures and other contaminants than non-urban climates. These characteristics arguably make urban climates unique. Three important characteristics of urban climates include the emergence of urban heat islands, changes in precipitation and changes in ambient air quality. Examples of these specific urban climates are evident in the Asia and the Pacific region.

3.3.2.1 Urban Heat Island

Inhabitants of urban areas are subject to climatic conditions that represent a significant modification of the pre-urban climatic state including the well-known urban heat island (UHI) phenomenon (Oke 1973), arising from the modification of radiation, energy and momentum exchanges resulting from the built form of the city, together with the emission of heat, moisture and pollutants from human activities. Urban temperatures are typically 3–4 °C higher than surrounding areas due to UHI (Oke 1997), but can be as high as 11 °C warmer in urban "hotspots" (Aniello et al. 1995). Dark surfaces such as asphalt roads or rooftops, however, can reach temperatures 30–40 °C higher than surrounding air (Frumkin 2002). The UHI effect is one of the major problems of the twenty-first century (for a review see McKendry 2003; Landsberg 1981; Rizwan et al. 2008).

The UHI phenomenon has been studied in many places in the Asia-Pacific region; for example, Osaka and Bangkok (Taniguchi et al. 2009), Nanjing (Zeng et al. 2009), Shanghai (Tan et al. 2010) and Beijing and Wuhan (Ren et al. 2007). For the purpose of estimating the effect of urban warming over the past 100 years, Seoul, Tokyo, Osaka, Taipei, Manila, Bangkok, and Jakarta were selected as target cities. UHI was calculated by subtracting the temperature data of the four grids around the city from the observational temperature data in the city. In doing so, all urban areas demonstrated an increasing UHI effect with Osaka demonstrating the largest increase from approximately 2.4 °C in 1901 to almost 3 °C after 1981. The increases in Seoul, Tokyo, and Taipei were approximately between 1 °C and 2 °C. Jakarta and Bangkok exhibited smaller increases and Manila and Bangkok experienced rapid increases after 1961 (Kataoka et al. 2009). The point stressed here is that not only does the UHI effect exist but it is increasing in cities across the region.

UHI effects have not been identified as contributing to global warming (Parker 2004; Peterson 2003; Alcoforado and Andrade 2008). These and other studies indicate that effects of urbanization and land use change on land-based temperature records are negligible (0.006 °C per decade) as far as hemispheric- and continental-scale averages are concerned (Trenberth et al. 2007). At the same time, as cities increase in size and number, the UHI effect may play a role in regional climate (Kaufmann et al. 2007).

A further study presented evidence for a significant urbanization effect on the regional climate in southeast China. In this case, the region experienced rapid urbanization and estimates suggest a warming of mean surface temperature of 0.05 °C per decade. The spatial pattern and magnitude of estimates are consistent with those of urbanization characterized by changes in the percentage of urban population and in satellite-measured greenness (Zhou et al. 2004).

Another study examined the trends of urban heat island effects in east China and finds a significant influence of urbanization on surface warming over the region. Overall, UHI effects contribute 24.2 % to regional average warming trends (Yang et al. 2011). These results are consistent with a recent 50 year study that found most temperature time series in China affected by UHI (Li et al. 2004). Evidence, although only recently emerging, suggests that UHI in the region contributes to regional climate change.

3.3.2.2 Changes in Precipitation

Urbanization affects humidity, clouds, storms and precipitation. Studies have described shifts in precipitation patterns in and around cities compared to less densely populated areas (for a review see Souch and Grimmond 2006; Shepherd 2005). The exact mechanisms by which these urban precipitation patterns emerge are poorly understood (Lowry 1998). Unique aspects of urban areas that might affect precipitation levels include high surface roughness that enhances convergence; UHI effects on boundary layers and the resulting downstream generation of convective clouds; generation of high levels of aerosols that act as cloud condensation nuclei sources; and urban canopy creation and maintenance processes that affect precipitation systems.

No matter what the mechanism, urban areas are seen as cloudier and wetter, with heavier and more frequent precipitation within metropolitan areas than those outside, but within the same region (Lei 2011; Changnon 1979). Average increases of 28 % in monthly rainfall rates have been identified within 30–60 km downwind of cities (Shephard et al. 2002).

While most studies on urban precipitation have focused on the USA and Europe, several analyses have been conducted in Asia and the Pacific. Meng et al. (2007) identified increased strength in thunderstorms associated with tropical cyclones as they moved over Guanghzhou City, China. Inamura et al. (2011) simulated the effects of Tokyo on heavy rainfall indicating precipitation increases. These studies have confirmed trends found in other locations. On the other hand, researchers have also found anomalies in regional urban rainfall patterns. For example, Wang et al. (2009a) identified changes in the patterns of rainfall within Beijing associated with rapid urbanization. These changes, however, were restricted to the winter months, when rainfall increased in those areas undergoing the most rapid growth. During other seasons, rainfall patterns did not change significantly. Another study that examined rainfall data in the Pearl River Delta of China from 1988 to 1996 indicated a negative correlation with urbanization, causing an "urban precipitation deficit" during the dry season (Kaufmann et al. 2007). These authors hypothesize that given the Pearl River Delta's extreme urbanization rates the negative effects of built-up areas on precipitation may overwhelm effects, which could boost precipitation. These studies indicate that while urban climates in the Asia-Pacific region may demonstrate patterns similar to those of the now developed world, they may also provide for unique conditions that affect climate in new ways.

3.3.2.3 Air Pollution

The composition of the atmosphere over urban areas differs from undeveloped areas (Pataki et al. 2006). Importantly, urban air contains pollutants. Ambient air pollution refers to gases, aerosols and particles that harm human well-being and the environment. Cities have been seen as sources of air pollution, but upon closer examination air pollution is primarily a function of fuel consumption and land use changes. The impacts of air pollution on human health are discussed further in Sect. 5.3.

Once emitted the dispersion and dilution of air pollutants are strongly influenced by meteorological conditions, especially by wind direction, wind speed, turbulence and atmospheric stability. Topographical conditions and urban structures, like street canyons for example, have a great effect on these parameters. Cities that develop in valleys often undergo atmospheric inversions, which trap pollution and enhance effects. Air pollution has multiple health, infrastructure, ecosystem and climate impacts (Molina and Molina 2004).

While urban air pollution is a ubiquitous problem, trends vary by development status. In industrialized countries the 'classic' air pollutants, such as carbon monoxide, sulphur dioxide and total suspended particulates are decreasing dramatically, while nitrogen oxides and non-methane volatile organic compounds have reached a plateau or demonstrate weakly decreasing trends (Holdren and Smith 2000). In the developing world, air pollutants are increasing (UNEP/WHO 1993). However, the greatest problems with air pollution are often associated with cities in middle income countries (McGranahan and Murray 2003).

Increasingly, motor vehicle traffic is a major air pollution source (Mage et al. 1996). Motor vehicles emit carbon monoxide, hydrocarbons, nitrogen oxides and toxic substances including fine particles and lead. Secondary pollution, such as ozone, is a product of these primary pollutants, which react together in the atmosphere under the sun's energy. Given the trends in automobile usage, even in developing countries, automobiles are a source of air pollutants (Walsh 2003).

Most urban air pollution attention has focused on mega-cities (Mayer 1999; Molina and Molina 2004; Gurjar et al. 2004, 2008; Butler et al. 2007). High levels of air pollution emissions are associated with energy production and fuel consumption in mega-cities in China (He et al. 2002) and India (Kandlikar and Ramachandran 2000). These studies indicate that, in the 1990s, Chinese mega-cities such as Beijing, Shenyang, Xian, Shanghai, and Guangzhou; and Indian mega-cities cities such as Delhi and Mumbai were among the most polluted cities in the world (UNEP/WHO 1993). In a recent study using a multi-pollutant index (for total suspended particles, sulphur dioxide and nitrogen dioxide) researchers ranked the top ten mega-cities with the lowest air quality level. The ranking includes seven Asia-Pacific cities of Dhaka (1), Beijing (2), Karachi (4), Jakarta (5), Delhi (7), Shanghai (8) and Kolkata (9) (Gurjar et al. 2008).

It isn't the largest cities in the world that have the worst pollution levels, however. A recent global study that examined air pollution trends in over 8,000 cities suggests that urban nitrogen oxides, non-methane volatile organic compounds, carbon monoxide and sulphur dioxide emission levels were highest in Asia (Sarzynski 2012). When ranked by the largest total contribution of emissions, the top emitters of various compounds included Tokyo, Taipei, Seoul, Shanghai, Jakarta, Shenzhen, Ulsan and Tianjin. When examining the largest emitters per capita, however, several smaller, less well known, cities such as Anugul and Sidhi, India; Chengguan, Fengzhen Luzhai and Wulumuqi China; Dumai, Indonesia; Port Dickson, Malaysia; Pohang, Republic of Korea; and Rayong, Thailand ranked among the highest for different compounds. This suggests, as some have argued, that some of the smaller cities in the region suffer from some of the worst environmental challenges (Hardoy et al. 2001).

Urban air pollution can have regional effects. Emissions from cities may play a role in regional climate impacts as high levels of fine particulate matter can scatter and/or absorb solar radiation (Molina and Molina 2004). The visible manifestation of this regional air pollution is a brownish layer or haze pervading many areas of Asia (UNEP and C4 2002; Ramanathan and Crutzen 2002). Hotspots for this phenomenon, commonly known as *atmospheric brown clouds*, in Asia include South Asia, East Asia and the Indonesian region. Through the examination of temperature records in urbanized regions of China and India affected by the haze, researchers have demonstrated a significant cooling effect since the 1950s (Kaiser and Qian 2002; Menon et al. 2002). These effects are consistent with the predicted effects of elevated soot levels and fine particulate matter, despite general warming observed for most for the globe. Recent research suggests that the carbonaceous aerosols are from both biomass burning (slash-and-burn land clearance; waste burning in agriculture and forestry; and residential wood combustion for heating and cooking) and from urban fossil fuel combustion, establishing a role for urban activities in the source of these clouds (Gustafsson et al. 2009). The persistence of the haze has significant implications to the regional and global water and energy budget and health (see Chaps. 4 and 5).

3.3.3 Urbanization and Global Climate

Urban areas are major contributors of GHGs (Dhakal 2010). Estimates vary (Dodman 2009; Satterthwaite 2008), but the general consensus is that urban areas are responsible for approximately 72 % of global anthropogenic GHG emissions (IEA 2008). Given the recognition of cities as important contributors to these trends, research has developed that attempts to isolate the urban role in regional and global climate change (Bader and Bleischwitz 2009; Lebel et al. 2007).

An important distinction in understanding GHG emissions from urban areas includes "direct" and "indirect" emissions. More often, local inventories include estimations of GHGs related to activities of government, businesses and residents emitted from within the urban area, known as "direct" emissions. Measurements may also include emissions from activities located outside local jurisdictions but closely related to economic activities that are conducted within jurisdictions, known variously as "indirect" emissions (US EPA 2011). For example, power production and waste disposal may be conducted outside of cities, but relate to the energy and waste disposal needs of urban residents, businesses and governments. Traditional emissions inventories count only emissions that are produced within the study area, regardless of where the related good or service is ultimately consumed, thus placing the full responsibility for emissions reduction within the site of emission production.

More recent work attempts to include a consumption component. As such, urban protocol research has appropriated the term "scope" used for corporate emissions inventories (WRI 2002). Various scopes define the location of embodied energy-related emissions; for example, Scope 1 emissions are directly emitted from within an urban area, while Scope 2 includes emissions that are related to urban activities, particularly energy consumption, but emitted outside urban areas (in thermal power plants).

Several attempts have been made to estimate GHGs and standardize emission protocols across a number of cities (Kennedy et al. 2009a, b; Hillman and Ramaswami 2010; Sovacool and Brown 2010; Hoornweg et al. 2011). A number of GHG emission studies have been performed on cities in the region (Schulz 2010; Phdungsilp 2010; Dhakal 2009; Dhakal and Imura 2004; Marcotullio et al. 2011, 2012).

There have been studies that examined GHG emissions across the region using gridded GHG emission data, urban boundaries and thermal power plant locations to estimate, at the regional scale, urban contributions of GHGs (Marcotullio et al. 2011, 2012). The analysts found that amongst sources identified, energy production is the dominant source of GHG emissions; with evidence that peri-urban areas are significant sources of GHG emissions. Finally, as demonstrated by studies in air pollution, the largest emitting urban areas are not the highest per capita emitters.

3.3.3.1 Urban GHGs by Source

For calculating the GHG emissions from urban areas Kennedy et al. (2009b) following the Intergovernmental Panel on Climate Change (IPCC), identify a set of standardized sources including energy (stationary combustion, mobile combust and fugitive sources); waste; industrial processes and product use; and Agriculture, Forestry and other Land uses (AFOLU). We follow this format and present data on GHG emissions from cities in the region by source.

(a) *Energy production*

The energy sector typically includes stationary combustion, mobile combustion and fugitive sources. The energy source category includes emissions of all GHGs resulting from these activities. We separate mobile combustion and concentrate emissions from emissions for stationary sources including electricity and district heating.

Studies of urban GHGs in the Asia and Pacific region emphasize energy. For example, Mitra et al. (2003) emphasized the importance of the energy sector for Delhi and Calcutta. Ajero (2002) included GHG emissions from energy production in a study of Metro Manila. Sovacool and Brown (2010) examined energy use in buildings and industry across several cities in Asia. Dhakal (2009) separated energy production and transport in an analysis of emissions from four Chinese cities (Beijing, Shanghai, Tianjin and Chongquin).

Evidence supports the notion that energy consumption is an important contribution to GHG emissions from cities in the Asia and Pacific region. For four cities in China, electricity production alone accounted for between 34 % and 41 % of emissions (Dhakal 2009). In Metro Manila, electricity consumption accounted for 40 % of total emissions (Sovacool and Brown 2010). In 2000, urban Asia energy production and GHG emissions released directly from within urban areas accounted for 61.7 % of all emissions from urban areas (Table 3.6). This conservative figure (which doesn't account for all thermal power plant

Table 3.6 Asia total and urban GHG emissions by sector, 2000

Asia total and urban GHG emission by sector, 2000 (million metric tons)					
	Total GHG emissions		Urban GHG emissions		Urban share of total
Sector	(amount)	(percent)	(amount)	(percent)	(percent)
Agriculture	2,460	17.49	145	3.37	5.88
Energy	6,743	47.94	2,648	61.71	39.27
Industry	1,564	11.12	492	11.46	31.46
Transportation	1,238	8.80	432	10.06	34.89
Residential	1,293	9.20	321	7.48	24.84
Waste	766	5.45	253	5.89	33.00
Total	14,065	100.00	4,292	100.00	30.51

Source: Marcotullio et al. (2012). A geography of urban greenhouse gas emission in Asia. *Global Environmental Change*, *22*(4), 944–958

emissions), strongly suggests that energy production is a dominant source of emissions for Asian cities. That is, only 71 % of all thermal power plants in the region were located within urban areas, leaving emission from 29 % outside cities and not accounted for even though, the electricity consumption may be within urban areas.

(b) *Transportation*

GHG emissions from mobile sources are both important contributions to total emission levels and challenging to estimate. Generally, analysts have observed an inverse relationship between urban ground transportation energy use and population density (Newman and Kenworthy 1989, 1999). On the other hand, air transport GHG emissions are sometimes ignored by urban GHG analysts. Aviation emissions, however, are an increasingly important contribution to total GHG emissions, particularly in the Asia-Pacific region.

Transportation-related GHG emissions are a low but growing portion of total GHG emissions for Asia (Table 3.6). In 2000, for the entire region, transportation accounted for 8.8 % of total GHG emissions. In 2000, transportation-related emissions in urban Asia accounted for a higher percentage of total urban GHG emissions than for the region; approximately 10.6 %. This level is similar to that found by analysts for individual cities. For example, transport accounted for 8 % of total energy consumption in Beijing and 10 % in Shanghai (APERC 2007). Others have identified higher levels for individual cities. For example, transportation accounted for 37 % of Tokyo's energy consumption and 25 % of Seoul's energy consumption in 1998 (Dhakal and Imura 2004). According to Phdungsilp (2010), in 2005 Bangkok's transportation sector accounted for 60 % of energy demand. Estimates suggest that for Dhaka, transportation accounts for 25–30 % of total emissions (Alam and Rabbani 2007).

As mentioned earlier, urbanization is bound up with automobile usage and hence energy consumption and GHG emissions. In general, as nations urbanize, their citizens increasingly shift from non-motorized transport such as bicycling and walking to motorized passenger transport. With increasing urban expansion, more urban dwellers move to the city outskirts and employment areas also shift. Within this peri-urbanization, travel distance tends to lengthen, which has been noted in Asia and the Pacific (APERC 2007). Moreover, in rapidly developing countries, demand for private transportation far outstrips infrastructure supply, creating congestion, high levels of accidents and increasing pollution and GHG emissions (Vasconcellos 2001). With increasing infrastructure provision, we expect transportation GHG emissions in the region to rise rapidly (Marcotullio and Marshall 2007).

(c) *Industrial processes and product use*

The industrial processes and product use category includes GHG emissions from industrial products that are not primarily for energy purposes. A wide range of industrial processes and products emits GHGs that are not the result of combustion. Three broad categories for non-energy industrial use include: (i) feedstock, (ii) reducing agents, and (iii) non-energy products such as lubricants, greases, waxes, bitumen and solvents.

In 2000, for all of Asia, industrial processing and product use accounted for approximately 11.2 % of total anthropogenic GHG emissions. Importantly, these emissions varied across the region as identified by locations of manufacturing. Urban Asia industrial processes and product use GHG emissions accounted for 11.5 % of all urban emissions (Table 3.6). Researchers identified selected industrial cities with high-energy use. For example, in Bangkok in 2005, industry accounted for 31 % of total energy consumption (Phdungsilp 2010) and 25 % of Thailand's carbon dioxide emissions came from manufacturing and construction (Corfield 2008a), dominated by industries in the Bangkok Metropolitan Region. Industry dominated carbon dioxide emissions in Beijing, Shanghai, Tianjin and Chongqing, although industrial emissions have been declining in share for Beijing (from 65 % to 43 %) and Shanghai (from 75 % to 64 %) over the past 20 years (Dhakal 2009).

(d) *Waste and wastewater*

Waste GHG emissions are those from waste management activities (Kennedy et al. 2009b). Much of these emissions are in the form of methane from landfills, dumps and wastewater treatment. Global methane emissions from wastewater treatment under anaerobic conditions and from municipal solid waste landfills are estimated to range from 8 % to 11 % and 3–19 % of global anthropogenic methane emissions, respectively (Wunch et al. 2009; IPCC 1996). The waste sector as a whole accounts for just under 4 % of global GHG output. In the future a large proportion of the GHG emission from urban wastewater is expected to be from cities in developing countries, although researchers note that much will depend upon whether a methane recovery system in place or not .

In 2000, for all of Asia, waste accounted for approximately 5.6 % of total GHG emissions. During that year, in urban Asia, waste accounted for approximately 5.9 % of all GHG emissions (Table 3.6). In individual cities the share of

GHG emissions from the waste sector can be higher. Bangkok waste-related GHG emissions, for example, accounted for approximately 11.5 % of total GHG emissions (Kennedy et al. 2009b). In some rapidly growing cities, such as selected cities in India, (Mumbai, Delhi, Kolkata and Chennai), municipal solid waste is growing faster than population, raising concern over GHG emissions (Jha et al. 2008).

(e) *Residential*

Residential emissions include those GHG emission not related to energy production. Importantly, they include biomass burning for heat and cooking. There is some data available for this important aspect of local contributions to GHG emissions. In 2000, Asian residential emissions accounted for 9.2 % of all GHG emissions in the region and in urban Asia, residential emissions accounted for approximately 7.3 % of all emissions (Table 3.6). This suggests that much of the residential GHG emissions occur outside the urban areas.

(f) *Agriculture, forestry and other land use (AFOLU)*

The world's forests have a substantial role in the global carbon cycle (Nabuurs et al. 2007) and urban areas hold significant amounts of carbon in their forests (Nowak and Crane 2002); but, in general, urban GHG emissions from forestry as well as from agriculture are considered low (Kennedy et al. 2009b).

Agriculture emissions include carbon dioxide, methane and nitrous oxide from agricultural activities. In 2000, Asian agriculture (excluding those from forestry and other land uses) accounted for 17.9 % of all GHG emissions in the region. However, in urban areas, GHG emission shares were much lower. In urban Asia in 2000, agriculture (excluding those from forestry and other land uses) accounted for approximately 3.37 % of total urban emissions. Agricultural activities in Delhi and Metro Manila accounted for 2 % and 9 % of total emissions, respectively (Sovacool and Brown 2010). For urban India as a whole, agricultural GHG emissions from within urban areas accounted 7.2 % of all Indian urban GHG emissions (Marcotullio et al. 2011).

3.3.3.2 Urban GHGs Attributed to Aspects of Dense Settlement

While urban areas are major contributors to climate change, there is a large variation in GHG emissions amongst cities. Some of the variation is due to urban factors or those related directly to population size, density and growth rate of cities. Several studies have emphasized various features of cities and their impact on energy consumption and GHG emissions (Sadownik and Jaccard 2001; Lefevre 2009; Permana et al. 2008; Li 2011; Lebel et al. 2007).

Population size is the most important contributing factor to overall urban emissions, but the largest urban GHG emitters per capita are those cities with high levels of emissions and smaller populations, rather than the largest cities. Asia, however, is known for its urban density. The distribution of dense cities in Asia varies from 518 persons/km^2 to over 1,711 persons/km^2. The pattern of emissions per capita highlights the potential effect of density on energy efficiency. As mentioned earlier, there is a common understanding that the lower density urban areas use more transportation-related energy than the higher density cities (Newman and Kenworthy 1999; Weisz and Steinberger 2010) and studies have verified this relationship (Parshall et al. 2010). Australian analysts have identified the differential dependence on the private automobile among cities of varying densities with the highly sub-urbanized urban areas having the highest dependence and therefore highest transportation energy consumption (Lenzen et al. 2008).

Density can also affect the delivery of higher density fuels and electricity and hence affect GHG emissions. For example, in a study of households in China and India, researchers found that urban households have greater access to electricity grids and modern fuels, appliances and equipment and therefore the energy-use patterns differ among rural and urban households with urban households averaging higher percentages of coal, liquid petroleum gas (LPG) and electricity usage (Pachauri and Jiang 2008). Research also suggests that the least dense Asian urban centres have GHG emission per capita levels over twice the regional average and over three times that of the lowest emission group; the medium high density urban areas (Marcotullio et al. 2012).

As mentioned, many studies point out that while cities have high GHG emissions levels, those emitted directly outside cities are even higher. That is, GHG emissions per capita levels in suburban areas are higher than those in core parts of cities. This is not typically found in developing parts of the world however, although there is some evidence in Asia that peri-urban areas are important direct GHG emitters (Marcotullio et al. 2011, 2012). The geographic characteristics are defined by 20, 40 and 80 km distances from urban extents. The data suggest that uniformly a significant share of GHG emissions is released from areas immediately beyond urban extents (up to 20 km outside the boundaries of urban areas) (Table 3.7). Within Asia as a region, approximately 43 % of all GHG emissions are released in these peri-urban areas. In East Asia, the share of GHG emissions released at this distance reaches 47.4 % of total GHG emissions.

Given the higher share of GHG emissions, it is not surprising that the per capita emission levels typically released from the 20 km buffer areas are higher than those from the urban areas. For the region as a whole, the average GHG emissions per capita released from within 20 km of urban extents is 4.59 tonnes per capita. This difference is true for all sub-regions. Moreover, for the region as a whole the per capita levels in the 20 km buffer are only surpassed by the levels of GHG emissions per capita of those furthest from urban areas, 5.29 tonnes per capita. That is, the areas with highest per capita emissions are those in the most rural. In these areas, emissions are largely due to agriculture and the share of population is typically small (ranging from 2.3 % to 18 % of the total by sub-region).

Finally, urban growth rate can influence GHG emissions. The relationship in Asia suggests that slower growing cities are higher GHG emitters than those growing faster. This could be due to the fact that the slower growing urban areas are the largest and hence the biggest emitters. At the same time, the smaller cities are the most rapidly growing or demonstrate the highest relative growth rates but low total emissions (Marcotullio et al. 2012).

Table 3.7 Asian distribution of population and GHG emissions by distance from urban areas, 2000 (& of total and metric tonnes per capita)

Asian distribution of population and GHG emissions by distance from urban areas, 2000 (percent of total and metric tonnes per capita)

Sector	Within Urban extent	Urban extent –20 km	20–40 km	40–80 km	Remainder	Region
Asia						
Population	34.84	36.07	16.47	8.88	3.74	
Total CO2 equivalents	30.51	43.23	12.76	8.32	5.17	
CO2 equivalents/capita	3.35	4.59	2.97	3.59	5.29	3.83
East Asia						
Population	45.34	33.73	12.04	6.61	2.28	
Total CO2 equivalents	34.50	47.35	9.86	5.38	2.91	
CO2 equivalents/capita	4.11	7.58	4.42	4.39	6.89	5.40
South Asia						
Population	23.83	42.56	22.03	9.08	2.50	
Total CO2 equivalents	23.20	43.87	20.12	9.65	3.16	
CO2 equivalents/capita	2.01	2.12	1.88	2.19	2.61	2.06
Southeast Asia						
Population	28.59	33.96	15.12	13.26	9.07	
Total CO2 equivalents	23.71	37.26	14.35	15.19	9.48	
CO2 equivalents/capita	2.23	2.95	2.55	3.08	2.81	2.69
Central Asia						
Population	40.66	20.96	11.53	9.04	17.81	
Total CO2 equivalents	26.84	32.56	9.21	12.98	18.40	
CO2 equivalents/capita	5.60	13.18	6.78	12.19	8.77	8.49
West Asia						
Population	50.97	16.09	14.27	12.94	5.73	
Total CO2 equivalents	31.26	26.34	13.54	14.46	14.41	
CO2 equivalents/capita	4.01	10.72	6.21	7.31	16.47	6.55

Source: Data from Marcotullio et al. (2012). A geography of urban greenhouse gas emission in Asia. *Global Environmental Change*, *22*(4), 944–958

3.3.3.3 GHG Emissions Attributed to Non-Settlement Aspects

There are a number of non-urban factors that can influence GHG emission patterns from cities. Perhaps the most important among socio-economic and biophysical factors are wealth and climate. There is a general consensus in the literature that cities with higher income typically have larger global environmental impact than cities of lower income (McGranahan 2005; McGranahan et al. 2005). This relationship is understood to include GHG emissions and the results have been verified by researchers comparing results across a number of cities globally (Kennedy et al. 2009b). It has also been identified within the region (Bai and Imura 2000; Marcotullio 2005). Moreover, at the household level, energy consumption for higher income residents is higher in India and China than lower income households (Pachauri 2004; Pachauri and Jiang 2008). In Asia, the highest GDP per capita group of cities (those with more than 1990 US$5,027 per capita) have the highest GHG emissions per capita, suggesting that as GDP per capita increases, GHG emissions per capita do as well.

This relationship, however, may be more complex than a simple rise in GHG emissions with increasing wealth. Some have found that selected cities in lower income countries, Shanghai in China for example, have higher GHG emissions per capita than cities in high income countries like Tokyo in Japan (Dhakal and Imura 2004). Hence, the relationship between GHG emission levels and wealth may be more complex than a simple positive correlation. Indeed, research has demonstrated that a more complex relationship exists between wealth and GHG emissions in the region. That is, for Asia, a rise in income is an inverted relationship, such that GHG emissions fall after a specific level, but then rise again with higher levels of income; a cubic relationship (Marcotullio et al. 2012).

Another non-urban factor that has been found to be important in influencing urban GHG emissions is climate, including temperature (Kennedy et al. 2009b). In Asia, there is a relationship between the heating degree-days (HDDs) experienced by urban centres and GHG emissions. HDDs are the number of days that a city experiences temperatures below a certain level, requiring heating in buildings. Cities that are located in areas of high HDDs have higher GHG emissions per capita than cities with low HDDs. This is also true of elevation. Cities at higher elevation require more heating than those at lower elevation and therefore use more energy and emit more GHGs.

3.4 Urban Climate Change Hazards and Vulnerabilities in Asia and the Pacific

Globally, temperatures have increased approximately 0.74 °C over the past century and that 11 of the 1995–2006 years rank among the 12 warmest years in the historical record of global surface temperatures (IPCC 2007b). Current trends suggest that for the next two decades a warming of about 0.2 °C per decade is projected. The scientific consensus is that the global climate is changing due to human influence on the system in a variety of ways (Goudie 2006; Houghton 2009). Besides warming, the most fundamental climate-related physical changes to the Earth system include: (i) changes in precipitation levels, (ii) sea-level rise, and (iii) increased variability of weather, including extreme events (such as tropical cyclones).

The impact of climate change on urban areas has been an area of growing interest (IPCC 2007b; UN-Habitat 2011a, b; Prasad et al. 2008). Research demonstrates the potential risks from climate change are significant including flooding, coastal erosion, saltwater intrusion into groundwater supplies, elevated temperatures and heat waves, drought, disease outbreaks, landslides, and increasing damage from tropical storms and cyclones (APN 2010; Nicholls 1995). Furthermore urban risk from climate change is exacerbated by man-made hazards, including subsidence caused by groundwater withdrawal; patterns of urbanization and development. Such as, expansion of impervious surfaces aggravating storm water runoff, man-made structures obstructing drainage; reduction of river channel capacity (APN 2010; Haruyama 1993; World Bank 2010). Moreover, a large portion of the urban population lives in areas that will be significantly affected by climate related changes: coastal, arid and mountain zones.

Specific studies have examined the number of people and value of property at risk, how various climate-related changes harm urban management, quality of life, physical infrastructure and urban markets, and whether or to what extent people and urban systems are vulnerable and resilient to climate change-related risks and hazards. Both disaster and hazard reduction research and climate change adaptation research communities focus on analyses of the underlying causes of exposure and vulnerability and have goals of integrating findings into planning and management (Solecki et al. 2011).

3.4.1 Urban Risks and Hazards Associated with Climate Change

Examinations of urban climate change risks and vulnerabilities focus on the human and economic assets potentially exposed to harm from various climate change-related hazards Some of this research is future scenario-based (i.e., populations at risk from sea-level rise). Alternatively, studies that examine the impacts of climate change examine previous and contemporary events that are or could be related to climate change (the impacts of landslides for example may be enhanced with climate change). Understanding the threats and impacts of climate change on the region's cities is all the more important given the large and increasing urban populations in the region. Moreover, analysts suggest Asia is a climate change 'hotspot' and Asian cities are particularly vulnerable to future climate change harms (Yusuf and Francisco 2009; World Wildlife Fund 2009).

3.4.1.1 Increased Temperatures

Temperatures in the Asia-Pacific region are changing and the likely range of global average surface temperature change is projected to be 2.4–6.4 °C in 2090–2099 relative to 1980–1999 (IPCC 2007b). Generally, there is consensus among climate scientists that future warming will be defined by summer heat waves of longer duration and greater intensity and frequency in East Asia with fewer very cold days in East Asia and South Asia (Christensen et al. 2007).

We understand that climate change will have a wide variety of human health impacts. The World Health Organization (WHO) attributes a mortality rate of more than 150,000 annually since the 1970s to climate-induced diseases, and projects that twice this number will die due to climate change by 2030 (McMichael et al. 2004) (see also Sect. 5.3).

Increasing temperatures and specifically heat waves, however, are particularly important for cities because they act in concert with the UHI phenomenon to increase demand for water and cooling, exacerbate air pollution and heat stress; and increase risk of mortality (Shimoda 2003; Prasad et al. 2008; Beniston and Diaz 2004; Cruz et al. 2007).

Increased temperatures cause heat stress. Exposure to extreme hot weather is associated with increased morbidity and mortality, compared to an intermediate 'comfortable' temperature range (Curriero et al. 2002). The European heat wave of 2003, for example, killed 70,000 people (Robine et al. 2007) demonstrating the impacts of increases in extreme maximum temperature events.

The safest temperature range is closely related to mean temperature for an individual city, so it varies around the world (Patz et al. 2005). An international study of cities found the temperature threshold for heat-related deaths ranged from 16 °C to 31 °C and heat thresholds were generally higher in cities with warmer climates (McMichael et al. 2008). Despite the fact that many cities in the Asia-Pacific region lie in tropical and sub-tropical zones, many have recorded incidences of UHI and higher death rates during heat waves. From 2000 to 2009 there were 60 extreme temperature events, which claimed over 8,700 lives (International Federation of Red Cross and Red Crescent Societies 2010). Heat waves in Shanghai elevated deaths in the city, particularly during the 1998 and 2003 heat waves (Tan et al. 2007, 2010). Heat-related deaths are not uncommon among the sick and elderly in Ho Chi Minh City (Asian Development Bank 2010).

The ability of individuals to combat excessive heat is a function of age (Åström et al. 2011). The elderly and the young are typically more at risk. As Asian ages and populations in cities become older, heat stress-related mortality is projected to increase. One model suggests that with future climate change many countries are projected to experience a four- to five-fold increase in excess mortality due to heat stress with China and India experiencing large losses in absolute terms (Takahashi et al. 2007).

As mentioned earlier, cities in Asia already suffer from high levels of air pollution. Rising temperature can also lead to increased air pollution and associated incidence of disease and higher temperatures can lower air quality through increasing the incidence of smog events (UN-Habitat 2011a). Changes in concentrations of ground-level ozone (a secondary pollutant), for example, have been projected with increasing temperatures (Ebi 2010). Exposure to raised concentrations of ozone, the main component of smog, is associated with higher hospital admissions for a variety of respiratory conditions and also early mortality (Confalonieri et al. 2007). This is particularly important for residents of cities in valleys that are susceptible to temperature inversions. Over 10 % of the Asia-Pacific urban population live in mountainous cities, which are typically located in valleys and therefore susceptible to inversions.

In the future, regions that are heavily urbanized will be more adversely affected by temperature-related climate changes than rural ones (Costello et al. 2009). Urban populations, therefore, will suffer higher exposure to these hazards than rural populations creating higher risks, especially for those with pre-existing respiratory disease (Ayres et al. 2009). Heat stress in combination with UHI and air pollution in developing cities in Asia will likely further enhance respiratory and cardiovascular illnesses (Patz et al. 2000) and the joint impact of these health-related stresses may be greater than the sum of their effects (Satterthwaite et al. 2007).

3.4.1.2 Sea-Level Rise

Scientists suggest that sea level has been rising around the world at an average rate of 1.8 mm per year between 1961 and 2003. This change has largely come about through increases in ocean temperatures. As sea temperatures have increased the volume of ocean water has expanded. This phenomenon is considered to be an important factor currently attributed to sea-level rise. At the same time, melting ice sheets may become more important in the future (Church et al. 2008). Across the twentieth century sea level rose by an estimated 0.17 m, although with significant regional variation (IPCC 2007b).

The IPCC predicts a further rise of 0.26–0.59 m of global sea-level rise by 2100 (Meehl et al. 2007). Independent estimates of future sea level, however, indicate that global seas could rise over 1 m by 2100 (Overpeck and Weiss 2009; Pfeffer et al. 2008; Vermeer and Rahmstorf 2009). Higher sea levels have dramatic implications for coastal cities.

Over one quarter of the urban population lives in coastal ecosystems (McGranahan, et al. 2005) and many of the world's mega-cities are located in coastal areas (Nicholls 1995). The term coastal is considered in a broad sense in light of the local geomorphological, ecological and economic characteristics (Klein et al. 2003). The global urban population living in areas of low elevation coastal zones (LECZs) may be as high as 352 million with approximately two-thirds in Asia (McGranahan et al. 2007). In Asia and the Pacific approximately 29 % of the urban population lives in coastal ecosystems of varying elevation. The potential threat of sea-level rise to these populations depends on a number of factors including a city's geographic location and features, and the infrastructure and socio-economic characteristics of the residents (de Sherbinin et al. 2007; UN-Habitat 2011b).

Recent assessments suggest that coastal mega-cities in the Asia-Pacific region are particularly vulnerable to climate change (Fuchs 2010; Hanson et al. 2011; Nicholls et al. 2008). Amongst 136 port cities, one study found that 38 % (52 ports) are located in Asia and many of these are located in deltaic regions. Cities in deltaic regions tend to have higher risk of coastal flooding (Nicholls et al. 2008). This same study estimated that by 2070, 90 % of the total estimated asset exposure in these large port cities will be concentrated in eight nations, six of which are in Asia (China, USA, India, Japan, Netherlands, Thailand, Viet Nam and Bangladesh). For populations, approximately 90 % of the exposure in the 2070s will be contained in 12 countries, eight of which are in Asia (China, USA, India, Japan, Netherlands, Thailand, Viet Nam, Bangladesh, Myanmar, Egypt, Nigeria and Indonesia). Altogether, Asian cities houses 65 % of the globally-exposed population living beneath the 100-year water level mark (Hanson et al. 2011).

Sea-level rise acts together with a number of other factors to put both property and people at risk. For example, as sea levels rise, there is inundation from flooding and storm damage (including wind), wetland loss and change, erosion, saltwater intrusion and rising water tables (Nicholls and Tol 2006). An important economic, ecological and human risk factor associated with sea-level rise is coastal erosion. Arthurton (1998) noted that although rarely catastrophic, coastal erosion may be a substantial hazard for some mega-cities. The study by Panya Consultants (2009) analysing climate change impacts for the Bangkok Metropolitan Region (BMR) suggests coastal erosion in the Upper Gulf of Thailand is a critical deterrent to the sustainable development of the BMR, and forced retreats are already occurring in Bangkok's coastal area (World Bank 2010). In Mumbai, the cost of coastal erosion was estimated at US$2.5 million/km for capital works for protecting prime waterfront property (Asian Development Bank 2007). Furthermore, a recent study that examined the impact of several different factors associated with sea-level rise for Jakarta estimated that by 2100, costs could run in excess of 1.2 % of the country's GDP (Ward et al. 2011).

3.4.1.3 Changes in Hydrology

Increases in temperature predicted by climate scientists will have associated changes in precipitation. While some areas will see increases, there will be areas that experience decreases in average precipitation, changes in seasonal distribution and a general increase in the spatial variability of precipitation. Gleick (2010) summarizes the evidence from global climate models as "dry areas will get drier, while wet areas will get wetter."

It is expected that there will be an increase in the frequency of intense precipitation events associated with monsoon rains in parts of East and South Asia. For Australia and New Zealand precipitation will likely decrease in southern Australia in winter and spring. Precipitation is also expected to decrease in south-western Australia in winter, while precipitation is predicted to increase in the west of New Zealand's South Island. Changes in rainfall in northern and central Australia are uncertain (Christensen et al. 2007).

Increases in rainfall in areas of the region that are already experiencing high rainfall patterns will potentially have a large number of significant impacts. These include adverse effects on the quality of surface and groundwater, increased risk of infectious, respiratory and skin diseases, disruption of commerce transportation and daily activities, loss of property and increased landslides, and the resultant loss of life and increased morbidity from all these changes.

The Asia-Pacific region suffers from flooding. Floods are among the most costly and damaging disasters and their frequency and severity has generally increased in the last decades (McCarthy et al. 2001). While flooding is associated with high levels of rainfall, it is also associated with sea-level rise and storm surges and may be exacerbated by other hazards such as land subsidence (World Bank 2010).

Between 2000 and 2009, of the 1,739 reported flood events globally, 655 (38 %) occurred in Asia. These events affected 892 million people, killed 36.8 million and caused US$85 billion in damages in Asia (International Federation of Red Cross and Red Crescent Societies 2010). Cities in Asia, and particularly those of China, India and Thailand, were ranked as being the most vulnerable (in terms of population and asset exposure) to future coastal flooding (Nicholls et al. 2008). The World Bank (2010) identified Bangkok, Ho Chi Minh City and Manila as "hotspots" in Asia. In Bangkok, existing flood protection is considered inadequate for even a 30-year event and exposes 30–35 % of Bangkok's land area and approximately one million people to inundation (Fuchs 2010). This predicted risk was tragically realized during November 2011 when the city experienced its worst floods in over half a century. The impact was so great that the Thai MPs called for a study to examine the relocation of the capital to a less flood-prone province (Bangkok Post 2011).

History has demonstrated that these are not the only cities at risk to flooding in the region, however. In 1988, floods in Bangladesh inundated 52 % of the country and covered 85 % of Dhaka for several weeks. It is estimated that of the six million inhabitants of the city, between 2.2 and 4 million were affected. The total death toll was reported to exceed 2,300 with 150 deaths in Dhaka. Ten years later, in 1998, floods again affected Dhaka, impacting 30 % of housing in the metropolitan area (International Federation of Red Cross and Red Crescent Societies 2010). On 26 July 2005, Mumbai received 944 mm of rain in 14 h (Bhagat et al. 2006), resulting in flooding that caused 500 fatalities and US$2 billion in damage (Hallegatte et al. 2010). Flash flooding in Iloilo, the Philippines, in 2008 affected 152 of its 180 *barangays* and up to 500 people were killed, while 261,335 were affected (International Federation of Red Cross and Red Crescent Societies 2010). Other significant impacts of recent urban flooding have been felt throughout the region (Table 3.8).

In the future, however, impacts may be more significant. By 2050, it is likely that there will be increased flooding events affecting Bangkok, Ho Chi Minh City and Manila. For example, researchers predict that 62 % of Ho Chi Minh City's population will be affected by a 1-in-30 year event. In Manila, Bangkok and Ho Chi Minh City, costs of damage from climate change-related flooding are estimated to range from 2 % to 6 % of the regional GDP. Therefore, a 1-in-30 year flood in Manila could cost between US$900 million and US$1.5 billion, given current flood control infrastructure (World Bank 2010). By the 2080s, the costs of the Mumbai flood event of 2005 will more than double for the city and total losses (both direct and indirect) associated with a 1-in-100 year event could triple compared with the current situation (US$690–US$1890 million) (Hallegatte et al. 2010). Moreover, the IPCC (2007b) predicts increased flooding over the next two or three decades from glacier melt in the Himalayas. Alam and Rabbani (2007) noted how melting glaciers will add to existing damage in Dhaka caused by river floods and excessive rainfall during the monsoon.

For much of Asia, an increase in annual precipitation will also exacerbate landslides. Landslides including those related to dump collapses are currently significant threats in the region. In Ho Chi Minh City, for example, June through

Table 3.8 Climatic changes, possible impacts, and potential urban planning-related consequences

Climatic change	Possible Impacts	Potential urban planning-related consequences
Increased temperatures	Groundwater depletion	Water shortages
	Water shortages	Distress migration to cities/towns due to droughts in rural areas
	Drought	Interruption of food supply networks and higher food prices
	Degraded air quality (smog)	Potential energy price increases (e.g., from reduced hydro-electricity generation in places where it exists)
		Exaggerated urban heat island effect
		Increased energy demands for cooling
		Need for higher and/or additional wastewater treatment
		Population health impacts (e.g., increased mortality during heat waves, decreased access to food/nutrition)
Increased precipitation	Increased flooding	Interruption of food supply networks
	Increased risk of landslides or mudslides on hazard slopes	Property damage (homes and businesses)
		Disruption of livelihoods and city/town economies
		Damage to infrastructure not designed to standards of occurrences being experienced
		Distress migration to cities due to floods in rural areas
		Displacement and population movement from informal settlements built on steep slope hazard lands, etc.
		More favorable breeding grounds for pathogens (e.g., mosquitoes and malaria)
		Population health impacts (increased incidences of water-borne diseases like cholera)
Sea-level rise	Coastal flooding	Displacement and population movement from coastal flood areas
	Salt water intrusion into groundwater supplies in coastal areas	Property damage (homes and businesses)
	Increased storm surge hazard	Damage to infrastructure not designed to standards of occurrences being experienced
		Disruption of livelihoods and city/town economies
		Population health impacts (injuries, increased mortality and illness)

(continued)

Table 3.8 (continued)

Climatic change	Possible Impacts	Potential urban planning-related consequences
Increased extreme weather episodes (storms, cyclones, hurricanes)	More intense flooding Higher risk of landslides/ mudslides on hazard slopes	Property damage (homes and businesses) Damage to infrastructure not designed to standards of occurrences being experienced Population health impacts (injuries, increased mortality, distress) Disruption of livelihoods and city/town economies Interruption of food supply networks

Source: UN-HABITAT (2011a). *Planning for climate change, a strategic values-based approach for urban planners*. Nairobi: UN-Habitat

August is landslide season. The city has identified 42 hotspots in high danger of landslides (Nahn 2010). In 2000, a landslide in Mumbai killed at least 60 people in slum districts in the east of the city (BBC 2000). In 2000, heavy rains in Quezon City from typhoons caused a 15-m hill in the dump to collapse, burying hundreds of homes, killing 288 people and displacing several 100 families. In 2006, a landslide buried the entire Barangay Guinsaugon and affected another 80 barangays, causing 154 deaths, with 968 reported missing, 3,742 displaced and 18,862 affected (World Bank 2011).

While increased precipitation creates significant risks for cities, so does water scarcity. Currently, modelled global results show that 150 million people live in cities with perennial water shortage, defined as having less than 100 L per person per day of sustainable surface and groundwater flow within their urban extent (McDonald et al. 2011). Many of these urban areas are located in arid ecosystems. The Asia-Pacific region has a large proportion of semi-arid drylands (Safriel et al. 2005) and the urban population living in these areas exceeds 35 % of the total urban population in the entire region. Moreover, of this population, approximately 56 % live in semi-arid, arid or hyper-arid regions. Some of these areas have already become fully arid as a result of climate change. For example, a new desert is reportedly forming on the eastern edge of China's Qinghai-Tibet Plateau, which has traditionally been a grassland area used for herding (World Bank 2007b).

Water availability in dry lands is projected to decline from the current average of 1,300 m^3 per person per year (in 2000), which is already below the threshold of 2,000 m^3 required for minimum human well-being (Thirlwell et al. 2007). Water stress is likely to increase in these areas. According to UNFCCC (2007) climate change will bring increasing water stress to over 100 million people due to decreases in freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins such as Changjiang.

Change in freshwater availability is not only due to lack of precipitation, but also due to seasonal differences that accompany warming. For example, as mentioned, global warming is causing glacier melting in the Himalayas. While in the short term this runoff increases the likelihood of flooding, erosion, mudslides and glacier lake outburst flooding (GLOFs) in many South Asian nations; in the longer term, this may also lead to a rise in the snowline and the disappearance of many glaciers thus reducing water storage. Large populations rely on the seven main rivers in South, Southeast and East Asia fed by glacier melt runoff from the Himalayas. Throughout Asia one billion people could face water shortages leading to drought and land degradation by the 2050s (Christensen et al. 2007; Cruz et al. 2007).

It is not surprising then that of the 162 million urbanites that researchers predict to undergo perennial water shortage by 2050, the majority will be in Asia (94 million) (McDonald et al. 2011). Indeed, water shortage is one of the most serious potential threats arising from climate change in the region (Parry et al. 2007). For example, the National Capital Region of Delhi is facing severe water shortfalls and municipal demand is currently competing with irrigated agriculture. Water shortages are exacerbated by high levels of leakage from water supply systems, local pollution of water bodies and groundwater, saltwater intrusion of aquifers and inadequate infrastructure (Marcotullio 2007; Rodolfo and Siringan 2006; de Sherbinin et al. 2007; APN 2010). Delhi's water is transported 300 km and unaccounted for water losses are over 40 % in the city (Revi 2009). A snapshot of recent reports that highlight current city water stress is presented in Table 3.9.

3.4.1.4 Increased Frequency and Intensity of Tropical Storm Events

Tropical cyclones are intense storms that originate over tropical waters and can sustain winds exceeding 64 knots. In North America they are called hurricanes; in the western North Pacific, typhoons; in India they are called cyclones; and in Australia tropical cyclones. Between 2000 and 2009, 416 windstorms were recorded in Asia, which caused over 160,000 deaths and economic losses estimated at US$ 366 billion (International Federation of Red Cross and Red Crescent Societies 2010).

At the urban level, the increase in storms and their increasing intensity has been recorded. The number of tropical storms affecting Ho Chi Minh City is reported to have increased over recent years (Asian Development Bank 2010). The flooding in Mumbai in 2005 was related to a cyclone, which left more than 1,000 dead (de Sherbinin et al. 2007). The tropical storm Ketsana, which hit Manila and the surrounding area, created flood waters reaching nearly 7 m and killed hundreds of residents (World Wildlife Fund 2009).

Increased intensity of tropical storm events in the future will increase coastal flooding with all the related knock-on effects (McCarthy et al. 2001). With an increase of 4 °C one estimate suggests average annual insured losses from tropical cyclones affecting China alone will increase by 32 % to reach approximately US$0.5 billion; 100-year losses will increase by 9 % to reach US$1.340 billion, and 200-year losses will increase by 17 % to reach approximately US$1.8 billion (Dailey et al. 2009).

Table 3.9 Recent reports of water stress in cities in Asia and the Pacific

Recent reports of water stress in Asia and the Pacific cities	
The news article, titled – 'Greater **Jakarta** on alert for drought' – reports on a prolonged dry spell that threatened to disrupt supplies to Greater Jakarta (Jakarta Post 2011)	Unusually low monsoon rainfall resulted in a 30 % cut in the water supply in **Mumbai**, described as the 'worst water shortages in its history'; water shortages in **Delhi** and other cities were also mentioned (BBC 2009)
With reference to **Calcutta** – 'Droughts have been more frequent in the last few decades and are projected to get worse, which will lead to even more salt-water intrusion and thus deteriorate surface and groundwater quality' (WWF 2009)	'China's £1.1bn desalination plant is just the latest megaproject in its increasingly desperate race against water shortages … '**Tianjin** has a chronic shortage. Drought, overuse and pollution have left its population of ten million with just a 10th of the water of the average global citizen' (Guardian 2011)
'Extreme climate events can have serious impacts on **Karachi**'s water supply. While droughts, such as in 1999–2001, cause water shortages in the city, extreme monsoon rainfalls can cause flooding and ensuing outbreaks of waterborne diseases' (WWF 2011)	'Although freshwater is naturally abundant in the metropolitan **Shanghai** area, the city experiences high water stress due to the rising demand of 23 million inhabitants' (WWF 2011)

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3.4.2 Basic Urban Service Challenges Associated with Climate Change

This section provides an overview on the potential impacts of climate change to urban service delivery, given current physical trends. The focus is on selected services including transportation, water supply, sanitation, food, energy and industry. All these services will be impacted by changes in temperature, precipitation, storm events and sea level rise.

3.4.2.1 Transportation

Climate change has a number of impacts on transportation systems that threaten to disrupt movement within cities. Weather conditions, including storms and floods, have immediate impacts on travel and can cause service interruptions to both public and private transportation (for example via subways, flooded roads, etc.). Heavy precipitation events can also cause due damage in the form of erosion of supporting transportation infrastructure such as highways trusses, seaports, bridges and airport runways. In coastal cities this is a particularly significant aspect of climate change as it can combine with seal-level rise and inundate highways and transit systems. Salt water can also corrode infrastructure. In the worst case scenarios, entirely new sub-systems are needed in free-from-flooding zones. High temperatures can damage roads, rails and transit vehicles as well as support systems (deforming rails that result in slower traffic). Prolonged high daily temperatures degrade paved roadways used by heavy vehicles and necessitate frequent repairs. Both steel and concrete can buckle under high temperatures. High winds can reduce the use of upper decks on bridges and impede traffic speeds (Transportation Research Board 2008; Mehrotra et al. 2011).

Transportation costs due to weather-related risks in the region are already significant and will increase with climate change. During the great flood of 1998 both inter- and intra-city bus links from eastern Dhaka were shut down because of inundation and an estimated 384 km of paved roads were inundated (Alam and Rabbani 2007). In 2007, 34 % of the total transport infrastructure was damaged in Bangladesh, including roads, bridges and culverts, road approaches, highways, buildings and railways infrastructures (rail line and bridges), costing about US$363 million (Bangladesh Ministry of Food and Disaster Management 2007). The 2006 flood in Aceh, Indonesia, caused US$35 million to the transportation sector, which was 24 % of total infrastructure costs from the storm (World Bank 2007a).

In Hyderabad, India, climate extremes have adversely impacted transportation infrastructure in several ways. Floods have directly resulted in infrastructure damage, the breakdown of transport networks and the slowdown of services. Heat waves have caused direct damage to electronic devices, and gradual temperature increases working in a more concealed way have slowly damaged railway and road infrastructures (Mehrotra et al. 2011).

3.4.2.2 Water Supply and Sanitation

Climate change can affect the availability, treatment and distribution of urban water supplies and the ability to sanitize wastewater (Major et al. 2011; Case 2008). Warm temperatures can help to degrade water supply infrastructure in similar ways to transportation infrastructure. Warm temperatures can lead to a degradation of water quality through increased biological and chemical activity. For example, heat waves can increase water solubility and, therefore, enhance concentrations of contaminants including algae, microbes and parasites. Warm temperatures also increase evaporation from reservoirs thus potentially requiring changes or additions to infrastructure (Thirlwell et al. 2007). Increases in temperatures also affect water demand as the population uses more water for personal services (drinking, showering, watering lawns, etc.).

Increasing storm events can lead to street, basement and sewer flooding and high levels of storm water run-off. More intense rainstorms will increase runoff into receiving water bodies. If water levels overwhelm treatment plants, the result will increase combined sewer overflows. The resulting cascade of events will include high nutrient loads and eutrophication of water bodies. Those downstream may suffer from taste and odour problems and loading of pathogenic bacteria and parasites in supplies. Intense rainstorms will also increase erosion and stream sediment load, decreasing the quality of water and the life of reservoirs. Higher loading in rivers may disrupt freight traffic and require increases in the frequency of dredging (Major et al. 2011).

As a result of climate change the timing and type of precipitation may change, causing disparities between supply and demand. Reduced snowfall results in less water stored in snowpack and glaciers. On the other hand, if the same amount of precipitation occurs as rain, rather than snow, water will move through the hydrological cycle more quickly. This places demands on reservoir capacity, dams and supply systems. Reduced snowfall can also impact the quality of rivers and the ecosystem services they deliver (Major et al. 2011).

In coastal cities all of these impacts are experienced along with several other important challenges. Coastal cities that rely on groundwater supplies may find increased saltwater intrusion as sea level rises and more coastal dwellers turn to groundwater if surface waters are inadequate to meet demand (Hanson et al. 2011). An increase in sea level may also increase the probability of flooding of wastewater plants. Higher sea levels can inundate fresh and saline wetlands and threaten the stability of canals and embankments, which can impact water via supply and quality as well as cause flooding. Saltwater intrusion is a major threat to Shanghai's water supply; the Qingcaosha reservoir was constructed in an attempt to safeguard drinking water supplies against salinity, rising demand and pollution (Engel et al. 2011). During the dry season, saltwater intrusion of 100 km or more was reported from the Bay of Bengal (Allison et al. 2003).

Asian cities currently have a variety of water supply and sanitation challenges including inadequate provision of water supply and sanitation services, inadequate drainage, ground water overdraw and land subsidence, increasing water consumption and high leakage rates (Marcotullio 2007). Climate change in the region is expected to exacerbate these challenges as well as pose new ones (IPCC 2007b; APN 2010).

3.4.2.3 Food

Climate change can impact urban food systems. The basic urban food system is composed of several elements including the production, distribution, processing, consumption and waste. Food production (agriculture) may be affected by climate change in a variety of ways. Temperature changes will have an impact on the types and yields of crops through, *inter alia*, exceeding temperature thresholds for crops, increasing plant metabolism, changing soil moisture and shifting pest types and abundance. Changes in precipitation levels will affect irrigation and water inputs. On the one hand, reports suggest that climate change will only have a minor effect on global food supplies (Rosenzweig and Parry 1994) and in some regions change will be beneficial to some areas (Reilly et al. 2003).

In Central and South Asia, however, crop yields are predicted to fall by up to 30 % and reduced soil moisture and evapo-transpiration may increase land degradation and desertification, increasing the risk of hunger in several countries. At the same time, agriculture may expand in productivity in northern areas of the region (IPCC 2007b).

Food distribution systems may be affected by various climate-related changes. In a study of 18 low- and middle-income countries urban food insecurity equalled or exceeded rural levels in 12 (66 %) of those (Ahmed et al. 2007). Lack of urban connections to agricultural production sites will lower food availability and increase food prices. Rising prices impact urban populations, particularly the poor, reducing their calorific intake and the diversity and nutritional value of foods consumed (Cohen and Garrett 2010). Maintaining two-way flows of food between cities and rural areas is crucial to India's development and climate change can have dramatic impacts on this important link (Revi 2009).

Moreover, a nutritional transition has accompanied urbanization and economic development (Popkin 1994, 1999). Diet changes have also been observed and, interestingly, within Japanese urban populations meat has become an important component of Tokyo residents' diet overtaking fish consumption for the first time in the early 2000s. Such diet changes may have important implications for the environmental footprint of cities triggering land use change and environmental pollution (Gadda and Gasparatos 2009).

Nutritional transition is defined by changes in diet with rising income. Higher added-value processed foods, meats and dairy products are consumed in larger amounts with increasing incomes. Higher income households' demand for ready-to-eat and easily prepared foods is higher than poorer households. This is important for urban areas, as they concentrate wealth. As urban areas demand more food and more diverse food products, the complexity of urban food systems increases and with it the potential risk of being disrupted. For example FAO (2000) calculated the truckloads of food necessary to feed the burdening populations of cities in Asia by 2010. They estimated that Bangkok would need 104,000 additional 10-tonne truckloads each year; Beijing would have over 302,000; Mumbai, 313,000; Dhaka, 205,000; Jakarta, 205,000; Karachi 217,000; and Shanghai almost 360,000. Moreover, they estimated that food losses between the production and retail stages ranged from 10 % to 30 % and are caused by a combination of on-farm, transport, distribution and spoilage problems, which are greater in urban than rural areas. Given the large amount of food necessary for these areas and the increasing distance needed to get food to the urban market, climate-related disruptions in the transportation system create risk for urbanites.

3.4.2.4 Energy Production, Transmission and Distribution

Climate change is likely to impact urban energy systems by affecting infrastructure and demand for energy. Energy infrastructure is susceptible to various aspects of climate change for transportation, water supply and sanitation. Hammer et al. (2011) argued that climate effects on energy systems include those on resource production and delivery, power generation and transmission and distribution systems.

Resource production includes fuel stocks, which are typically located outside urban areas, but which are affected by climate change. Drilling platforms and refineries are vulnerable to weather events. For example, during 2008 heavy snowfall in central and southern China blocked rail networks and highways used for delivering coal to power plants in these regions. Of China's 31 provinces, 17 were affected including hundreds of millions of people in these provinces who were forced to ration power (Hammer et al. 2011).

Urban poor households use a mix of fuels, including biomass. In developing parts of the Asia-Pacific region, the use of biomass fuels for cooking and heating remains significant. For example, about 25 % of the urban poor in the Philippines use fuel wood primarily for cooking and about 45 % of household procure their fuel sources from their own rural plots (Approtech Asia 2005). In India, Sri Lanka and Thailand, wood harvesting has produced a halo of deforestation around cities (Sawin and Hughes 2007). The extent and renewability of biomass will depend upon changes in temperature and precipitation as well as population growth.

Power plants located in coastal areas are at risk from the impacts of storm surges, floods, etc. The recent nuclear power problems experienced by Japan due to the 2010 earthquake-induced tsunami have resonated with those examining the possibilities of like effects, but due to climate change. For example, Urban and Mitchell (2011) note that disaster risks caused by storm events such as typhoons, etc. and the resulting flooding could pose increasing threats by damaging nuclear power plants and subsequent risks to health and safety.

While hydroelectric plants are very important in the region, a recent report has suggested that over half of existing and planned capacity for major power companies in South and Southeast Asia is located in areas that are considered to be water scarce or stressed (Sauer et al. 2010). This analysis suggests that delays in project execution and loss of output due to water scarcity could be significant. With changes in precipitation occurring, the lifetime use and effectiveness of these plants may come under question.

The combination of urban population growth and changing local weather can place increased demands on energy systems for energy generation and distribution. Increases in demand are the most important economic impacts for energy at the global scale, particularly in tropical areas. Climate warming may increase the demand for space cooling, for example. Air conditioning in the commercial sector already accounts for a greater proportion of final energy demand than in the residential sector in developed countries. In Hong Kong, air conditioning accounts for as much as 60 % of total electricity use in the commercial sector (Hunt and Watkiss 2011). In Chinese cities, over the past 15 years, air conditioner ownership rates have increased to exceed an average of one unit per household and in Guangzhou ownership rates have increased from approximately one per every other household to more than two per household during this period (Hammer et al. 2011). The increases in such appliances reflect the increased demand on systems that may also occur in more northern areas with further warming.

3.4.2.5 Industry and Services

Manufacturing is an important component of economic development in the Asia-Pacific region, which is often called the “factory of the world” (UN-Habitat 2011c). Export-led growth, originally based in the industrial sector, but increasing in services, continues to be a significant source of economic growth and employment. Foreign direct investment is typically attracted to the region’s cities that are linked to the global economy through transportation and communications networks. Scholars have correlated urban development of the region with the growth of industries and manufacturing (Lo and Yeung 1996). These industrial firms typically locate around the region’s cities in doughnut fashion (Marcotullio 2003).

Manufacturing industries that are not directly dependent on natural resources and tourism generally would not be affected by climate unless key infrastructure is destroyed by events such as floods or landslides, or unless shipments are affected. However, manufacturers are influenced by climate change in two other ways. First, they would be affected through the impact of government policies pertaining to climate change such as carbon taxes (thereby increasing the cost of inputs). Second, they could be affected through consumer behaviour that in turn is affected by climatic variations. For example, less cold-weather clothing and more warm-weather clothing might be ordered (Wilbanks et al. 2007). Not enough is known, however, of the potential impact to industries.

3.4.3 Greater Risk and Vulnerability for the Urban Poor

The vulnerability or security of individuals and urban areas is determined by the condition of natural resources and infrastructure as they change with climate, availability of financial, social and natural resources, and by the entitlement of individuals and groups to call on these resources (Adger et al. 2003; IPCC 2007a). That is, vulnerability is not simply defined by exposure to physical risks and hazards and the damage that is done, but also includes the capacity of communities to adapt. This capacity allows for individuals, households and cities to adjust to climatic changes, to mediate related damage, to cope with changes and take advantage of opportunities. Capacity to adapt is embodied in both the physical infrastructure within urban systems as well as urban socio-economic structures.

One of the main constraints on adaptive capacity for cities in the region is the number of those poor and marginalized, the elderly, and the young. These groups typically have lower access to formal services and depend in greater part on ecosystems services. Therefore, they are highly exposed to climate change effects and do not have high adaptive capacity. For example, the urban poor typically live in vulnerable ecological zones (high slopes, flood prone areas, waste dumps, etc.) and sometimes without land tenure. Even small perturbations in the supply of water sources affect these populations given that they largely depend upon informal arrangements (local private markets). Hence, not only do these groups have lower capacity to adapt, they are more vulnerable to the effects of climate change than other groups. Cities that have large population shares of the poor, elderly and young often have insufficient infrastructure to support the basic needs of these people and, therefore, suffer from an "adaptation deficit" (Satterthwaite et al. 2007).

As such, some have considered that not only are the effects of climate change predicted to be especially strongly in the town and cities of the least developed countries (Dodman 2011), it is those that face the highest risk to climate change events that have the most constraints on their capacity to adapt and, ironically, contribute the least to climate change (Bicknell et al. 2009; Costello et al. 2009).

While the Asia-Pacific region has experienced a decrease in the number of those in poverty; the total numbers that remain in a state of poverty continues to be of grave concern. Notwithstanding the significant drop of those in poverty over the past decades, there are still significant concerns for the poor. Unfortunately, due to the financial crisis, poverty reduction has slowed since 2008. Asia and the Pacific remains home to the largest number of those in poverty (Wan and Sebastian 2011). A recent report that examined climate variability and the adaptive capacity of 11 cities in Asia found the most vulnerable were those of lower income. The rating from most vulnerable to least included Dhaka, Jakarta, Manila, Calcutta, Phnom Penh, Ho Chi Minh City, Shanghai, Bangkok, Hong Kong, Kuala Lumpur and Singapore (World Wildlife Fund 2009). Dhaka was cited as having a large poor population located a few metres above sea level. Jakarta, Manila, Calcutta and Phnom Penh all have relatively low adaptive capacity.

3.5 Urban Mitigation and Adaptation Strategies in Asia and the Pacific

Urbanization of Asia and the Pacific includes billions of people and has unfolded in ways that both contribute to climate change and place much of this population at risk of climate change-related hazards. Given the low adaptive capacity of many cities much of the urban population is left vulnerable.

Continued growth without responding to climate change is unwise. A recent UN-Habitat (2011c) report calls for future urban development in the region to include "green and low carbon development," which was also the major focus of the recent 2012 Rio+20 conference. Otherwise, not only will the prosperity of the region suffer, but if certain "tipping points" or physical system thresholds are exceeded, evidence indicates that the Earth system may uncontrollably flip into an irreversible state. There is a real possibility that we will see a range of major large-scale events that will be beyond human management (Pearce 2007). Given the scale of urbanization, economic activity, GHG emissions and adaptation deficits; local, regional and global consequences could be significant.

Mitigation and adaptation are two responses to increasing climate change. The goals of these actions are to prevent "dangerous climate change" (Hansen et al. 2006) and avoid the costs of changing atmospheric dynamics and the cascading effects that will detrimentally affect high quality human development into the future. This section overviews mitigation and adaptation issues and action in Asia and the Pacific and although they are presented separately, these actions can be complementary, substitutable or independent of each other.

3.5.1 Urban Mitigation Strategies

Mitigation strategies and measures contribute to the stabilization of GHG concentrations in the atmosphere. This includes any action taken by individuals, corporations or governments to reduce GHG emissions. The goal of mitigation is to minimize the effects on global climate change and prevent "dangerous" anthropogenic interference with the climate system.

Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels. Studies indicate that there is substantial economic potential for the mitigation of global GHG emissions that could offset the projected growth of global emissions or reduce emissions below current levels (IPCC 2007c).

Mitigation measures have both sector and non-sector applications. A sector application might include methane emission reductions through waste management or sewage treatment, while a non-sector mitigation measure includes activities such as education, training and public awareness related to climate change.

3.5.1.1 Urban Design

Attention to evolution of urban form and layout has substantial potential to influence GHG budgets (Swart and Raes 2007; Hamin and Gurran 2009). Planning new urban areas can, from the start, include commuter rail, thus reducing congestion and transport-related emissions. Consideration of where people work, study and play can reduce problems of access that lead to sprawl, low density, dispersed and decentralized urban development (Alberti 2005; Ewing 1997) and long commutes (Hayashi et al. 2004).

Climate-appropriate architecture and placement of a building on a site can greatly reduce energy consumption. Insulation, trees and placement of windows have impacts on needs for air-conditioning, heating and lighting (Whitelegg and Williams 2000). Solar hot water heaters, heat pumps and fluorescent lighting are examples of key component technologies. For the city of Kyoto, Japan improvements in just household and commercial energy efficiency could cut 1990 emissions in half by 2030 (Jarvis 2003; Mokhtarian 2002). Makati City, Philippines has developed elevated walkways that connect tall buildings to reduce traffic and congestion (Prasad et al. 2008).

Vegetation in and around buildings and transport roots may contribute to climate control, reducing UHI effects (Barter 2000). Green spaces and parks can make a modest contribution to carbon sequestration, but more studies are needed to identify the effectiveness of this measure (Chin 2000; Pataki et al. 2006). Examples of the greening of cities have increased in the region over the last few decades. Singapore, known as the region's "Garden City" through a programme launched by Lee Kuan Yew, encouraged the planting of trees and the incorporation of grass verges, green corridors along roadways, trees, and parks into city developments. Emphasis has been placed on local flora, and encouraging ecological sensitive afforestation (Corfield 2008b; Prasad et al. 2008). Seoul has re-claimed the Cheonggyecheon River in the middle of the city, including the removal of a 5.6 km elevated highway. The new park provides tourism, recreation and UHI reduction benefits (Cho 2010). In Shanghai, the city's plan stresses the importance of incorporating greenbelts into downtown Shanghai within the layout of urban development. By 2008, the city's parks and urban green spaces reached 22,000 ha. In Shanghai, urban greenery rose from 1 m^2 per capita in 1990 to 12.5 m^2 per capita in 2008. Temperatures have dropped by 5 % since the increase in urban greenery and the widespread use of green roofs within the city. Moreover, Shanghai envisions that 30 % of the city will be covered by greenery by 2020 (Solecki 2011).

Urban spatial planning will often need to consider both adaptation and mitigation issues simultaneously as there may be complementarities as well as trade-offs (Sari and Salim 2005). For example, street trees and green spaces cool buildings but take space. Many adaptation actions appear to require more space and a less densely-built environment; modularity may be a solution. Coordination of urban land use and transport infrastructure is a key planning and governance issue.

3.5.1.2 Transportation

As transportation is a large and growing contributor to total GHG emissions, national governments are using a variety of mitigation measures in this sector including, *inter alia*, mandatory fuel economy and biofuel blending of fuels, taxes on vehicle purchases, registration, use and motor fuels and investments in public transportation infrastructure (IPCC 2007c).

At the local level, meeting the green mobility needs of people and for transport of goods within and among cities is a key issue for reducing GHG emissions. Different cities have taken different approaches reflecting differences in initial densities, roles in national economies and histories of investment in public mass-transit systems (Santos et al. 2010). Some cities in the region, like Singapore, have largely escaped the vehicle-trap, whereas others like Bangkok and Kuala Lumpur remain dominated by these modes of transport.

Well-designed systems are likely to be multi-modal (Lebel et al. 2007). In densely built-up areas non-motorized transport remains plausible if pedestrian areas are safe and convenient (Liu and Deng 2011). Mass-transit systems are particularly important for commuting to and from the workplace. Addressing mobility needs while reducing emissions is more challenging when it comes to how people shop or spend leisure time (Dhakal 2010).

Restraints or disincentives on private vehicle ownership along with promotion and investments in public transport are key (Savage 2006; Lebel 2004; McGranahan and Satterthwaite 2003). Singapore, for example, has used a mixture of incentives and regulatory instruments to control traffic congestion and emissions from cars, electronic road pricing, efficient public transport, and taxing car purchase and use (Solecki and Leichenko 2006; Barter 2005). Other cities in the region, such as Jakarta, Kunming and Seoul, have introduced “Bus Rapid Transit” and dedicated lanes (Hook 2005; Pucher et al. 2005). In Beijing and Shanghai, two- and three-wheeled motor vehicles were banned, stimulating the rapid rise in electronic bikes (E-bikes) (World Energy Council 2011). Making transport systems more sustainable will require a mix of policy instruments (Lebel et al. 2007).

3.5.1.3 Energy Production and Demand

The energy sector is the largest contributor of anthropogenic GHG emissions globally. National governments have attempted a number of different mitigation measures including the reduction of fossil fuel subsidies, taxes or carbon charges on fossil fuels, feed-in tariffs for renewable energy technologies, tax incentives and obligations for renewable energy technologies and energy producer subsidies and waste management regulations (IPCC 2007c). In Southeast Asia, while Singapore has the largest number of diverse activities for climate change mitigation, Thailand appears to have one of the most advanced national energy efficiency policies (including development of solar, wind, biomass, biogas, hydro, bio-fuels, geothermal and fuel cells) (Yuen and Kong 2009). Thailand’s policies are driven by the government’s intent on becoming a regional energy hub (Australian Business Council for Sustainable Energy 2005).

At the urban level, researchers have demonstrated that residential and commercial electricity consumption typically grows with wealth (Pachauri and Jiang 2008). People purchase more appliances to make homes and work places comfortable and convenient (Dhakal 2010). The levels of associated emissions depend on how and where that electricity is produced. Typically, and as noted previously, energy is produced outside but consumed inside urban areas; and inventories and reduction measures need to take these relationships into account (McGranahan 2005; Bai et al. 2010).

Electricity production is an important source of GHGs and the types and quality of fuels used to make electricity have major impact on emissions. In China, many cities are highly dependent on low-grade coal. Alternative energy sources such as wind, solar or biomass are options for some cities. The China low carbon city programme recognizes that exact mix of policies and targets should reflect local conditions. Singapore has adopted more efficient technologies such as combined-cycle gas turbines in gas-fired power plants, improving overall power generation from 37 % in 2000 to 44 % in 2004 (Prasad et al. 2008).

Policies to implement green energy sourcing are in effect in some cities in the region. Albay Province, Philippines, is developing geothermal energy and already the renewable source generates 25 % of its energy (Prasad et al. 2008). A solar city programme in Dezhou, China, has stimulated over 100 solar enterprises to install over 3 million m^2 of solar water heaters, which now account for 16 % of the national market. With this success, the city is now in the process of developing the China Solar Valley project, which is one of the biggest solar power projects in the country (ICLEI et al. 2009). In Rizhao, China, 99 % of households in the central districts use solar water heaters. Most of the traffic signals, street lights and parks are illuminated through photovoltaic cells. In addition, 6,000 households have solar cooking facilities and more than 60,000 greenhouses are heated by solar panels, thus reducing overhead costs for farmers (Bai 2007).

Another option for municipalities is to recycle and capture waste energy, for example, from the incineration of solid waste or through the capture of emissions from landfills. In cities with major industrial activities there may be other opportunities for waste heat capture. Waste management and methane recovery programmes, for example, have been initiated in Naga City, Philippines; Thungsong, Thailand; and Ratnagiri, India (ICLEI et al. 2009).

To lower demand actions at the local level, cities in the region have been addressing public lighting and building efficiency. In Makati City, Philippines; and Guntur and Jabalpur, India, programmes to replace street lights with more energy-efficient systems with programmable controls has reduced electricity consumption by up to 35 % (Prasad et al. 2008; ICLEI et al. 2009).

Energy efficient commercial and residential buildings are an important mitigation contribution (Levine et al. 2007). In Beijing, the China Agenda 21 Demonstration Energy-Efficient Office Building, which hosts the Chinese Ministry of Science and Technology has been built with a number of energy conservation features, including both building envelope and mechanical system measures, a cross-shaped building design was used to maximize day-lighting potential, windows were located on the north and south facades to better control solar heat gain, passive solar, photovoltaics and geothermal power systems. In India, the CII-Godrej Green Business Center (CII-Godrej GBC) building in Andhra Pradesh is the first Platinum-rated LEED-certified building outside the US, and was the most energy-efficient building in the world at the time it was rated. These are but a few of the energy efficient buildings springing up around the region (Hong et al. 2007).

Well-designed urban areas provide opportunities to install high quality energy distribution systems that are managed 'intelligently' with respect to peak and lower patterns of energy demand. Cities typically emphasize multiple local benefits when pursuing emission reductions.

3.5.1.4 Urban Development and Climate Change Mitigation Opportunities

While cities are sources of GHG emissions, urban areas are more carbon efficient because they offer greater access to public transport, shorter commuting distances to regularly used services, and smaller, more compact settlements and thus closer social connections than rural areas. Cities are nodes of exchange for goods, information and people that don't reside in them. These services are of value well beyond a city's boundary. The emissions embedded in goods and services flow to cities can be large. Carbon management needs to become more integrated, considering emissions and sequestration, and must also be multi-levelled to include emissions associated with energy production and diets that arise beyond city borders but because of consumption patterns within them (Lebel et al. 2007).

3.5.2 Urban Adaptation Strategies

Adaptation strategies are those that facilitate an adjustment in natural or human systems to a new or changing environment. For cities, climate adaptation strategies facilitate mechanisms necessary to address modifications brought upon by climate change. Researchers now believe that adaptation strategies are necessary to address the unavoidable impacts of climate change (IPCC 2007a).

Various types of adaptation are available to individuals and communities including anticipatory and reactive, private and public and autonomous and planned strategies. Moreover, responses include technological, behavioural, managerial and policy measures. In developing nations, some researchers are promoting community-based adaptation plans, which focus on addressing daily hazards, and as an extension also address climate risks (Satterthwaite et al. 2007). Adaptation plans enhance the adaptive capacity of communities and, as a result, reduce climate risk vulnerability.

The UNFCCC provides support for the formulation and implementation of national adaptation programs of action (NAPAs) in least developed countries. To date, 39 NAPAs have been submitted and many of them from the Asia-Pacific region (Bangladesh, Bhutan, Cambodia, Kiribati, Lao PDR, Maldives, Nepal, Samoa, Solomon Islands, Timor-Leste, Tuvalu and Vanuatu). At the same time, however, many nations in the region have prepared adaptation strategies and implemented adaptation policies at different governmental levels.

Some of these policies focus on cities. In India, for example, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was initiated in 2005. This mission targets 60 of the largest and most important cities in the country. The government provides US$10 billion for infrastructure development, urban poverty and improvements in urban governance. The Republic of Korea has developed a National Climate Change Adaptation Master Plan through the Framework Act on Low Carbon, Green Growth (LCGG). In this plan, local governments develop 5-year adaptation plans based on the national plan. These and other efforts demonstrate that there are adaptation options available for cities.

While there has been action at multiple levels to enhance adaptive capacity, more extensive adaptation measures are required to reduce vulnerability to future climate change (IPCC 2007a). Moreover, while there is increasing academic literature on adaptation options to climate change, few studies have considered urban areas, which require specific consideration and analytical approaches (for exceptions see Hallegatte et al. 2011; Hunt and Watkiss 2011; Rosenzweig et al. 2011). This subsection overviews adaptation action in urban water resources and infrastructure in coastal areas and urban food, transportation and energy systems.

3.5.2.1 Urban Water Resources and Infrastructure in Coastal Areas

Water resources adaptation could be the lead sector in reducing vulnerability to climate change, particularly in developing countries (Muller 2007). Adaptation strategies that address sea-level rise and increasing storm surges include, *inter alia*, setting up early warning systems; relocation of infrastructure and people away from flood zones; improving drainage and pumping systems in areas that flood; protection of infrastructure through building sea walls and barriers; creation and/or protection of existing natural barriers (marshland, wetlands and beaches); and reduction of wave energy through off-shore barriers. These have been organized into strategies that protect, accommodate or retreat (Leonard et al. 2008).

Adaptation strategies that address water supply include expanded rainwater harvesting, water storage and conservation techniques, water reuse, desalination and water-use and irrigation efficiency and integrated water resource management (World Bank 2011; Prasad et al. 2008).

Some sea-level rise and storm surge responses have been seen in the region. For example, climate change is considered in the design of infrastructure projects such as coastal defence in the Maldives. Local government in Navotas City, Metro Manila has implemented a programme to construct sea walls and pumping stations along the most vulnerable inundation zones (Prasad et al. 2008).

One of the strongest urban responses has been to flooding. Shanghai has developed a flood control project that is designed to both regulate water flow and facilitate water-quality monitoring. The project will provide water-level data in real time, enabling the water authority to see conditions across the entire region as they develop and make decisions to protect areas downstream from flooding or overflow. Hanoi, Viet Nam now has a comprehensive water adaptation programme, which includes actively improving flood preparedness and prevention standards, strengthening the dyke system to protect the right bank of the Red River and monitoring and responding to dyke emergencies (Prasad et al. 2008).

The extreme rainfall event of 2005 has been a lesson for Mumbai. The city is setting up a response mechanism based on real-time monitoring of rainfall at 27 locations in the city to handle recurrences of similar events in the future. The Central Water Power Research Station in Pune is currently in the process of preparing a detailed scale model for carrying out the hydraulic model studies for the Mithi River. This model is intended to provide a basis for long-term planning of Mumbai taking into account the impacts of climate change and sea level rise (Gupta 2006). Flood protection in Dhaka includes major changes in land use in Dhaka West. Improvements of the drainage system was highlighted by the 2008 Bangladesh Climate Change Strategy and Action plan (Alam and Rabbani 2007).

3.5.2.2 Food

One adaptation response to urban food system vulnerability has been to increase urban food production. Increasing urban agriculture reduces potential food price shocks and other disruptions that might arise with climate-related changes (Larsen and Barker-Reid 2009; UNDP 1996). Food may be grown in city open spaces (backyards, school yard, wastelands, rooftops, parks) and more high-tech agricultural spaces (hydroponic operations, aquaponics, greenhouses, vertical farms). Cities in Asia and the Pacific with formal policies and programmes to support urban agriculture include Bangkok, Beijing, Brisbane, Melbourne, Mumbai and Shanghai (Barata et al. 2011). In 2002, Beijing residents grew 55 % of the vegetables consumed in the city (Wang et al. 2009b). The city includes tens of thousands of household farms and the municipal government plans to cultivate gardens on 3 million m^2 of roof space over a 10-year period (Halweil and Nierenberg 2007). Many of those involved in this type of activity are migrants. One estimate suggests that over 600,000 migrants (17 % of the total that year) were engaged in activities directly related to urban agriculture (Wang et al. 2009b).

Urban agriculture occurs in cities without formal programmes, particularly in peri-urban areas. Peri-urban agriculture in Hyderabad, India plays an important role in supporting livelihoods of a diverse group of people from different castes, religions and social classes (Buechler and Devi 2002). Although there are only a few 100 vegetable growers along the Musi River, in a city of seven million, these farmers provide an important diversity of fresh vegetables to the city's markets (Jacobi et al. 2009). Urban agriculture may also indirectly contribute to sustainable management through the demand for urban open spaces, including flood zones, buffer zones, steep slopes, roadsides, river bank and water harvesting (Dubbeling et al. 2009). Many suggest that urban sustainability is tightly linked with the city's ability to feed part of its population (Halweil and Nierenberg 2007).

At the same time, urban agriculture still provides only a small percentage of food for most cities. The same climate challenges that face rural farmers also face urban farmers, and the challenges are greater in urban areas. There are risks from urban agriculture particularly when wastewater is used to irrigate crops or food is grown in contaminated soils (Cole et al. 2008).

3.5.2.3 Transportation

Adaptive transportation strategies include realignment and/or relocation of infrastructure and implementing design standards and planning for roads, rail and other infrastructure to cope with warming and drainage (World Bank 2011). For example, both Taipei's subway entrances were raised to avoid flash flooding and, like Japan, the inter-city trains are on elevated tracks to avoid flooding during the typhoon season (Mehrotra et al. 2011). Generally, it is important for all transportation networks to avoid flood-prone areas and incorporate climate change into all relevant decisions concerning transportation infrastructure (Coffee et al. 2010). For cities exposed to flooding, zoning rules can be used to relocate existing storage yards for buses and train cars out of flood-prone areas (Mehrotra et al. 2011).

During the expansion of transportation infrastructure, inclusion of informal settlements in regular service may require serving marginal land, but can also have co-benefits for economic development and poverty reduction by providing residents with better access to jobs and business opportunities (World Bank 2011).

Green infrastructure can help make transportation more resilient, with direct advantages such as decreasing run-off during rainstorms and indirect advantages such as improving water and air quality (Bloomberg 2010). Research has shown that pervious pavements can lead to a reduced need for road salt application on streets in the winter by as much as 75 % (Foster et al. 2011).

Low-cost adaptation options in the transportation sector include improving transportation customer communications, retrofitting existing bus fleets with white roofs to reduce solar heat gain; ventilation to ensure adequate air circulation; and working with ports and maritime businesses to synchronize shipping schedules around high tides to avoid problems with bridge clearance (World Bank 2011).

Recent research argues that Asia lags in formulating and implementing adaptation strategies for the transportation sector. One study surveyed 21 countries around the region and the results highlight low awareness of climate change impacts on transportation (75 % recorded low awareness by policy-makers). Moreover, the majority of the respondents indicated that there are no existing laws, rules or guidelines to assess environmental and climate change impacts (Regmi and Hanaoka 2011).

3.5.2.4 Energy Transmission and Efficiency

Adaptation strategies for energy systems include underground cabling for utilities, strengthening of overhead transmission and distribution infrastructure, using renewable sources and reducing dependence on single sources of energy (Prasad et al. 2008). The World Bank (2011) argues that energy efficiency, conservation and renewable energy investments serve as important adaptation and mitigation strategies. Conservation and efficiency programmes can reduce peak electricity demand and limit the risk of blackouts, while developing distributed energy systems involving co-generation and local renewable energy can buffer the effects of interruptions in transmission. Crucial components of any urban-related adaptation policies are vulnerability assessments, emergency warning systems and adjustments in design standards to reflect climate impacts on the energy sector.

3.5.3 Urban Climate Change Policy and Governance

Governance is a crucial part of any mitigation and adaptation strategy. A growing number of municipalities, NGOs and civil society organizations have been involved in actions to reduce GHG emissions and formulate and implement adaptation measures. In the bigger picture, responses to climate may best be served at all governance levels including the local, with the urban level an important site for addressing climate change (Bulkeley 2010).

As such there has been much attention given to the planning and development of various strategies and the underlying reasoning as to why these measures are appropriate and why they should be effective for cities in the region (Prasad et al. 2008; UN-Habitat 2011b; World Bank 2011). These normative studies have been important because they not only provide guidelines, but point out best practices and, therefore, highlight on-going activities and showcase successes.

From these types of studies several policy recommendations have been offered for cities in Asia and the Pacific. There are, at least, five areas of policy concern including: development and disaster risk management; capacity building; local participation; financing; and sector specific strategies. This chapter reviews several sector specific strategies. We restrict our review in this section to the cross-cutting issues and provide thoughts on opportunities for urban climate governance.

3.5.3.1 Development and Disaster Risk Management Strategies

Many policy and governance studies emphasize the importance of integrating climate adaptation and mitigation strategies with development and disaster risk management strategies. Although particularly important in developing world cities, focusing on the local development needs when developing and implementing climate policies is considered to be a good idea for all cities. For example, sustainable development policies include lowering the share of the urban population with poor housing. This is not only a development policy, but also a risk reduction policy, as those in poor housing also typically live in high risk areas. Adaptation policies include finding secure tenure for all residents in areas away from potential flood zones or protecting these areas from future exposure to climate related hazards. Pro-poor strategies are a necessary component of adaptation as most of those at risk are in low income communities with low adaptive capacity (Satterthwaite et al. 2007). At the same time, all communities would benefit from a review of land use planning and regulations with an eye on incentives and restrictions related to building in storm surge areas or on building and materials standards that address reducing GHG emissions.

Furthermore, development strategies include planning for the long term economic, social and environmental health of the city. City planning and infrastructure decisions can "lock in" urban form and particular sector strategies for long periods of time, especially when physical investments have extended life spans. City decision makers have been advised to strategically plan for the future and include mitigation and adaptation strategies within these plans (UN-Habitat 2009).

For developed and developing world cities, disaster risk management policies focus on the need for risk assessments for exposed cities and populations within cities, early warning systems and evacuation plans including emergency preparedness and neighbourhood response systems and improved education about climate risks (Kovats and Akhtar 2008). In any context, these policies can double as those for adaptation, if the focus of the disaster is on climate related risks.

3.5.3.2 Capacity Building

Improving capacity within government and civil society is considered a key ingredient for policy and governance. Given global trends in decentralization, this is a major challenge, as national governments are increasingly less able or willing to support local government (Satterthwaite et al. 2007).

As climate change impacts are local, local decision makers and stakeholders need to improve their understanding of climate change, its potential impacts in their context, appropriate options for responses and their ability to effectively collaborate. City governments are responsible for decisions and actions related to the delivery of a wide range of services that can be improved with mitigation and adaptation strategies including: land use planning and zoning; water supply, sanitation, and drainage; housing construction, renovation, and regulation; economic development; public health and emergency management; and transportation and environmental protection. Stakeholders and bureaucrats working within any of these sectors can benefit from capacity building to reduce vulnerability and GHG emissions.

Moreover, rarely does a single city agency have the authority for all planning decisions and investments that shape urban form and responses to climate change, nor do city agencies act alone. Indeed, the literature calls for agencies to engage in "joined-up thinking" (Revi 2009). Climate change mitigation and adaptation in cities requires collaborative problem-solving and coordination across sectors. This is also true in the governance context. As municipalities are often called upon to act as conveners of a wide range of partners, collaborative skills that help to bring together broad partnerships that include other governments, local communities, non-profit organizations, academic institutions, and the private sector are considered critical to success (World Bank 2011).

3.5.3.3 Participation

Participation is a key ingredient in good governance and, therefore, effective development of mitigation and adaptation policies. For example, a city land-use planning process can be an arena in which stakeholders make and institutionalize key decisions relating to the energy sector, such as where to site energy infrastructure and how to address traffic congestion. With local knowledge through participating civil society organizations, energy and other vital infrastructure can be planned to effectively reduce populations living in vulnerable locations.

Participation from all local groups that are exposed to climate change hazards is particularly important for adaptation measures. While climate change is a global phenomenon, adaptation hinges on the quality of local knowledge, local capacity and the willingness to act (Satterthwaite et al. 2007). It is, therefore, necessary to have local citizens participate in adaptation strategy development and implementation.

Those that have been and are currently exposed to climate-related risks are already coping. While these actions are not formal they are in many cases effective, although only as immediate responses. To develop long term effective strategies the knowledge and experience as well as the needs of these groups must be included in all urban climate policies. Moreover, to develop adaptation strategies and maintain effective mitigation strategies the affected, including the poor, need to be brought into the formal process.

3.5.3.4 Insurance and Financing

Insurance and finance help to reduce economic risk and are key to infrastructure and housing development. Interestingly, the global insurance industry has demonstrated increasing interest in climate change research and in climate change-related urban vulnerabilities (Munich Re Foundation 2011; Dailey et al. 2009; Swiss Re 2006; Lloyd's 2008). The consensus goal of the industry is to take a more leading role in understanding and managing the impacts of climate change. Insurers realize that understanding climate-related risk is necessary to inform underwriting strategy (from the pricing of risk to the wording of policies), for business counselling purposes (including business development and planning) and to help to create meaningful, tangible partnerships to mitigate risk (Lloyd's 2008).

While this may be effective in developed cities, where much of the insurance risk exposure is located, there is a desperate need for insurance in cities of developing nations (Wilbanks et al. 2007). Approximately 99 % of households and businesses in low income nations do not have disaster insurance (Satterthwaite et al. 2007). In this case, and particularly for the urban poor, macro- and micro- climate insurance may provide some relief (Pierro and Desai 2008).

3.5.3.5 Opportunities for Urban Policy and Governance Research

Despite the large and growing literature on climate change adaptation policies, the reality is that urban climate governance has largely focused on mitigation (Satterthwaite et al. 2007). Even with mitigation strategies, cities have failed to pursue systematic and structural approaches to GHG reductions and instead prefer to implement no-regret measures on a case by case basis (Alber and Kern 2008). That is, while research and transnational municipal networks have advocated a systematic approach to urban mitigation strategies including GHG emission assessment, target setting and performance monitoring, many cities have failed to implement this approach.

Most measures are undertaken in the energy sector (with notable exceptions such as London and New York City) and GHG emissions reductions are typically restricted to municipal sources. A review of the literature suggests that two key issues lie at the heart of the gaps between the rhetoric and reality of urban responses; institutional capacity of municipalities and the political economy within which such approaches are framed and implemented (Bulkeley 2010). The first issue includes constraints such as jurisdictional boundary limitations or municipal resources and the second issue includes limitations of political leadership or the lack of complementarity of climate change policies and other social and economic goals. The author of the review argues, therefore, that opportunities for understanding the lack of progress in both systematic mitigation policy and adaptation measures exist. These include a focus on the relationship between public and private authority, the ways in which the policy problem of climate change is constituted and the basis of policy interventions in the infrastructures that mediate human-environment relations. Engaging issues of power underpinning urban outcomes, for example, may provide new insights into the influences of climate governance and environmental justice within and out with the city.

3.6 Conclusions: Resilient Cities in Asia and the Pacific

3.6.1 Urbanization and Resilience

Climate resilient cities are those that can withstand climate effects and not change dramatically. That is, they include biophysical and socio-economic sub-systems that can withstand floods, intense storms, heat waves, droughts, etc., and continue to develop in a fairly predictable manner. Cities that are not resilient change dramatically to new states with new relationships emerging both within the socio-economic sub-system and between the socio-economic and biophysical sub-systems. Resilient cities are sustainable cities, in that they can function with shocks. Resilience can only be achieved when urban areas move along a more sustainable pathway. The goal of policy makers and stakeholders for their individual urban centres, urban regions as well as nations in the face of climate change is to enhance resilience. In the present review of cities in the Asia-Pacific region, we identify some important aspects that impinge on this goal. Addressing uncertainties, research gaps and policy needs related to climate change and urbanization will help make cities in the region more resilient.

3.6.2 Uncertainties

Uncertainty includes imperfect knowledge of both the current trends and conditions the region is experiencing and future predictions. In this case, there is considerable uncertainty as to the exact types and intensities of changes in climate that the region will experience, the cascading effects of these changes as well as the current trends. Those estimating regional change (from population to GHG emissions to climate) know all too well the limitations of the currently available data and the models. For example, in this study we use UN population statistics to describe urbanization. These statistics, however, are not standardized across countries, meaning that the definition of urban varies by nation. As discussed in the present Chapter, estimates of GHG emissions from cities vary, in large part, because researchers use different information and different methods to calculate emissions.

Some response from the scientific community has been to provide ranges for future estimates and to qualify statements about specific current trends. These are important qualifications that allow readers to assess the validity of the data. Another way is to provide the scientific consensus on issues, stating whether the community of researchers agrees and to what level on specific issues.

Unfortunately, due to the newness of many of the aspects under study that we present here, it is difficult to identify a community consensus in all issues. We have, however, attempted to identify the major trends that the region is undergoing as key findings. These findings, we believe, most researchers and scholars working in this area would agree upon.

Notwithstanding the uncertainties in the data and methods, however, there are good reasons to fault on the side of caution. Termed the precautionary principle, decision makers and stakeholders would benefit in the face of uncertainty to weigh the desirable actions on the side of the lowest risk of harm. In this way, decisions are prudent and protections relaxed when scientific findings provide sound evidence that no, or acceptable, harm will result. Moreover, and related to this concept, despite uncertainties, the no-regrets policy approach argues that actions must be taken now to build capacity and adapt to long term climate changes.

3.6.3 Research Gaps

As mentioned throughout the present Chapter there are areas in research on climate and urbanization that need further attention. We have identified five important research gaps.

The first is the lack of information and study on the urbanization dynamics and socio-ecological relationships in medium and smaller settlements. Much of the findings that we identified are through studies of the largest and perhaps best managed cities in the region. Less is known of the smaller urban centres.

Second, there is more need for data collection and monitoring, particularly spatial information in terms of urban socio-economic changes and linkages to climate. Importantly, researchers need to continue to work on urban GHG protocols so that cross urban differences can be better evaluated.

Third, there is much work to be performed in understanding the options for and costs and impacts of sector-wide mitigation strategies at the urban level. In this regard, not only do we need to further evaluate strategies for different sectors, but better understand any potential trade-offs between different sectors and between mitigation and adaptation measures.

Fourth, there is a need to develop a better understanding of the costs of adaptation, particularly for small- and medium-sized communities and also for vulnerable populations. Given that these communities are already burdened by weather-related hazards, the task for researchers has become more urgent.

Finally, as mentioned above, there needs to be a better understanding of the factors behind urban climate governance. While transitions have occurred, the exact mechanisms as to the triggers and contexts are not well understood.

3.6.4 Policy Needs

We have already presented several areas where the research community would like to see policy movement. In this section we highlight some issues that emerge from the findings of the present Chapter. These include four main policy arenas.

First, given the large urban population and the predicted changes to come, urban climate policy must be developed at all levels of governance. Cities cannot alone address the challenges they face. Policy support is needed at the national and international levels. The urbanization of the Asia-Pacific region has global implications for economic growth and climate.

Second, and related to the first, is that more attention is needed to develop effective mitigation measures across different sectors. These measures must be tailored for each individual urban context and be part of an appropriate strategic/flexible systems planning effort. Short-, medium- and long-term strategies are needed to develop responses that will not "lock-in" carbon intensive trajectories.

Third, the cities, nations and global institutions need to place more effort in developing adaptation strategies under a no-regrets policy framework. The large vulnerable urban population must be included in the development of these policies and plans. Moreover, policies focused on reducing everyday risk in these communities will go a long way to reducing climate risk and increasing adaptive capacity.

Fourth, there should be more emphasis on retaining functioning ecosystems within and around urban areas as part of mitigation and adaptation strategies. As mentioned at several points in this Chapter, using ecosystem services offers options for GHG mitigation and given that the poor often depend upon these services, they should be part of adaptation strategies as well.

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