ipcc

INTERGOVERNMENTAL PANEL ON Climate Change

Climate Change 2022

Mitigation of Climate Change



WGIII

Working Group III contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

WMO UNEP

8 Urban Systems and Other Settlements

Coordinating Lead Authors:
Shuaib Lwasa (Uganda), Karen C. Seto (the United States of America)

Lead Authors:
Xuemei Bai (Australia), Hilda Blanco (the United States of America), Kevin R. Gurney (the United States of America), Şiir Kılkış (Turkey), Oswaldo Lucon (Brazil), Jin Murakami (Japan), Jiahua Pan (China), Ayyoob Sharifi (Japan/Iran), Yoshiki Yamagata (Japan)

Contributing Authors:
Vanesa Castán Broto (United Kingdom/Spain), Winston Chow (Singapore), Galina Churkina (the Russian Federation/Germany), Felix Creutzig (Germany), David Dodman (Jamaica/United Kingdom), Burak Güneralp (Turkey/the United States of America), Rafiq Hamdi (Belgium), Bronwyn Hayward (New Zealand), Angel Hsu (the United States of America/Singapore), Lucy Hutyra (the United States of America), Nadja Kabisch (Germany), Meredith Keller (the United States of America), Timon McPhearson (the United States of America), Peter Newman (Australia), David Nowak (the United States of America), Alan Organschi (the United States of America), Minal Pathak (India), Mark Pelling (United Kingdom), Clara Pregitzer (the United States of America), Anu Ramaswami (the United States of America), Mia Reback (the United States of America), Diana Reckien (Germany), Jen Shin (the United States of America), Michael Westphal (the United States of America), Lee White (Australia)

Review Editors:
Carolina Burle Schmidt Dubeux (Brazil), Diana Ürge-Vorsatz (Hungary)

Chapter Scientists:
Meredith Keller (the United States of America), Enock Ssekuubwa (Uganda)

This chapter should be cited as:
Lwasa, S., K.C. Seto, X. Bai, H. Blanco, K.R. Gurney, Ş. Kılkış, O. Lucon, J. Murakami, J. Pan, A. Sharifi, Y. Yamagata, 2022: Urban systems and other settlements. In IPCC, 2022: *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.010

8

Table of Contents

Executive Summary 863

8.1 Introduction 866
8.1.1 What Is New Since AR5? 866
8.1.2 Preparing for the Special Report on Cities and Climate Change in AR7 867
8.1.3 The Scope of the Chapter: A Focus on Urban Systems 867
8.1.4 The Urban Century 868
8.1.5 Urbanisation in Developing Countries 871
8.1.6 Urban Carbon Footprint 871

8.2 Co-benefits and Trade-offs of Urban Mitigation Strategies 873
8.2.1 Sustainable Development 873
8.2.2 Economic Development, Competitiveness, and Equity 875
8.2.3 Coupling Mitigation and Adaptation 876
Cross-Working Group Box 2: Cities and Climate Change 877

8.3 Urban Systems and Greenhouse Gas Emissions 880
8.3.1 Trends in Urban Land Use and the Built Environment 880
8.3.2 Informal Urban Settlements 884
8.3.3 Trends in Urban Greenhouse Gas Emissions 884
8.3.4 Scenarios of Future Urbanisation and Greenhouse Gas Emissions 887
Box 8.1: Does Urbanisation Drive Emissions? 887

8.4 Urban Mitigation Options 894
8.4.1 Avoiding Carbon Lock-in 894
8.4.2 Spatial Planning, Urban Form, and Infrastructure 896
8.4.3 Electrification and Switching to Net-Zero-Emissions Resources 899
8.4.4 Urban Green and Blue Infrastructure 902
Box 8.2: Urban Carbon Storage: An Example from New York City 905
8.4.5 Socio-behavioural Aspects 908
8.4.6 Urban-Rural Linkages 910
8.4.7 Cross-sectoral Integration 910

8.5 Governance, Institutions, and Finance 911
8.5.1 Multi-level Governance 912
Box 8.3: Coordination of Fragmented Policymaking for Low-carbon Urban Development: Example from Shanghai, China 913
8.5.2 Mitigation Potential of Urban Subnational Actors 913
8.5.3 Urban Climate Networks and Transnational Governance 914
Box 8.4: Net-zero Targets and Urban Settlements 914
8.5.4 Financing Urban Mitigation 915
8.5.5 Barriers and Enablers for Implementation 916

8.6 A Roadmap for Integrating Mitigation Strategies for Different Urbanisation Typologies 919
8.6.1 Mitigation Opportunities for *Established* Cities 921
8.6.2 Mitigation Opportunities for *Rapidly Growing* Cities 922
8.6.3 Mitigation Opportunities for *New and Emerging* Cities 922

8.7 Knowledge Gaps 925
8.7.1 COVID-19 and Cities 925
8.7.2 Future Urban Emissions Scenarios 926
8.7.3 Urban Emissions Data 926

Frequently Asked Questions (FAQs) 927
FAQ 8.1: Why are urban areas important to global climate change mitigation? 927
FAQ 8.2: What are the most impactful options cities can take to mitigate urban emissions, and how can these be best implemented? 927
FAQ 8.3: How do we estimate global emissions from cities, and how reliable are the estimates? 927

References 928

Executive Summary

Although urbanisation is a global trend often associated with increased incomes and higher consumption, the growing concentration of people and activities is an opportunity to increase resource efficiency and decarbonise at scale (*very high confidence*). The same urbanisation level can have large variations in per capita urban carbon emissions. For most regions, per capita urban emissions are lower than per capita national emissions. {8.1.4, 8.3.3, 8.4, Box 8.1}

Most future urban population growth will occur in developing countries, where per capita emissions are currently low but expected to increase with the construction and use of new infrastructure and the built environment, and changes in incomes and lifestyles (*very high confidence*). The drivers of urban greenhouse gas (GHG) emissions are complex and include an interplay of population size, income, state of urbanisation, and how cities are laid out (i.e. urban form). How new cities and towns are designed, constructed, managed, and powered will lock-in behaviour, lifestyles, and future urban GHG emissions. Low-emission urbanisation can improve well-being while minimising impact on GHG emissions, but there is risk that urbanisation can lead to increased global GHG emissions through increased emissions outside the city's boundaries. {8.1.4, 8.3, Box 8.1, 8.4, 8.6}

The urban share of global GHG emissions (including carbon dioxide (CO_2) and methane (CH_4)) is substantive and continues to increase (*high confidence*). In 2015, urban emissions were estimated to be 25 $GtCO_2$-eq (about 62% of the global share) and in 2020, 29 $GtCO_2$-eq (67–72% of the global share).[1] About 100 of the highest emitting urban areas account for approximately 18% of the global carbon footprint. {8.1.6, 8.3.3}

The urban share of regional GHG emissions increased between 2000 and 2015, with much inter-region variation in the magnitude of the increase (*high confidence*). Globally, the urban share of national emissions increased 6 percentage points, from 56% in 2000 to 62% in 2015. For 2000 to 2015, the urban emissions share across AR6 WGIII regions increased from 28% to 38% in Africa, from 46% to 54% in Asia and Pacific, from 62% to 72% in Developed Countries, from 57% to 62% in Eastern Europe and West-Central Asia, from 55% to 66% in Latin America and Caribbean, and from 68% to 69% in the Middle East. {8.1.6, 8.3.3}

Per capita urban GHG emissions increased between 2000 and 2015, with cities in the Developed Countries region producing nearly seven times more per capita than the lowest emitting region (*medium confidence*). From 2000 to 2015, global urban GHG emissions per capita increased from 5.5 to 6.2 tCO_2-eq per person (an increase of 11.8%); Africa increased from 1.3 to 1.5 tCO_2-eq per person (22.6%); Asia and Pacific increased from 3.0 to 5.1 tCO_2-eq per person (71.7%); Eastern Europe and West-Central Asia increased from 6.9 to 9.8 tCO_2-eq per person (40.9%); Latin America and Caribbean increased from 2.7 to 3.7 tCO_2-eq per person (40.4%); and Middle East increased from 7.4 to 9.6 tCO_2-eq per person (30.1%). Albeit starting from the highest level, Developed Countries had a decline of 11.4 to 10.7 tCO_2-eq per person (–6.5%). {8.3.3}

The global share of future urban GHG emissions is expected to increase through 2050, with moderate to low mitigation efforts, due to growth trends in population, urban land expansion, and infrastructure and service demands, but the extent of the increase depends on the scenario and the scale and timing of urban mitigation action (*medium confidence*). In modelled scenarios, global consumption-based urban CO_2 and CH_4 emissions are projected to rise from 29 $GtCO_2$-eq in 2020 to 34 $GtCO_2$-eq in 2050 with moderate mitigation efforts (intermediate GHG emissions, SSP2–4.5), and up to 40 $GtCO_2$-eq in 2050 with low mitigation efforts (high GHG emissions, SSP3–7.0). With aggressive and immediate mitigation policies to limit global warming to 1.5°C (>50%) with no or limited overshoot by the end of the century (very low emissions, SSP1–1.9), including high levels of electrification, energy and material efficiency, renewable energy preferences, and socio-behavioural responses, urban GHG emissions could approach net-zero and reach a maximum of 3 $GtCO_2$-eq in 2050. Under a scenario with aggressive but not immediate urban mitigation policies to limit global warming to 2°C (>67%) (low emissions, SSP1–2.6), urban emissions could reach 17 $GtCO_2$-eq in 2050.[2] (Figure TS.13) {8.3.4}

Urban land areas could triple between 2015 and 2050, with significant implications for future carbon lock-in. There is a large range in the forecasts of urban land expansion across scenarios and models, which highlights an opportunity to shape future urban development towards low- or net-zero GHG emissions and minimise the loss of carbon stocks and sequestration in the agriculture, forestry and other land use (AFOLU) sector due to urban land conversion (*medium confidence*). By 2050, urban areas could increase up to 211% over the 2015 global urban extent, with the median projected increase ranging from 43% to 106%. While the largest absolute amount of new urban land is forecasted to occur in Asia and Pacific, and in Developed Countries, the highest rate of urban land growth is projected to occur in Africa, Eastern Europe and West-Central Asia, and in the Middle East. The infrastructure that will be constructed concomitant with urban land expansion will lock-in patterns of energy consumption that will persist for decades if not generations. Furthermore, given past trends, the expansion of urban areas is likely to take place on agricultural lands and forests, with implications for the loss of carbon stocks and sequestration. {8.3.1, 8.3.4, 8.4.1, 8.6}

The construction of new, and upgrading of, existing urban infrastructure through 2030 will result in significant emissions (*very high confidence*). The construction of new and upgrading

[1] These estimates are based on consumption-based accounting, including both direct emissions from within urban areas, and indirect emissions from outside urban areas related to the production of electricity, goods, and services consumed in cities. Estimates include all CO_2 and CH_4 emission categories except for aviation and marine bunker fuels, land-use change, forestry, and agriculture. {8.1, Annex I: Glossary}

[2] These scenarios have been assessed by WGI to correspond to intermediate, high, and very low GHG emissions.

of existing urban infrastructure using conventional practices and technologies can result in significant committed CO_2 emissions, ranging from 8.5 $GtCO_2$ to 14 $GtCO_2$ annually up to 2030 and more than double annual resource requirements for raw materials to about 90 billion tonnes per year by 2050, up from 40 billion tonnes in 2010 (*medium evidence*, *high agreement*). {8.4.1, 8.6}

Given the dual challenges of rising urban GHG emissions and future projections of more frequent extreme climate events, there is an urgent need to integrate urban mitigation and adaptation strategies for cities to address climate change and withstand its effects (*very high confidence*). Mitigation strategies can enhance resilience against climate change impacts while contributing to social equity, public health, and human well-being. Urban mitigation actions that facilitate economic decoupling can have positive impacts on employment and local economic competitiveness. {8.2, Cross-Working Group Box 2, 8.4}

Cities can only achieve net-zero GHG emissions through deep decarbonisation and systemic transformation (*very high confidence*). Three broad mitigation strategies have been found to be effective in reducing emissions when implemented concurrently: (i) reducing or changing urban energy and material use towards more sustainable production and consumption across all sectors, including through compact and efficient urban forms and supporting infrastructure; (ii) electrification and switching to net-zero-emissions resources; and (iii) enhancing carbon uptake and storage in the urban environment (*high evidence*, *high agreement*). Given the regional and global reach of urban supply chains, cities can achieve net-zero emissions only if emissions are reduced within and outside of their administrative boundaries. {8.1.6, 8.3.4, 8.4, 8.6}

Packages of mitigation policies that implement multiple urban-scale interventions can have cascading effects across sectors, reduce GHG emissions outside of a city's administrative boundaries, and reduce more emissions than the net sum of individual interventions, particularly if multiple scales of governance are included (*high confidence*). Cities have the ability to implement policy packages across sectors using an urban systems approach, especially those that affect key infrastructure based on spatial planning, electrification of the urban energy system, and urban green and blue infrastructure. The institutional capacity of cities to develop, coordinate, and integrate sectoral mitigation strategies within their jurisdiction varies by context, particularly those related to governance, the regulatory system, and budgetary control. {8.4, 8.5, 8.6}

Integrated spatial planning to achieve compact and resource-efficient urban growth through co-location of higher residential and job densities, mixed land use, and transit-oriented development (TOD) could reduce GHG emissions between 23% and 26% by 2050 compared to the business-as-usual scenario (*robust evidence*, *high agreement*, *very high confidence*). Compact cities with shortened distances between housing and jobs, and interventions that support a modal shift away from private motor vehicles towards walking, cycling, and low-emissions shared and public transportation, passive energy comfort in buildings, and urban green infrastructure can deliver significant public health benefits and have lower GHG emissions. {8.2, 8.3.4, 8.4, 8.6}

Urban green and blue infrastructure can mitigate climate change through carbon sequestration, avoided emissions, and reduced energy use while offering multiple co-benefits (*robust evidence*, *high agreement*). Urban green and blue infrastructure, including urban forests and street trees, permeable surfaces, and green roofs[3] offer potential to mitigate climate change directly through sequestering and storing carbon, and indirectly by inducing a cooling effect that reduces energy demand and reducing energy use for water treatment. Global urban trees store approximately 7.4 billion tonnes of carbon, and sequester approximately 217 million tonnes of carbon annually, although urban tree carbon storage and sequestration are highly dependent on biome. Among the multiple co-benefits of green and blue infrastructure are reducing the urban heat island (UHI) effect and heat stress, reducing stormwater runoff, improving air quality, and improving mental and physical health of urban dwellers. {8.2, 8.4.4}

The potential and sequencing of mitigation strategies to reduce GHG emissions will vary depending on a city's land use, spatial form, development level, and state of urbanisation (i.e., whether it is an established city with existing infrastructure, a rapidly growing city with new infrastructure, or an emerging city with infrastructure buildup (*high confidence*). New and emerging cities will have significant infrastructure development needs to achieve high quality of life, which can be met through energy-efficient infrastructures and services, and people-centred urban design (*high confidence*). The long lifespan of urban infrastructures locks in behaviour and committed emissions. Urban infrastructures and urban form can enable socio-cultural and lifestyle changes that can significantly reduce carbon footprints. Rapidly growing cities can avoid higher future emissions through urban planning to co-locate jobs and housing to achieve compact urban form, and by leapfrogging to low-carbon technologies. Established cities will achieve the largest GHG emissions savings by replacing, repurposing, or retrofitting the building stock, targeted infilling and densifying, as well as through modal shift and the electrification of the urban energy system. New and emerging cities have unparalleled potential to become low or net-zero GHG emissions while achieving high quality of life by creating compact, co-located, and walkable urban areas with mixed land use and transit-oriented design, that also preserve existing green and blue assets. {8.2, 8.4, 8.6}

With over 880 million people living in informal settlements, there are opportunities to harness and enable informal practices and institutions in cities related to housing, waste, energy, water, and sanitation to reduce resource use and mitigate climate change (*low evidence*, *medium agreement*). The upgrading of informal settlements and inadequate housing to improve resilience and well-being offers a chance to create a low-carbon transition. However, there is limited quantifiable data on

[3] These examples are considered to be a subset of nature-based solutions or ecosystem-based approaches.

these practices and their cumulative impacts on GHG emissions. {8.1.4, 8.2.2, Cross-Working Group Box 2, 8.3.2, 8.4, 8.6, 8.7}

Achieving transformational changes in cities for climate change mitigation and adaptation will require engaging multiple scales of governance, including governments and non-state actors, and in connection with substantive financing beyond sectoral approaches (*very high confidence*). Large and complex infrastructure projects for urban mitigation are often beyond the capacity of local municipality budgets, jurisdictions, and institutions. Partnerships between cities and international institutions, national and regional governments, transnational networks, and local stakeholders play a pivotal role in mobilising global climate finance resources for a range of infrastructure projects with low-carbon emissions and related spatial planning programmes across key sectors. {8.4, 8.5}