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Renewables in Cities - 2019 Global Status Report

Couture, Toby; Busch, Henner; Hansen, Teis; Guerra, Flávia; Leidreiter, Anna ; Murdoch, Hannah; Ranalder, Lea; Seyboth, Kristin

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Total number of authors:

8

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

RENEWABLES IN CITIES

2019 GLOBAL STATUS REPORT



CITY
NOW

2019

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 Greenpeace International
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 Solar Cookers International (SCI)
 World Council for Renewable Energy (WCRE)
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 World Wildlife Fund (WWF)

MEMBERS AT LARGE

Michael Eckhart
 Mohamed El-Ashry
 David Hales
 Kirsty Hamilton
 Peter Rae
 Arthouros Zervos

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SCIENCE AND ACADEMIA

AEE – Institute for Sustainable Technologies (AEE INTEC)
 Council on Energy, Environment and Water (CEEW)
 Fundación Bariloche (FB)
 International Institute for Applied Systems Analysis (IIASA)
 International Solar Energy Society (ISES)
 National Renewable Energy Laboratory (NREL)
 National Research University Higher School of Economics (HSE)
 South African National Energy Development Institute (SANEDI)
 The Energy and Resources Institute (TERI)

CHAIR

Arthouros Zervos
 National Technical University of Athens (NTUA)

EXECUTIVE SECRETARY

Rana Adib
 REN21



REN21

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REN21 is an international policy network of experts from governments, inter-governmental organisations, industry associations, non-governmental organisations, science and academia. It grows from year to year and represents an increasing diversity of sectors. REN21 provides a platform for this wide-ranging community to exchange information and ideas, to learn from each other and to collectively build the renewable energy future.

This network enables the REN21 Secretariat to, among other activities, produce this first edition of the *Renewables in Cities 2019 Global Status Report (REC-GSR)*, making the report a truly collaborative effort.



REN21 COMMUNITY INVOLVEMENT IN THE REC-GSR:



380

experts contributed to the REC-GSR, working alongside an international authoring team and the REN21 Secretariat



61%

of contributors are new members of the REN21 Community, indicating the attractiveness of this focus on cities in the energy transition



More than

50

interviews were conducted with city or sector-specific experts from around the world

RENEWABLE ENERGY POLICY NETWORK FOR THE 21st CENTURY

REN21: RENEWABLES NOW!

REN21 is the only global renewable energy community of actors from science, governments, NGOs and industry. We provide up-to-date and peer-reviewed facts, figures and analysis of global developments in technology, policies and markets.

Our goal: enable decision-makers to make the transition to renewable energy happen – now!

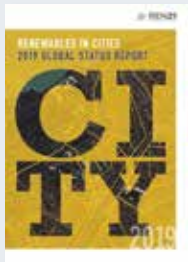
**Making
the invisible
visible.**

REN21 changes the way we think about renewable energy.

SHAPE THE FUTURE



KNOWLEDGE



RENEWABLE IN CITIES - GLOBAL STATUS REPORT (REC-GSR)

The cities report is the first comprehensive resource to map out the current trends and renewable energy developments in cities. It uses the same rigorous standards found in the *Renewables Global Status Report* series.



RENEWABLES GLOBAL STATUS REPORT (GSR)

First released in 2005, this report is the industry standard for the status of renewables for a given year. The GSR's robust process for collecting data and information makes it the most frequently referenced report on renewable energy market, industry and policy trends.



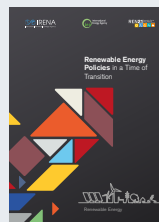
REGIONAL REPORTS

These reports detail renewable energy developments in a region, improving data and knowledge and, in turn, informing decision making and changing perceptions.



GLOBAL FUTURES REPORT (GFR)

This series captures the current thinking about a sustainable energy future. Each report presents the collective and contemporary thinking of many experts.



THEMATIC REPORTS

Each report covers, in detail, a specific topic where a knowledge gap exists.

DEBATES



REN21 RENEWABLES ACADEMY

A biennial event developed by, and for, the REN21 community, where members meet and discuss how to spur the renewable energy transition. The REN21 Academy's structure reflects REN21's collaborative and transparent culture.



COMMUNITY

INTERNATIONAL RENEWABLE ENERGY CONFERENCE (IREC)

A high-level political event where government, private sector and civil society meet to build collective know-how to advance renewables at the international, national and sub-national levels. The IREC is hosted by a national government and is held biennially.



MAKING THE CONNECTIONS

Good decisions require good information. REN21's *Renewables Global Status Report (GSR)* tracks the annual development of renewables using the most up-to-date information and data available. Its neutral, fact-based approach documents in detail the annual developments in market, industry and policy. The report is a collaborative effort, drawing on an international network of more than 1,500 authors, contributors and reviewers from over 155 countries. Now in its 15th year, the GSR is the most frequently referenced report on renewable energy market, industry and policy trends.

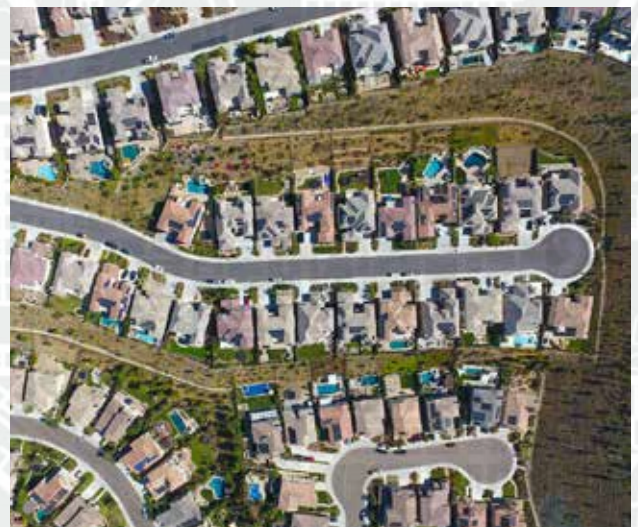
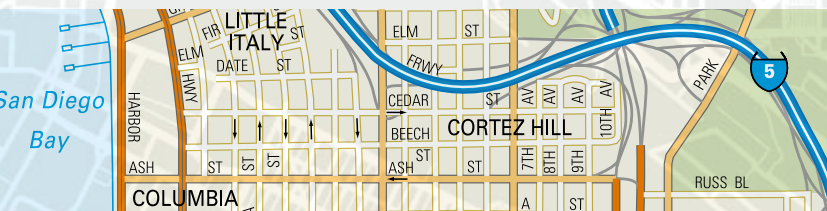
Since the first edition of the GSR in 2005, REN21 has continuously expanded its reporting. To highlight regional trends, REN21 has developed a *Regional Renewable Energy and Energy Efficiency Status Report* series and is now including reporting on renewable energy development in cities, considering the crucial involvement of cities in the energy transition and the existing data gap.

The new report series, *Renewables in Cities 2019 Global Status Report*, builds on the success of the *Renewables Global Status Report* and focuses specifically on the state of renewables in cities around the world and on the role of local action in the renewable energy transition. It looks at trends and developments of renewable energy in cities and its associated benefits, including impacts on air pollution, energy security and access, and socio-economic issues. This publication will help improve understanding of cities' role in the energy transition, increase visibility for local action and showcase effective policies, finance and business models to inform decisions.



Bridging and building the energy future.

www.ren21.net

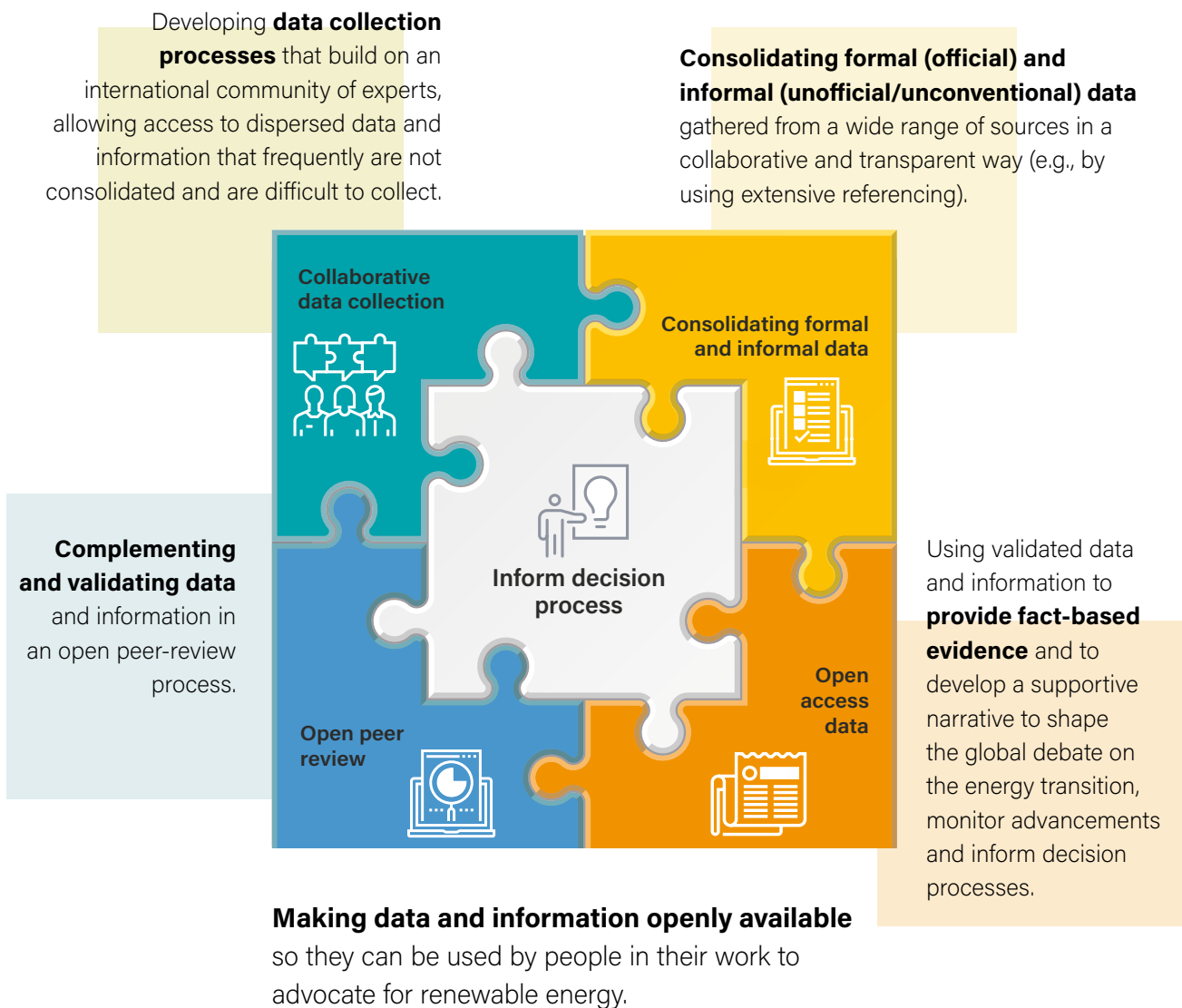


San Diego, United States of America

REN21 DATA AND REPORTING CULTURE

REN21 has developed a unique renewable energy reporting culture, allowing it to become recognised as a neutral data and knowledge broker that provides credible and widely accepted information. Transparency is at the heart of the REN21 data and reporting culture.

The REN21 reporting culture comprises the following elements:

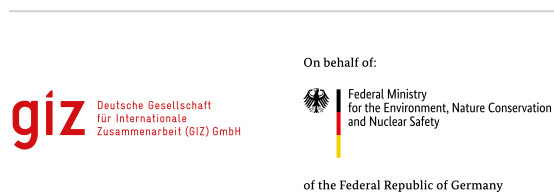


Building on this process, REN21 has contributed significantly to making renewable energy visible in the global debate, drawing decision makers' attention to it and changing the norm in reporting and tracking. REN21 has been successful in "making the invisible visible" – beginning with its first status report on renewable energy in 2005 – and aims to continue in this mission by highlighting the critical role of cities in the renewable energy transition.

ACKNOWLEDGEMENTS

Note: Some individuals have contributed in more than one way to this report. To avoid listing contributors multiple times, they have been added to the group where they provided the most information. In most cases, the lead topical contributors, lead city contributors, regional contributors, sidebar authors and advisory committee members also participated in the *Renewables in Cities 2019 Global Status Report* data contribution, review and validation processes.

The *Renewables in Cities 2019 Global Status Report* was co-developed with an Advisory Committee whose joint expertise and work were fundamental in guiding the creation of the report, including defining the outline, supporting data collection and reviewing drafts.



This report was commissioned by REN21 and produced in collaboration with a global network of research partners. Financing was provided by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU). A major share of the research for this report was conducted on a voluntary basis.

LEAD AUTHORSHIP

Toby Couture (E3 Analytics)

CHAPTER AUTHORS

Henner Busch (Lund University)

Flávia Guerra (Lund University)

Teis Hansen (Lund University)

Anna Leidreiter (World Future Council)

Hannah E. Murdock (REN21)

Lea Ranalder (REN21)

Janet L. Sawin (Sunna Research)

Kristin Seyboth (KMS Research and Consulting)

PROJECT MANAGEMENT AND RESEARCH DIRECTION (REN21 SECRETARIAT)

Lea Ranalder

Rana Adib

SPECIAL ADVISORS

Peter Droege (Liechtenstein Institute for Strategic Development – LISD)

Janet L. Sawin (Sunna Research)

RESEARCH AND PROJECT SUPPORT (REN21 SECRETARIAT)

Thomas André, Fiona Corcoran, Jack Corscadden, Chloé de Bethmann, Alyssa Fischer, Duncan Gibb, Vibhushree Hamirwasia, Hwajin Kim, Eleonora Moro, Katharina Satzinger

COMMUNICATION SUPPORT (REN21 SECRETARIAT)

Laura E. Williamson

Anna Swenson, Florencia Urbani

EDITING, DESIGN AND LAYOUT

Lisa Mastny, Editor

weeks.de Werbeagentur GmbH, Design

PRODUCTION

REN21 Secretariat, Paris, France

ACKNOWLEDGEMENTS (continued)

SIDEBAR AUTHORS

Adam Brown
 Rebecca Cole (Rocky Mountain Institute – RMI)
 Eveline Lemke (Thinking Circular)
 Eleonora Moro (REN21)
 Victor Olgyay (RMI)
 Anis Radzi (LISD)
 Joshua Sperling (US National Renewable Energy Laboratory – NREL)

ADVISORY COMMITTEE

Pandora Batra (CDP)
 Alix Bolle (Energy Cities)
 Celina Bonugli (World Resources Institute – WRI)
 Frédéric Boyer (Covenant of Mayors)
 Victoria Burrows (World Green Building Council)
 Tabaré Curras (World Wildlife Fund – WWF)
 Elizabeth Doris (NREL)
 Keane Gruending (Renewable Cities)
 Victoria Healey (NREL)
 Vincent Kitio (UN-Habitat)
 Jennifer Layke (WRI)
 Stefan Mager (Deutsche Gesellschaft für Internationale Zusammenarbeit – GIZ)
 Eric Martinot (Global Initiative for Distributed and Local Energy)
 Shannon McDaniel (Global Covenant of Mayors)
 Mohamed Mezghani (International Association of Public Transport – UITP)
 Martina Otto (United Nations Environment Programme – UNEP)
 Michael Renner (International Renewable Energy Agency – IRENA)
 Shirin Reuvers (CDP)
 Lily Riahi (UNEP)
 Kassie Rohrbach (Sierra Club)
 John Romankiewicz (Sierra Club)
 Claire Roumet (Energy Cities)
 Irene Skoula (C40 Cities)
 Philip Turner (UITP)
 Maryke van Staden (ICLEI – Local Governments for Sustainability)
 Peta Wolpe (Sustainable Energy Africa – SEA)

REGIONAL CONTRIBUTORS

Africa

Tanaka Chitsa (Southern African Research and Documentation Centre – SARDC); Zanie Cilliers (SEA); Mark Hankins (African Solar Designs); Danai Majaha (SARDC); Joel Nana (SEA); Simisha Pather-Elias (SEA); Yachika Reddy (SEA); Tanaka Shumba (SEA); Farhiya Tifow (African Solar Designs); Peta Wolpe (SEA)

Asia

Frank Haugwitz (Asia Europe Clean Energy (Solar) Advisory Co. Ltd.); Rian van Staden (Global 100% Renewable Energy Platform)

Europe

Denis Tänzler (Adelphi); Christoph Tollmann (Adelphi)

Latin America

Gonzalo Bravo (Fundación Bariloche); Lucas Furlano (Fundación Bariloche); Eduardo Noboa (Leuphana Universität Lüneburg)

Middle East and North Africa

Tarek AbdulRazek (Regional Center for Renewable Energy and Energy Efficiency – RCREEE); Akram Al Mohamadi (RCREEE); Mohamed Mahboug (RCREEE); Maged Mahmoud (RCREEE)

North America

Christina Becker-Birck (Cadmus Group); Lori Bird (WRI); Tyler Clevenger (WRI); Matt Goepppele-Parrish (WRI); Norma Hutchinson (WRI); Chad Laurent (Cadmus Group); Jennifer Layke (WRI); Auston Smith (WRI)

LEAD TOPICAL CONTRIBUTORS

Cities Overview

David Albertani (R20 Regions of Climate Action); Vaibhav Chaturvedi (Council on Energy, Environment and Water); Tabaré Curras (WWF); Elizabeth Doris (NREL); Hans-Josef Fell (Energy Watch Group); Irene Garcia (German Marshall Plan of the United States); Allison Hooks (CDP North America); Siir Kilkis (Scientific and Technological Research Council of Turkey/Intergovernmental Panel on Climate Change); Vincent Kitio (UN-Habitat); Silke Krawietz (SETA Network); Jeet Mistry (WWF); Martina Otto (UNEP); Florian Remann (GIZ); Kassie Rohrbach (Sierra Club); John Romankiewicz (Sierra Club); Orna

ACKNOWLEDGEMENTS (continued)

Rosenfeld (European Commission – EC); Stefan Schurig (Cities and Energy); Ted Sheldon (Province of British Columbia); Irene Skoula (C40 Cities); Freyr Sverrisson (Sunna Research)

Citizen Participation

Anna Berka (University of Auckland); Alix Bolle (Energy Cities); Simon De Stercke (Imperial College); Stefan Gsänger (World Wind Energy Association – WWEA); Tetsunari Iida (Institute for Sustainable Energy Policies); Julie MacArthur (University of Auckland); Josh Roberts (RESCOOP); Ibrahim Togola (Mali Folkecenter)

Finance

Ahmed Al Qabany (Islamic Development Bank); Sean Kidney (Climate Bonds Initiative); Silvia Kreibiehl (Frankfurt School of Management and Finance); Hussaain Mogaibel (Islamic Development Bank); Gerry Muscat (European Investment Bank – EIB); Julia Rawlins (Climate-KIC); Dirk Roos (EIB); Adair Turner (Energy Transitions Commission); Jarett Walker (Jarett Walker & Associates)

Health

Heather Adair Rohani (World Health Organisation – WHO); Nathan Borgord-Parnell (UNEP); Sandra Cavalieri (UNEP); Thiago Hérick de Sá (WHO); Jennifer Wang (Healthy Energy Initiative)

Heating and Cooling

Bärbel Epp (Solrico); Peter Lundberg (Asia Pacific Urban Energy Association - APUEA); Lily Riahi (UNEP); Gerhard Styri-Hipp (Fraunhofer Institute for Solar Energy Systems); Werner Weiss (AEE – Institute for Sustainable Technologies)

Transport

Robin Chase (New Urban Mobility); Ramon Cruz (Institute for Transportation and Development Policy – ITDP); Holger Dalkmann (Sustain 2030); Aimee Gauthier (ITDP); Jacob Mason (ITDP); Colin McKerracher (BloombergNEF Transport); Nikola Medimorec (Partnership on Sustainable, Low Carbon Transport – SLoCaT); Mohamed Mezghani (UITP)

LEAD CITY CONTRIBUTORS

Asia

Zeeshan Ashfaq (WWEA); Yong Chen (IRENA); Bima Fitriandana (ICLEI); João Graça Gomes (Shanghai Jiaotong University); Yingping Kuo (Pintung County Government); Qiongying Ma (GIZ); Tanay Sidki Uyar (Energy Section Marmara University, Renewable Energy Association of Turkey – EUROSOLAR Turkey); Yogesh Kumar Singh (National Institute of Solar Energy, Ministry of New and Renewable Energy, Government of India); Katarina Uherova Hasbani (EnRupt)

Europe

Jennifer Calder (WWF); Samuel Chademana (C40 Cities); Alexis Chatzimpiros (Samsø Energy Academy); Mark Draeck (United Nations Industrial Development Organization – UNIDO); Philipp Geres (GIZ); Rene Peter Hohmann (Cities Alliance); Viktoriia Iakovleva (UNIDO); David Jacobs (International Energy Transition GmbH); Ruud Kempener (EC); Darko Knezović (City of Mostar, Bosnia and Herzegovina); Albana Kona (EC); Sigrid Kusch-Brandt (University of Padua); Mariko Landström (Sitra); Benoit Lebot (International Partnership for Energy Efficiency Cooperation – IPEEC); André Månberger (Lund University); Rita Marouço (Coopernico); Günter Meinert (GIZ); Geylan Onay (UNIDO); Sandra Prüfer (Bonneconnections); Sandra Retzer (GIZ); Ana Romero Càlix (Barcelona Metropolitan Area); Stefan Sattler (City of Vienna, Austria); Jan Tarras-Wahlberg (Municipality of Skellefteå, Sweden); Laura Tozer (Durham University); Pekka Tuominen (VTT Technical Research Centre of Finland); Oras Tynkkynen (Sitra); Dirk Vansintjan (REScoop)

Latin America and the Caribbean

Suani Coelho (Institute of Energy and Environment – IEE, University of São Paulo); Rosane Ebert Miki (Sabesp – Departamento de Prospecção Tecnológica e Propriedade Intelectual); Cristina Fedrizzi (IEE, University of São Paulo); Gabriela Hernández-Luna (Universidad Autónoma del Estado de México); Debora Ley (Latinoamérica Renovable); Guido Sánchez (City of Lincoln, Argentina); Miguel Schloss (Surinvest)

Middle East and North Africa

Jinlei Feng (IRENA); Dafna Levy (Eilat Eilat Renewable Energy); Ishrat Salim Peerzada (Masdar); Elad Topel (Eilat Eilat Renewable Energy); Stephen Worsley

ACKNOWLEDGEMENTS (continued)

(Masdar); Badriyah Yosiyana (IRENA)

North America

Nico Albanese (BloombergNEF); Jessica Frech (University of Maryland); Nicholas Goedeking (University of California, Berkeley); Hazel Henderson (Ethical Markets); Matt Horne (City of Vancouver, Canada); Nathan Hultman (University of Maryland); Michael Lee (Quest Canada); LaRae Long (Ethical Markets); Alan Miller (Independent consultant); Wilson Rickerson (Converge Strategies LLC); Heather Rosmarin (Clean Energy Americas); Stefen Samarripas (American Council for an Energy-Efficient Economy); Kathryn Sheps (Simon Fraser University); Nilmini Silva-Send (Energy Policy Initiatives Center, University of San Diego); Heather Thompson (ITDP)

Oceania and the Pacific

Nik Midlam (City of Sydney, Australia)

Sub-Saharan Africa

Fred Abankwa (Cities Alliance); Said Abdella (Addis Ababa Environmental Protection Authority); Desmond Appiah (C40 Cities); Tibebe Assefa (C40 Cities); Manuel Araujo (Quelimane Municipality, Mozambique); Edmond Atangana Evina (Independent); Guy Benoit Eze (Independent); Phillip Dinga (C40 Cities); Fabrice Fouodji Toche (Global Village Cameroon); Dieter Holm (World Online South Africa); Alex Johnson (Accra Metropolitan Assembly); Godfrey Kabbyanga (City of Kasese, Uganda); Prosper Kuradusenge (Independent researcher); David Makori (Independent); Nicola Mander (Climate Action Planning Africa); Itumeleng Masenya (City of Durban, South Africa); Lebo Molefe (City of Johannesburg, South Africa); Zarina Moolla (C40 Cities); Evelyn Mugume (Independent); Nditsheni Mutswari (City of Tshwane, South Africa); Sibusiso Ntshalintshali (City of eThekweni, South Africa); Emanto Philip (Independent); Nadia Shah (C40 Cities); Adrian Stone (Energy and Climate Change Directorate, City of Cape Town, South Africa); Lisanda van Rensburg (Energy and Climate Change Directorate, City of Cape Town, South Africa); Sarah Ward (Energy and Climate Change Directorate, City of Cape Town, South Africa)

DATA CONTRIBUTORS AND REVIEWERS

Jordi Abadal Colomina (Inter-American Development Bank); Dennis Abel (University of Cologne); Diego Adrian de León Segovia (Columbia University); Umair Ahmed (Engro Corporation); Iqbal Akbar (INNO Technische Universität Berlin); Rahat Ali Khan (Institute of Information and Communication Technology, University of Sindh, Pakistan); Ana Altamirano (Student); Sonia Al-Zoghoul (Modern Arabia for Solar Energy); Edward Amankwah (Centre for Environmental Governance); David Amienyo (Siemens); Dang Anh Thi Nguyen (Independent consultant); Omar Aponte (Rochester Institute of Technology); Simeran Bachra (CDP); Sarah Baird (Let There Be Light International); Stefano Barberis (Rina Consulting); Felipe Barroco Cunha (Universidade Federal da Bahia); Meritxell Bennasar (Fundación Renovables); Patrick Blake (UNEP); Lucie Blondel (Climate Alliance); Andrea Bogi (European Geothermal Energy Council); Udochukwu Bola Akuru (University of Nigeria); Harriet Bulkeley (Durham University); Shann C. Turnbull (International Institute for Self-governance); Chia-Wei Chao (Risk Society and Policy Research Center); Sreenivas Chigullapalli (Indian Institute of Technology Bombay); Kelly Davies (Norton Rose Fulbright); Nicolas Demartin (GIZ); Matthieu Denoux (Mines Paris Tech); Jean-Philippe Denruyter (WWF); Irene di Padua (Solar Heat Europe – ESTIF); Chris Edeh (Africa Sustainable Energy Association); Madeleine Edl (UNEP); Wolfgang Faßbender (City of Bonn, Germany); BenJeMar-Hope Flores (Seoul National University of Science and Technology); Clairss Forecchi (Ministry of Foreign Affairs, Brazil); Mindy Fox (Solar Cookers International); Panagiotis Fragkos (E3Modelling); Krishnakumar G. (Society of Energy Engineers and Managers); Sandra Garavito (Independent consultant); Irfan Gondal (National University of Sciences); John Griffiths (City of Melbourne, Australia); Georg Günsberg (R20 Austria); Ahmed Hamza H. Ali (Egypt-Japan University of Science and Technology); Ursula Heumesser (City of Vienna, Austria); Win-Kai Hsieh (Taichung City, Chinese Taipei); Xu Huijin (Shanghai Jiaotong University); Lizzy Igbine (Nigerian Women Agro Allied Farmers Association); Edith Iriyuga (Natural Eco Capital); Osahon Iyalekhue (Community Research and Development Centre); Arnulf Jäger-Waldau (EC); Arne Georg Janssen (Cities Alliance); Wim Jonker Klunne (Energy4Africa); Jozsef Kadar (University of Haifa); Hortense Kagambèga Traoré

ACKNOWLEDGEMENTS (continued)

(Women Environmental Programme); Canan Karakaş Ulusoy (General Directorate of Highways, Turkey); Shorai Kavu (Ministry of Energy and Power Development, Government of India); Nazar I. Khan (Academy of International Studies, Jamia Millia Islamia University, New Delhi); Birol Kilis (Polar Teknoloji); Thorben Knust (Secretariat of Environment of the Metropolitan District of Quito); Jonathan Koifman (TVP Solar); Hesborn Kola (Valueline Technology); Nikhil Kolsepatil (ICLEI South Asia); Assem Korayem (Access-Power Egypt); Gloria Kuang-Jung Hsu (National Taiwan University); Senthil Kumar Arumugam (ICLEI); Bharadwaj Kummamuru Venkata (World Bioenergy Association – WBA); Ferdinand Laron (GIZ); Denis Lenardic (Independent expert); Sofia Lettenbichler (Euroheat & Power); Juergen Lorenz (JL Business & Technology Consultancy); Joshua Loughman (Arizona State University); Hugo Lucas (Institute for Energy Diversification and Saving – IDAE); Manuel Ludueña (Facultad de Ingeniería, Universidad de Buenos Aires); Lorcan Lyons (EC Joint Research Centre); Zacharias Malik (Cranfield School of Management); Silas Markert (École Polytechnique Fédérale de Lausanne); Ana Marques Leandro (Independent consultant); Rodrigo Matabuena (London Borough of Islington); Jim McMahon (Better Climate); Régis Meyer (Collaborative Energy); Carlo Minini (Turboden); Lawal Mohammed (Energy Commission of Nigeria); Sabatha Mthwecu (Tintley); Benard Muok (Jaramogi Oginga Odinga University of Science and Technology); Abdulaziz Murtozaev (Tashkent State Technical University); Osvaldo Musto (Independent consultant); Solomon Ojoawo (Ukpa Hansa Energy Solutions Limited); Verena Ommer (IRENA); Galal Osman (World Wind Energy Association – WWEA); Sarah Pan Larsson (E.ON Energilösningar AB); Karl Peet (SLoCaT); Kristian Petrick (eco-union); Constanca Pinto Moura (Danfoss); Inna Platonova (Southern Alberta Institute of Technology); Patrick Plötz (Fraunhofer Institute for Systems and Innovation Research); Stephane Pouffary (Pouffary Energies 2050); Luka Powanga (Regis University / Energy Africa); Pallav Purohit (International Institute for Applied System Analysis); Nizomiddin Rakhmanov (Tashkent State Technical University); Bard Rama (Czech Technical University of Prague – CVUT); Alfredo Redondo (C40 Cities); Patrick Reiter (Gesellschaft für Solarinstallation und Design mbH – S.O.L.I.D.); Ulrich Reiter (TEP Energy GmbH); Antonio Rodriguez-Martinez (Universidad Autónoma del Estado de Morelos); Mathis Rogner (International Hydropower Association – IHA); Clotilde Rossi di Schio (Sustainable Energy for All); Frieder Rubik (Institut für ökologische Wirtschaftsforschung); Bárbara Rubim (Climate Action Network International); Ignacio Sagardoy (Fundación Bariloche); Stefan Salow (GIZ); Palash Sanyal (University of Saskatchewan); Olga Savchuk (IN+ Center for Innovation, Technology and Policy Research); Abu Sayed (Luxur Green Energy); Michael Schimpe (Technical University of Munich); Susana Serôdio (Portuguese Renewable Energy Association – APREN); Md Shafiullah (King Fahd University of Petroleum and Minerals); Manoj Singh (Power Grid Corporation of India); Carol Singh (International Renewable Energy Academy); Scott Sklar (The George Washington University Solar Institute); Tycho Smit (Trinomics); Admir Softic (Ministry of Foreign Trade and Economic Relations, Bosnia and Herzegovina); Vaibhav Srivastava (Independent consultant); Lavinia Steinfort (Transnational Institute); Natalie Stewart (Green Building Alliance); Geoffrey Stiles (Carbon Impact Consultants); Satrio Swandiko Prillianto (Greenpeace Indonesia); Makoto Tajima (Institute for Sustainable Energy Policy – ISEP); Yael Taranto (SHURA Energy Transition Center); Shann C. Turnbull (International Institute for Self-governance); Galyna Trypolska (Institute for Economics and Forecasting, National Academy of Sciences of Ukraine); Alan Lin Tze-Luen (National Taiwan University); Helena Uhde (Beijing Institute of Technology); Andreas Ulbig (Adaptricity); Drona Upadhyay (Independent consultant); Cesar Vaca (B4Future); Daksha Vaja (Community Science Centre); Rodrigo Valdovinos (El Centro de Formación Técnica del Medio Ambiente – IDMA); Tineke van der Schoor (Hanze University of Applied Sciences); Csaba Vaszko (Independent consultant); Silvia Vera García (Institute for the Diversification and Saving of Energy (IDAE), Spanish Ministry for Ecological Transition); Eric Verdeil (SciencesPo); Ashish Verma (Adani North America Inc.); Rodrigo Vidal Maula (Política Ambiental y Energía, Municipio de Buenos Aires); Mariano Villares (Fundación Sostenibilidad Sin Fronteras); Marc Vives (Granollers Mercat); Louise Watt (IQ Air); David Wellington (UNEP); Alessa Wochner (Sciences Po); Illia Yeremenko (NGO Ecoclub); Jungmin Yu (Seoul Institute); Sha Yu (Pacific Northwest National Laboratory); Vladislav Zavadskiy (Independent consultant); Samer Zawaydeh (Association of Energy Engineers); Flora Zhu (SynTao); Michael Ziegler (GIZ); Silvia Zinetti (Independent consultant)

FOREWORD

I am excited to introduce the first-ever edition of our *Renewables in Cities Global Status Report* series. Discussing renewable energy in the context of cities sheds light on the many different drivers for developing renewables, and makes these diverse energy sources relevant to players both within and outside the energy sector.

Cities have adopted some of the most ambitious commitments for renewables globally. As substantial energy consumers and among the top contributors to carbon dioxide emissions worldwide, cities both can and must drive significant change. Renewable energy presents an opportunity for cities to make critical progress at a local level that will improve the lives, health and economic opportunities of residents and visitors alike.

For the sustainable energy transition to succeed, two key elements are necessary: renewables must be deployed much more rapidly in the electricity sector, and widespread electrification is needed in all economic sectors, including the end-use sectors of transport, industry, and heating and cooling. Cities have a unique role to play: the heating and cooling sectors are local markets, and cities are crisscrossed with roads and transport systems. Perhaps most importantly, through their influence at a local level, cities can encourage their residents and other citizens to support the energy transition.

To take full advantage of what cities can do on the energy front, it is important to create integrated frameworks at the national, sub-national and city levels. Energy strategies across multiple government levels should be coherent and directed towards the common goal of accelerating the renewable energy transition.

Data on local- and city-level renewable energy policies and achievements tend to be decentralised, limited and outdated. Building on our international community and rigorous data collection processes, REN21 plays a unique role in compiling and consolidating disperse data to build awareness of the energy debate, a process that we have developed and honed since 2005. This data culture and community allow REN21 to highlight data gaps and produce an accurate overview of city developments, trends and progress, thus advancing the story of cities' role in the energy transition.

On behalf of the REN21 Secretariat, I extend a warm thank you to our international community of collaborators. I would like to thank the pioneering spirits of those who have contributed to the first edition of this report. Special thanks go to our lead author Toby Couture; the chapter authors; Special Advisors Janet Sawin and Peter Droege; the Advisory Committee; Project Manager Lea Ranalder; and the entire team at the REN21 Secretariat for embarking on the first edition of what will become an established and referred-to series.



Rana Adib

Executive Secretary, REN21

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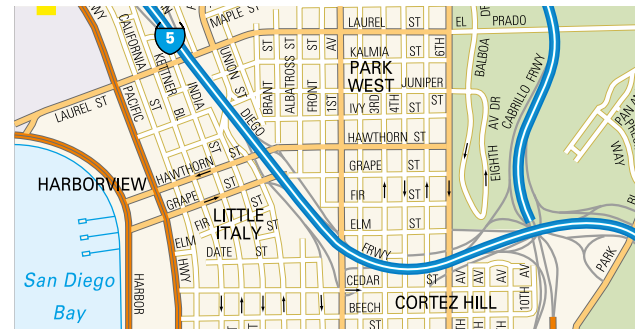


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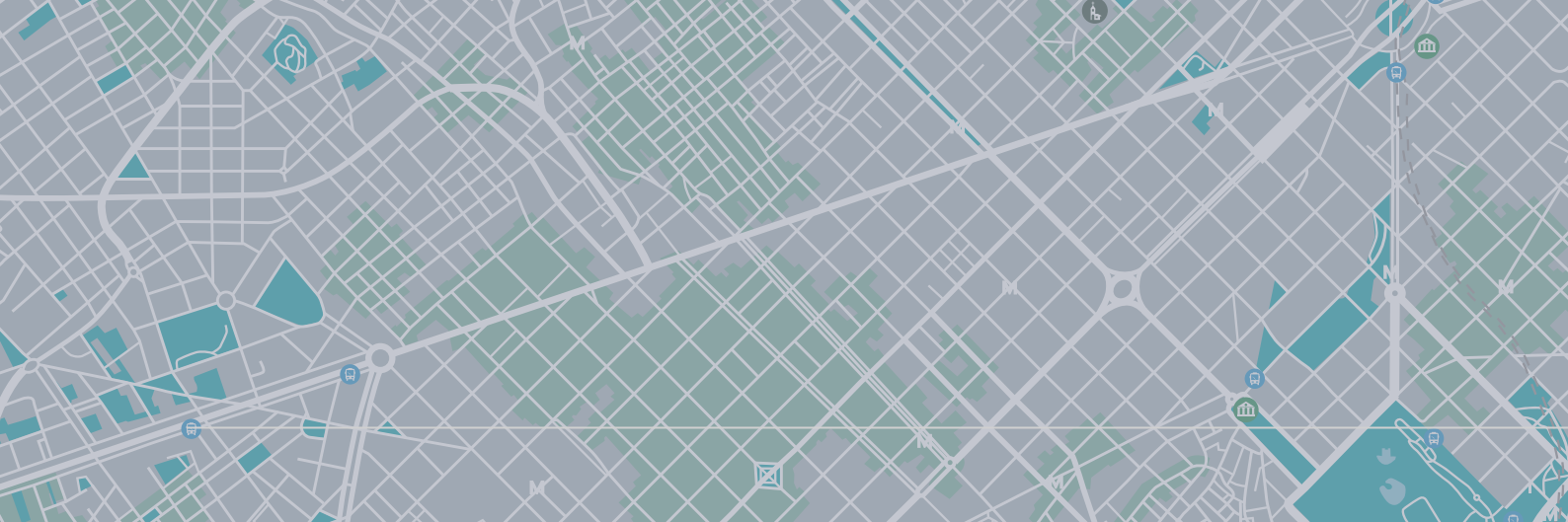
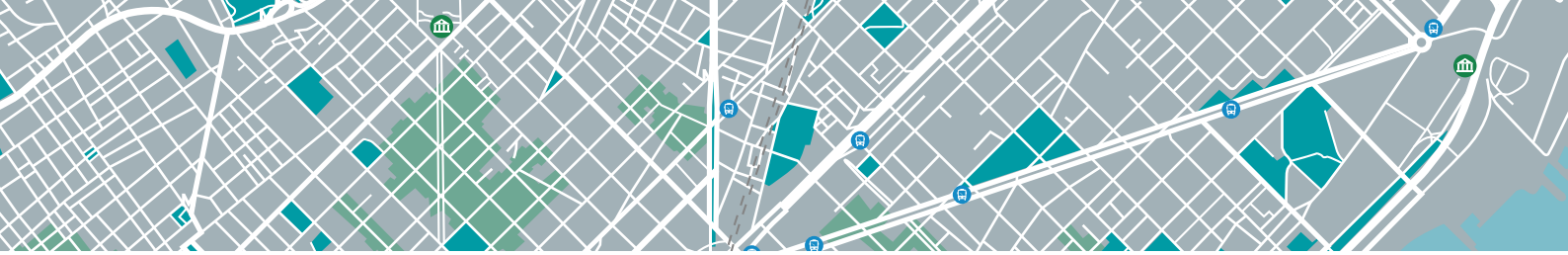
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Between these covers you will find the first edition of the Renewables in Cities Global Status Report. This report gathers information and data on what cities are doing around renewable energy. As this is the first edition, we are aware that there may be gaps or errors. We welcome your feedback: please send any comments to us by 31 December 2019 at re_cities@ren21.net.

In early 2020, REN21 will begin collecting data and information for the 2020 edition in this series. If you would like to contribute to the process, send us an email at the address above, and we will make sure to include you.



EXECUTIVE SUMMARY

CITIES IN THE RENEWABLE ENERGY TRANSITION

Cities are directly responsible for around two-thirds of global final energy use as well as for significant indirect consumption of energy that is embodied in materials, products and other goods. Due largely to this energy use, cities account for an estimated 75% of global carbon dioxide (CO₂) emissions.

In addition, cities account for 55% of the global population and for more than 80% of global gross domestic product. Thus, shifting to renewable energy in cities is critical to decarbonising the global energy system. At the same time, cities offer a lever to advance the transition towards renewable energy in all end-use sectors, not only in power but also in heating and cooling in transport.

Renewable energy offers cities the opportunity to achieve a wide range of objectives. Through their various roles, including urban planning and the provision of numerous services, cities are well-positioned to increase the use of renewable energy in their own activities and to support the deployment of renewables more broadly, while simultaneously achieving local objectives such as reducing air pollution to improve public health, mitigating climate change, supporting the local economy and building resilient infrastructure.

City governments around the world have set renewable energy targets. To achieve these targets, cities are using a variety of options at their disposal, including harnessing their own

purchasing power and creating local policies to encourage greater public and private uptake of renewables. Some cities have used their close ties to the community to engage residents, businesses and other local stakeholders.

Many have served as trendsetters, influencing and advocating for increased support for renewables at the state/provincial and national levels, and joining together in national and global city networks to exchange ideas and help drive renewable energy and climate action around the world.

Despite their many points of leverage, cities face challenges in their efforts to pursue ambitious energy and climate strategies. In many cases, municipal efforts are hampered by policies and regulations at higher levels of government. A lack of co-ordination among city departments also can impede progress. A city's ability to advance a renewable energy agenda depends heavily on local characteristics, including own financial resources, access to external financing, the size of the tax base, economic growth and the local administrative capacity and authority.

Cities account for an estimated

75%

of global CO₂ emissions.



DRIVERS

Efforts to accelerate renewable energy deployment at the city level are driven by a range of social, political, economic and environmental objectives. Through the uptake of renewables, cities have the opportunity to create more liveable urban areas, enabling a better quality of life.

Drivers for renewable energy uptake include:

- *Fighting local air pollution:* Renewable energy can reduce urban air pollution, which is among the greatest environmental threats to health and well-being.
- *Mitigating and adapting to climate change:* Not only are cities significant contributors to climate change through local greenhouse gas emissions, they also are vulnerable to its impacts, such as storms, fires and sea-level rise, which threaten public safety and urban infrastructure.
- *Reducing municipal energy costs:* Renewables offer cities the potential to limit exposure to volatile fossil fuel prices and to more easily control their energy expenses.
- *Supporting economic development:* Increased deployment of renewable energy can attract new industries and provide opportunities to develop new business models that result in additional jobs and local income.
- *Promoting a stable and secure energy supply:* Increasing the share of energy services provided by renewables can improve the energy security and autonomy of cities, making them less reliant on external sources.
- *Energy access:* Distributed renewable energy technologies can provide access to modern energy services for the millions of urban residents who continue to lack access.

URBAN POLICY LANDSCAPE

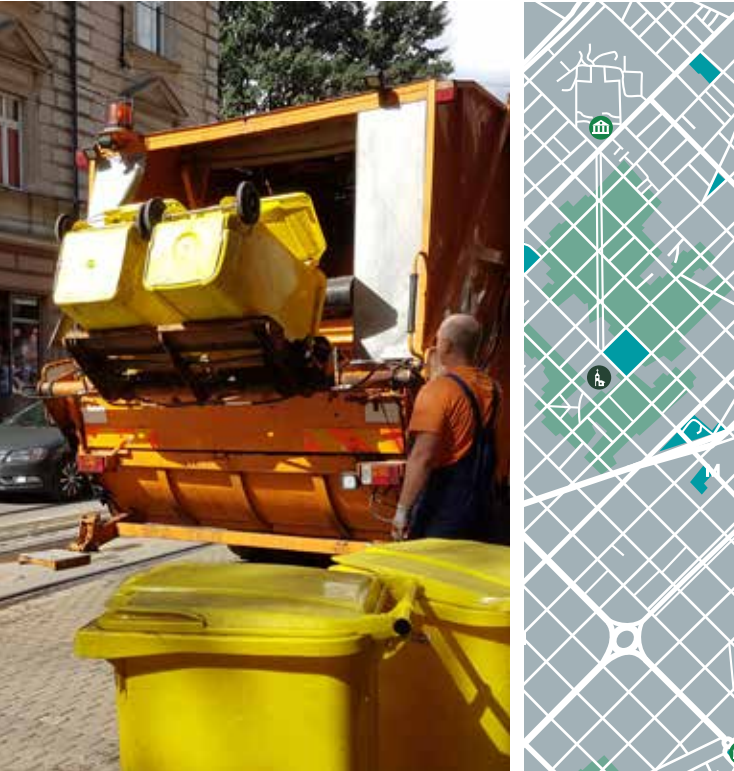
To achieve their targets in the power, heating and cooling, and transport sectors, city governments are enacting policies to encourage investment in renewables directly and to drive investments in key enabling infrastructure.

TARGETS

Thousands of cities and local governments have adopted renewable energy-specific targets and action plans, and around 250 cities worldwide have targets for 100% renewable energy. In addition, nearly 10,000 cities have adopted targets to reduce their greenhouse gas emissions, which, even if not directly emphasising renewables, would necessitate a shift away from fossil fuels and indirectly support scaling up renewable energy and improving energy efficiency.

Renewable energy targets adopted at the city level are often aspirational (i.e., non-binding) and lack enforcement provisions. Once adopted, however, such targets often gain a momentum of their own, enabling city governments to not only achieve their aspirations but exceed them. To support targets, many city governments have started to build in accountability mechanisms, introducing interim goals and reporting requirements.

City-level targets help to provide long-term certainty to local investors, better ensuring that public investments are aligned with the city's vision and making it easier to mobilise financing. They also play an important role in shaping city planning and permitting. With the support of city networks, targets also have helped to forge new coalitions among private companies, civil society organisations and citizens to push for increased renewable energy deployment.



Thousands of cities and local governments have adopted renewable energy-specific targets and **action plans**.

The main policy instruments used by cities can be broken down into four key categories:

- *Procurement and direct investment*, which include renewable energy purchases and direct investments in renewable energy technologies by municipal governments, as well as municipal support for investment in enabling infrastructure in urban areas.
- *Mandates and obligations*, which include technology-specific ordinances and building codes, some of which are stricter than national- or state-level regulations. A growing number of cities around the world are using mandates and building codes (particularly for new and public buildings) to help drive economies of scale and push down costs for citizens and businesses while spurring competition and local job creation. Enforcement remains a major challenge in many cities, however, particularly in rapidly growing cities in Asia, Africa, and Latin America.
- *Fiscal and financial incentives*, which include grants, rebates and tax exemptions (as well as fees and levies to discourage) to encourage specific behaviours and investment choices, in cities that have at least some control over taxation and other areas of public policy.
- *Enabling policies and urban planning/zoning*, which can help to improve the environment in which citizens and businesses operate (for example, by facilitating the emergence of new business models such as solar leasing or community-funded projects). Cities are enacting policies to reduce administrative, permitting and inspection-related barriers to renewable energy investment and are creating supportive zoning and other laws.

There also is a growing focus on the provision of infrastructure that could enable increased use of renewable energy in the heating, cooling and transport sectors. This includes district thermal networks, EV charging infrastructure and electrically powered public transit systems, all of which could allow cities to achieve higher shares of renewable energy.

Because no single policy option will successfully mobilise change across all urban residents and businesses, city governments increasingly are using various combinations of policy types, creating integrated approaches in an effort to steer the market towards cleaner and more renewable choices.

RENEWABLE ENERGY POLICIES

To meet their renewable energy targets, local governments are introducing an ever-wider array of support policies and measures, setting into motion new projects, investments and business models. Supportive policy is particularly important at the city level because urban areas frequently have tighter planning restrictions, higher land costs and more stringent inspection requirements than non-urban areas. Policy also can help to increase public support among citizens and other stakeholders.

Most city-level targets and policies are focused on the power sector. However, where they exist, policies in the heating, cooling and transport sectors have played a key role in advancing renewable energy at the local level, particularly in buildings. Innovative policies also have stimulated support for the deployment of technologies and infrastructure – such as electric vehicles (EVs) and charging networks – that have the potential to enable higher penetration of renewable energy in these sectors.

Renewable energy policies can be designed to apply strictly to municipal government operations or to apply city-wide. Many cities proceed in stages, first focusing on government operations and later expanding their policies to encourage deployment more broadly.

MARKETS

Urban deployment and use of renewable energy are increasing rapidly in response to growing recognition of associated benefits, attractive economics, new business models and support policies at various levels of government.

Although comprehensive data on renewable energy in urban markets are lacking, cities are increasingly purchasing renewable energy generation and investing in renewable technologies in the power, heating and cooling, and transport sectors. In addition, city actors are advancing the deployment of enabling technologies and infrastructure to ease the integration of rising shares of renewables into the energy system and to facilitate the interconnection of the power, heating and cooling, and transport sectors.

POWER

City governments and other urban actors are increasing their consumption of renewable electricity, and many have become renewable electricity producers.

Urban consumption of renewable electricity is increasing through a variety of mechanisms, including power purchase agreements (PPAs) with third-party producers. In addition, the modularity and scalability of renewable energy has provided city actors – including municipal governments, residents and businesses – with opportunities to become decentralised electricity producers, primarily through the use of on-site solar PV systems. By developing biogas projects (such as at local landfill sites and wastewater treatment plants), some cities are generating electricity (and heat) while greatly reducing local greenhouse gas emissions.

In addition, because most public lighting is concentrated in cities, where it can account for as much as 40% of a municipality's electricity budget, many city governments are embracing solar-powered street lights, which provide cost-effective and reliable solutions to public lighting needs. In 2017, global sales of solar street lighting reached a cumulative 3.8 million units.



HEATING AND COOLING

Solar thermal, bio-heat and geothermal technologies have emerged as affordable and reliable options to decarbonise the provision of heating and cooling in urban areas.

Modern renewable technologies can provide thermal energy for water and space heating and cooling, either through the use of stand-alone systems for individual buildings or via district energy networks. In a growing number of cities, renewables combined with energy efficiency improvements have enabled the development of “net zero” buildings and districts, with greatly reduced energy use and/or carbon emissions.

Stand-alone renewable energy systems typically include solar thermal systems on building façades and rooftops as well as modern biomass stoves and boilers. Numerous examples exist of solar thermal projects undertaken by city governments and local private investors in cities in Europe, Latin America and elsewhere. In addition, numerous cities use biomass, solar thermal and geothermal energy to produce heat for district heating systems (and in many cases, electricity as well).

TRANSPORT

In a growing number of cities, efforts to advance the use of renewables in transport are expanding from a focus on liquid biofuels and biomethane to include electric vehicles as well as hydrogen powered vehicles.

Urban transport represented around 40% of the energy used in the transport sector in 2015 and contributed an estimated 37% of transport-related CO₂ emissions. Due to its heavy reliance on diesel, petrol and other fossil fuels, road transport is often the largest source of local air pollution in urban centres around the world.

City governments have developed a wide range of strategies to reduce the need for vehicular transport while also supporting the development of a cleaner and more sustainable transport system. Electricity use in urban transport is expanding beyond light rail, trains and metros to include public fleets, passenger cars and other forms of electric mobility. Some cities are actively coupling the electrification of their metros, trams and public fleets with the procurement of renewable electricity and/or the scale-up of renewable power capacity.

In response to increasingly restrictive regulations governing road transport in urban centres (for example, low-emission zones and diesel bans), some city actors are exploring renewable alternatives. These include the use of electricity, biomethane and hydrogen

produced from renewable electricity to fuel buses, municipal and private fleets (such as waste collection trucks and delivery vehicles) and private vehicles.

Urban transport contributed an estimated

37%

of transport-related CO₂ emissions.

■ MOBILISING FINANCE AND ENABLING BUSINESS MODELS

More and more city governments are developing urban renewable energy projects. However, many challenges remain, such as the lack of their own funds and lack of access to external funds.

Municipal governments are increasing the flow of capital into renewable energy and other enabling technologies in two main ways. The first is by allocating their own municipal funds and/or borrowing funds for renewable energy-related projects. Bonds (municipal bonds as well as green bonds), public private partnerships, land value capture and dedicated funds from development finance institutions and green banks help municipal governments narrow the gap between the municipality's own available funds and what is needed to scale up renewables.

Some cities are trying to address the financing gap by increasing their reliance on the private sector. However, direct public investment continues to play a vital and catalytic role – particularly in the financing of enabling infrastructure – and it can be instrumental in mobilising additional finance at scale. The use of these and other sources of finance varies widely from city to city, and the exact numbers are not known.

The second means of increasing capital for renewable energy and related projects is the provision of municipal support for innovative business models that help create the conditions for citizens, local businesses and other actors to invest. Such business models include PPAs leasing (solar leasing, bus leasing and EV sharing), pay-as-you-go, peer-to-peer energy sharing and the development of energy service companies. City efforts to support innovative business models are more prevalent in some regions of the world than others.

However, challenges remain to increasing finance for urban renewable energy projects, such as a municipality's lack of its own funds and of access to external finance, investor perceptions of risks and low returns, bankability, institutional capacity and inertia, as well as information gaps.



■ CITIZEN AND COMMUNITY ENGAGEMENT

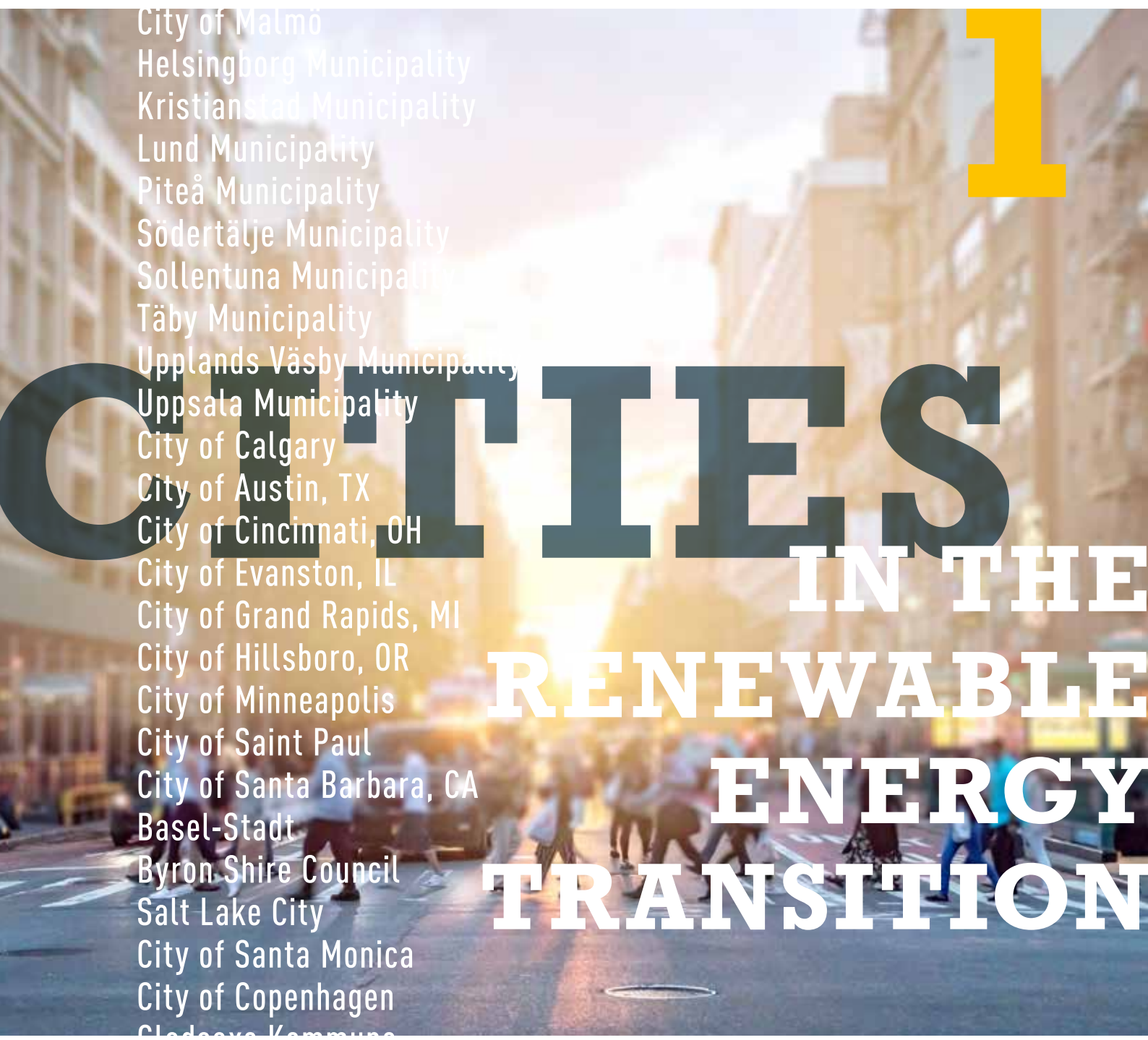
Citizen engagement is emerging as an important means of gaining public support for and sustaining momentum in the energy transition, as well as for driving more-ambitious goals at the national level.

Around the world, citizens are playing an increasingly active role in advancing renewable energy deployment. City residents can contribute in many different ways, including by choosing renewable energy tariffs, switching to green suppliers, and becoming prosumers by installing their own systems or by participating in one of the growing number of community energy projects emerging in and around urban areas.

Although frequently associated with northern European countries, such as Denmark and Germany, community renewable energy projects also exist in other regions and countries, including Australia, Canada, Japan, Thailand and the United States, and emerging in many other places around the world. City administrations are supporting these initiatives through, for example, fiscal and financial incentives and feed-in tariffs, which enable residents and businesses to generate their own electricity and sell it to the grid.

Cities in Europe, North America and Australia are experiencing higher levels of citizen involvement and investment than other regions, due in part to the existence of more-supportive market rules and enabling regulations. However, efforts are under way to reform market rules to allow for more citizen and prosumer engagement in Africa, Latin America and many parts of Asia and the Pacific.





1

CITIES IN THE RENEWABLE ENERGY TRANSITION

- City of Malmö
- Helsingborg Municipality
- Kristianstad Municipality
- Lund Municipality
- Piteå Municipality
- Södertälje Municipality
- Sollentuna Municipality
- Täby Municipality
- Upplands Väsby Municipality
- Uppsala Municipality
- City of Calgary
- City of Austin, TX
- City of Cincinnati, OH
- City of Evanston, IL
- City of Grand Rapids, MI
- City of Hillsboro, OR
- City of Minneapolis
- City of Saint Paul
- City of Santa Barbara, CA
- Basel-Stadt
- Byron Shire Council
- Salt Lake City
- City of Santa Monica
- City of Copenhagen
- Gladsaxe Kommune
- City of Boulder
- Oslo Municipality
- City of San Diego
- City of Stockholm
- Greater Manchester
- City of Columbia, SC
- City of Vancouver
- City of Fayetteville, AR
- City of Park City, UT



CITIES IN THE RENEWABLE ENERGY TRANSITION

GLOBAL STATUS OF RENEWABLE ENERGY

Over the past decade, many renewable technologies have seen remarkable advances and some have experienced sharp cost reductions, driven by innovation, increased competition, and policy support in a growing number of countries. The majority of countries now view renewable energy as clean, affordable and technologically mature and thus are including it in their development strategies. In addition, renewable energy can play a key role in economic growth and job creation; increased reliability, resilience and energy security; improved health through reduced air pollution; and expanded access to electricity and clean cooking facilities.¹

At the same time, scaling up renewable energy is key in combating climate change, as three-quarters of global carbon dioxide (CO₂) emissions come from the energy sector.² Alongside energy efficiency, renewable energy technologies play an important role in reducing greenhouse gas emissions. While there has been much progress in renewables, energy efficiency and energy access, the world is not on track to meet international goals, most notably limiting the rise in average global temperatures to 1.5 degrees Celsius (°C) as stipulated under the Paris Agreement.³ The 2018, the Intergovernmental Panel on Climate Change (IPCC) Special Report on the impacts of global warming of 1.5°C above pre-industrial levels found that just over a decade remained to keep global warming below this threshold.⁴ Any increase beyond that point would greatly intensify the risk of extreme climate events, such as drought, floods and very high temperatures for much of the world's population.⁵

Furthermore, review of the United Nations Sustainable Development Goal 7 (SDG 7) – on ensuring access to affordable,

reliable, sustainable and modern energy for all – has demonstrated that current efforts are not sufficient to achieve the targets set out for 2030.⁶ To meet these targets, there is an urgent need to extend renewable energy supply to the heating, coolingⁱ and transport sectors and to further accelerate renewable power generation.⁷

By the end of 2018, electricity generated from new wind and solar PV plants had become more economical than electricity from fossil fuel-fired plants in many places, and in some locations it was more cost-effective to build new wind and solar PV power plants than to continue to run existing fossil fuel power plants.⁸ Renewable energy capacity also can be brought online faster than capacity from conventional energy sources.⁹

However, while renewables are making great strides in the power sector, where they now supply more than a quarter of the world's electricity, this alone is not sufficient to achieve the energy transition that is needed to limit overall emissions.¹⁰ Electricity accounts for only around 17% of worldwide final energy demand, so there is an urgent need to decarbonise heating, cooling and transport, which together account for the remaining 83% of energy demand. (→ see *Figure 1*).¹¹ Many factors contribute to the slower uptake of renewables in heating, cooling and transport.¹² On a global level, progress in these sectors remains constrained by a lack of sustained policy support and by slow developments in new technologies, as well as by continued high fossil fuel subsidies and a lack of a sufficient carbon price.¹³ As of 2018, regulatory policies for renewable heat existed in only 20 countries, while mandates for renewable transport existed in 70 countries, compared with regulatory policies for renewables in the power sector existing in 135 countries.¹⁴

ⁱ Heating and cooling in the Renewables in Cities Global Status Report refers to applications of thermal energy including space and water heating, space cooling, refrigeration, drying and industrial process heat, as well as any use of energy other than electricity that is used for motive power in any application other than transport. In other words, thermal demand refers to all end-uses of energy that cannot be classified as electricity demand or transport.

SIDEBAR 1: The Renewables in Cities Global Status Report Series

Driven by concerns about climate change, local air pollution and health, as well as by growing socio-economic opportunities, more and more city governments are showing political ambition to engage in the renewable energy transition. Many have developed policies to support the use and production of renewables in their municipal activities and are drawing on their legal and regulatory authority as well as their convening power to support other urban players in such efforts. Cities also play a key role in advancing renewable energy deployment in local heating, cooling and transport markets, and thus are contributing to decarbonisation of the energy sector as a whole.

Although cities are critical players in the energy transition, globally consolidated data and information are lacking on city-level renewable energy targets, policies and action. The sheer geographical distribution of cities, their diversity (politically, economically, environmentally) and their varied institutional capacity makes documenting the evolution and uptake of renewables challenging. As a result, the limited data that are available tend to be outdated and are rarely consolidated. In addition, data often do not consider the changing roles that cities play in the energy system, since distributed renewable energy technologies enable them to potentially become energy producers.

Data gaps and limitations exist in the following key areas:

- municipal targets and policies to promote renewables in the power, heating and cooling, and transport sectors, both for municipal operations and for city-wide energy uses;
- shares of renewables in municipal and city-wide energy use;
- generation capacities for renewable electricity, heating and cooling, and transport fuels – by municipal governments and/or public utilities and other urban actors (businesses, residents, communities);
- renewable energy investment in cities, including municipal direct investment in renewables, city-wide investment by other urban actors and finance mechanisms for renewables; and
- community energy projects in cities, including the number of projects, installed capacities and investment.



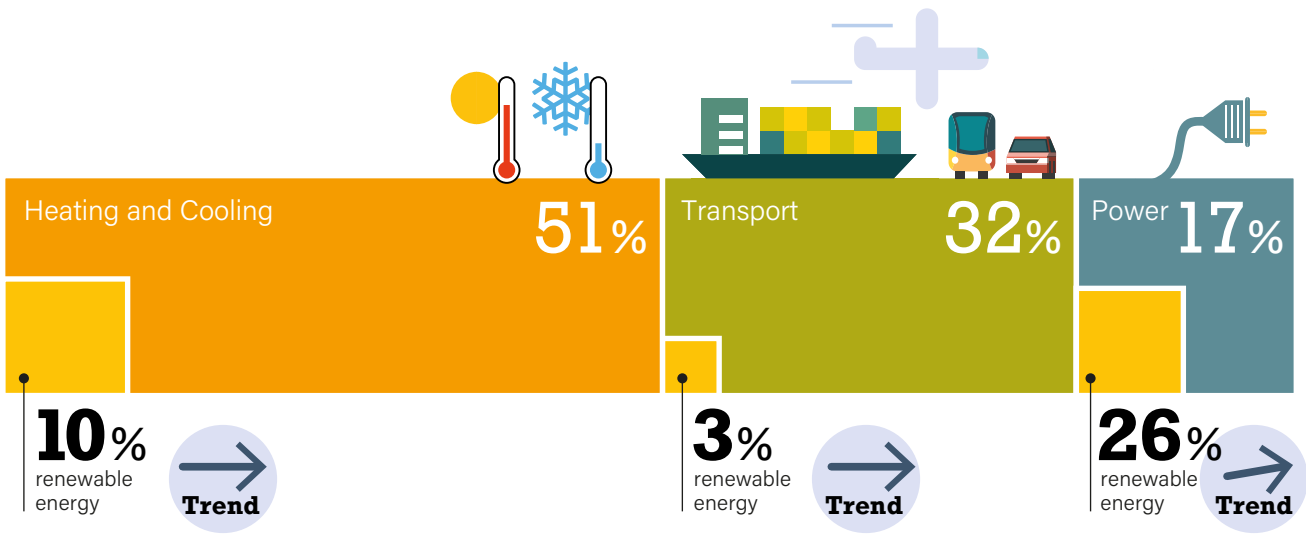
The lack of comprehensive data makes it challenging to concretely assess the role that cities play in advancing renewable energy, to determine objectives and baselines, and to monitor progress. Improving the data situation is also important for engaging cities more into the energy debate in a more holistic way, and for better integrating policy and regulatory frameworks at the local, sub-national and national levels. Improved data availability also makes it possible to increase knowledge about the opportunities that renewable energy presents for cities and to further accelerate renewable energy development.

REN21 is developing the *Renewables in Cities Global Status Report* series with the aim of building up continuous and reliable data on renewable energy developments in cities and creating a clearer and more comprehensive picture of renewables in cities around the world. This makes it possible to better inform decision makers within cities as well as in the wider energy arena and energy-consuming environments and to create additional opportunities to accelerate the energy transition.

REN21's reporting approach is well adapted to address the current data challenges. The data collection processes build on an international community of experts – allowing access to dispersed data and information that frequently are not consolidated and are difficult to collect – and on the consolidation of formal (official) and informal (unofficial/unconventional) data gathered from a wide range of sources in a collaborative way. This first edition in the series is the start of a continuous, collaborative process that aims to make renewable energy more visible in cities – and cities more visible in the energy transition – in order to accelerate renewable energy uptake worldwide.



FIGURE 1. Renewable Energy in Total Final Energy Consumption, by Sector, 2016



Note: Data should not be compared with previous editions of the Renewables Global Status Reports. Electricity also supplies final energy demand in the heating and cooling sector (71% in 2016), and transport sector (11% in 2016). Source: Based on OECD/IEA. See endnote 11 for this chapter.

ENERGY IN CITIES

Cities are important global actors (→ see *Sidebar 1, Figure 2 and Box 1*).¹⁵ In 2018, 55% of the global population, or 4.2 billion people, lived in cities, up from 43% (2.3 billion people) in 1990.¹⁶ Cities also are vital economic and financial centres, accounting for more than 80% of global gross domestic product (GDP).¹⁷

In the energy context, cities offer a lever to advance the transition towards renewable energy in all end-use sectors and to reduce energy-related carbon dioxide (CO₂) emissions. As of 2018, around two-thirds of global final energy use was concentrated in cities, compared with less than half (45%) in 1990.¹⁸ Further urbanisation, population growth, and economic development, as well as rising prosperity and living standards, are expected to contribute to growing energy demand at the municipal level.¹⁹

Cities also are responsible for considerable global energy use that does not actually take place in cities.²⁰ Urban residents and businesses indirectly consume large amounts of energy that is embodied in the materials used in infrastructure (concrete, steel, etc.), in the products applied in daily life (food, clothing, electronics, etc.) and in other goods that are consumed in cities but produced elsewhere.²¹ Because of their large energy and environmental footprints, cities contribute to land-use change, biodiversity loss and climate change, accounting for an estimated three-quarters of human-caused CO₂ emissions from final energy use.²² Shifting to renewable energy in cities is critical to decarbonising the energy system in order to achieve the objectives of the Paris Agreement.²³

ⁱ These factors make it difficult to track comprehensively the total energy use in cities and its associated environmental impacts.

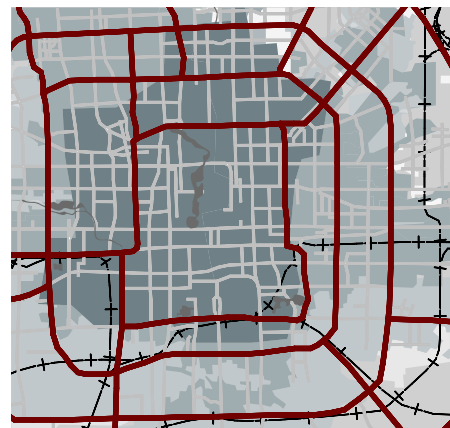
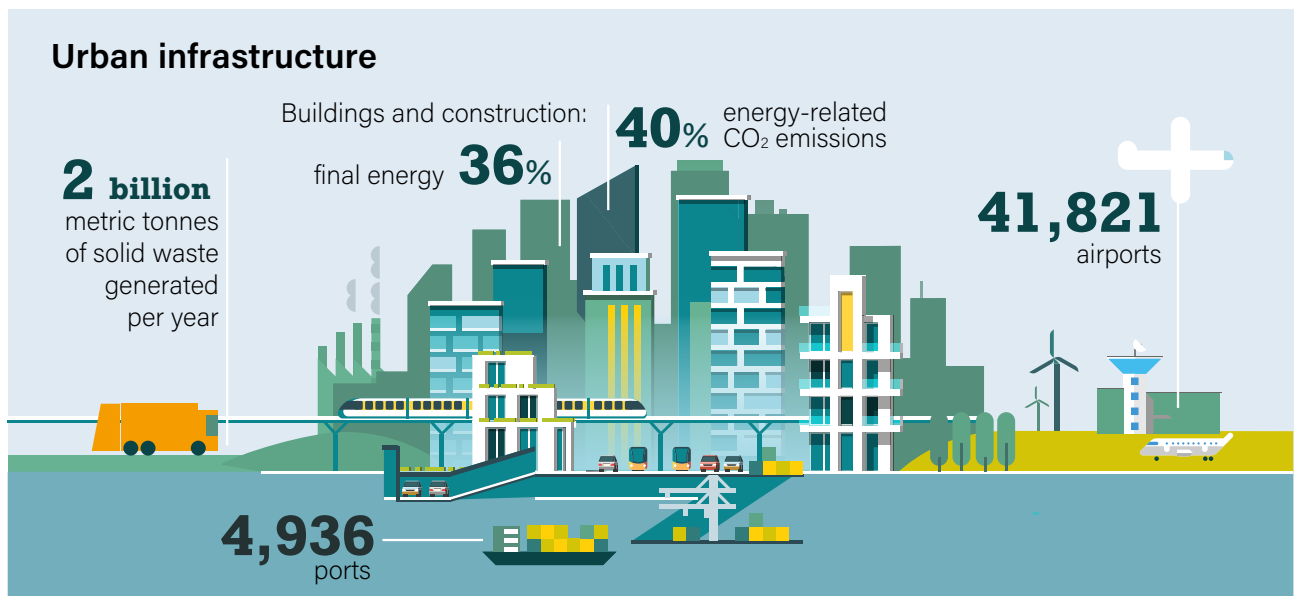
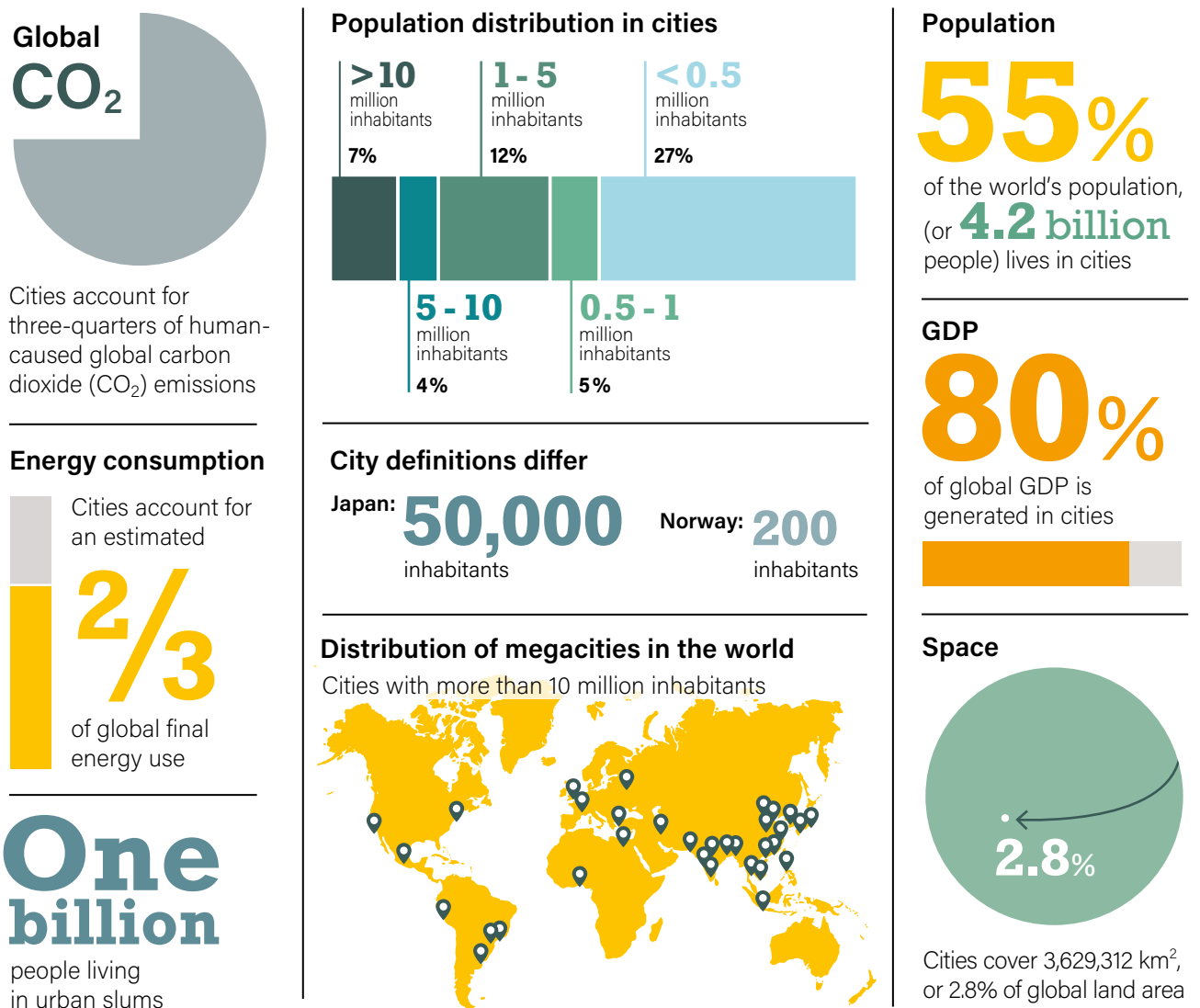


FIGURE 2. Cities in the World



Source: See endnote 15 for this chapter.

BOX 1. What is a City?

No international criteria or standards exist to determine what a city is. This makes comparing cities across different countries a challenging task, as boundaries are often fluid and national definitions can be inconsistent. Most definitions of “cities” rely on settlement density and/or population numbers, although the criteria vary widely across countries. In Japan, settlements are defined as cities when they have more than 50,000 inhabitants, whereas in Norway an urban area is defined as having more than 200 inhabitants. In other cases, cities may be defined by, for example, the presence of certain healthcare, governmental or educational services, or by the share of residents employed in sectors other than agriculture.

Generally, the term “urban area” refers to settlement areas that are more densely populated than suburban or peri-urbanⁱ communities within the same metropolitan area. The term “city”, meanwhile, has broader meanings: according to the United Nations, it can connote a political or civic entity, a geographic unit, a formalised economy or an infrastructure

bundle. In some instances, local communities, neighbourhood associations, urban businesses and industries may be subsumed under the term “city”. Most countries differentiate between “primary” and “secondary” cities, usually based on population thresholds or role.

In this report, “city” refers to the local decision-making bodies and government authorities, unless otherwise specified. For example, when cities adopt specific targets for renewable energy or pledge to meet ambitious climate goals, what is meant is that the city’s decision-making bodies (the mayor’s office, city council, etc.) have adopted such a target, although other key city-level stakeholders also can promote and pursue such aims. Key city-level stakeholders include individual citizens, groups of citizens and private enterprises, as well as various civil society groups that are active within the city.

ⁱ Residential area at the edge of a large city.

Source: See endnote 15 for this chapter.

The overall structure of a city – including its density, infrastructure and the characteristics of its buildings – greatly influences urban energy use. While energy use across the various end-use sectors differs greatly from city to cityⁱ, the heating, cooling and transport sectors often account for large shares of urban energy demand (→ see Figure 3).²⁴ Local market solutions and decentralised renewable energy technologies can play an important role in decarbonising these sectors, and cities can use their purchasing and regulatory power to advance the uptake of renewables while strengthening local economies and creating jobs.

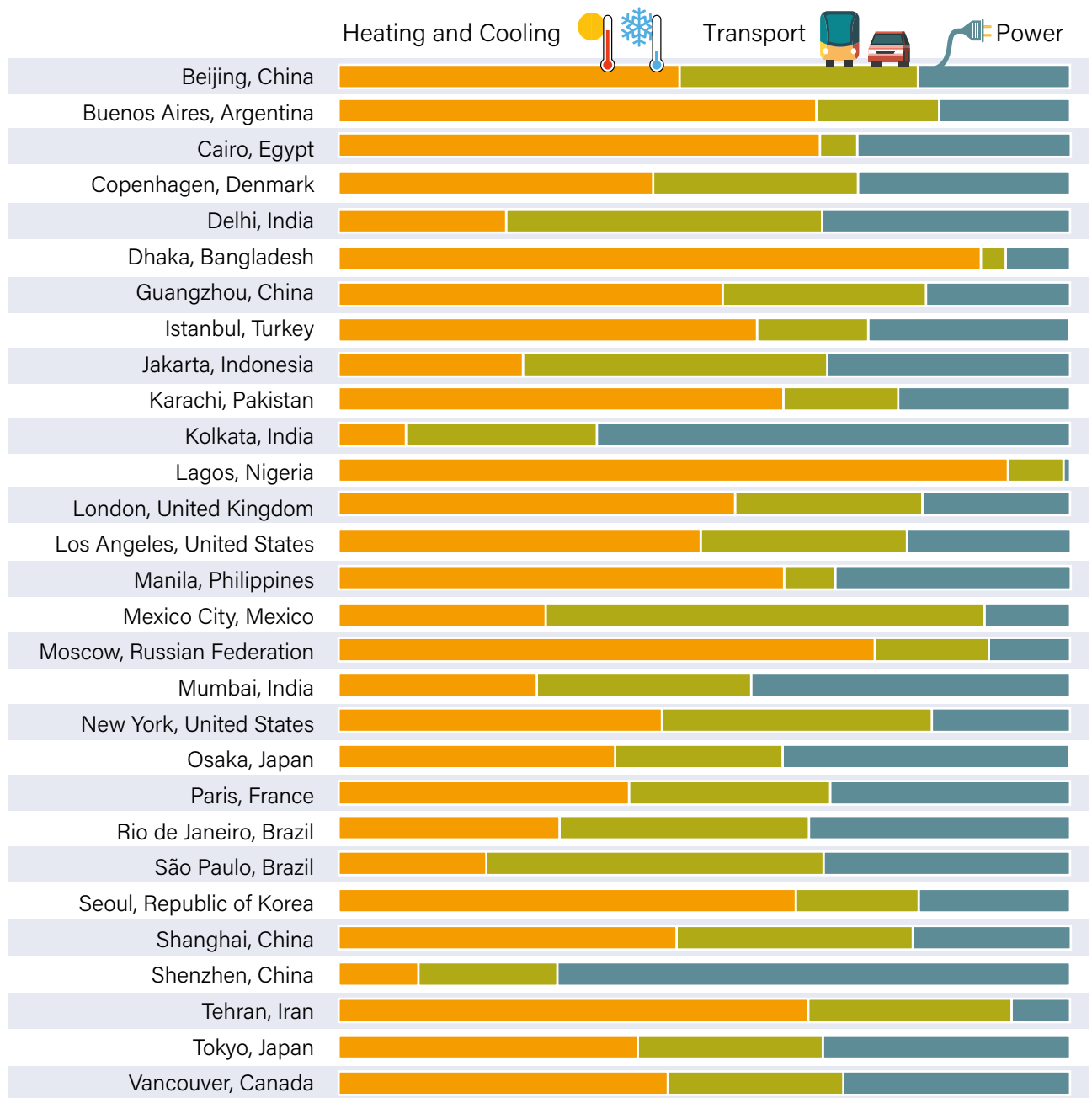
Buildings account for approximately half of all energy demand worldwide, and most built structures are located in and around urban centres.²⁵ For heating and cooling systems, where energy production is more localised and tends to occur close to the point of demand, the development of urban renewable heating and cooling markets is key to decarbonising these sectors.²⁶ In the transport sector, urban mobility is a primary source of air pollution in cities and accounts for a large share of the CO₂ emissions from road transportⁱⁱ.²⁷ Cities can support decarbonisation efforts by shifting fleets to renewable fuels and reducing overall road transport through improvements in land use, increased walkability and cyclability, and the promotion of public transport and shared mobilityⁱⁱⁱ.

ⁱ These differences reflect characteristics such as a city’s geography and climate, population densities and income levels, the cultural practices of inhabitants and the presence or absence of heavy industry within city borders.

ⁱⁱ In 2018, the global transport sector accounted for around one-third of final energy consumption and one-third of energy-related CO₂ emissions, from International Transport Forum, “How transport CO₂ reduction pledges fall short”, 19 November 2018, <https://www.itf-oecd.org/CO2-reduction-pledges>. In the European Union (EU), urban mobility accounts for 40% of the CO₂ emissions from road transport and for up to 70% of other pollutants from transport, from European Commission, “Urban mobility”, https://ec.europa.eu/transport/themes/urban/urban_mobility_en, viewed 15 October 2019.

ⁱⁱⁱ The “avoid/shift/improve” framework focuses on the mobility needs of citizens, aiming to decrease traffic congestion, improve air quality and reduce greenhouse gas emissions in cities by avoiding the need for motorised travel and travel length, shifting from most energy-intensive and polluting modes of transport towards active transport (including walking and cycling) or public transport and improving fuel efficiency and integrating renewables into transport. See Daniel Bongardt et al., Transformative Urban Mobility Initiative, *Sustainable Urban Transport: Avoid – Shift – Improve (A-S-I)* (Bonn and Eshborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, 2019), https://www.transformative-mobility.org/assets/publications/ASI_TUMI_SUTP_iNUA_No-9_April-2019.pdf

FIGURE 3. Energy Use by Sector in Selected Cities



Note: Depending on the city, a significant amount of electricity may be included in the heating/cooling and transport sector. Data are for recent years in which reliable statistics were available. Comprehensive data on energy use at the city level are not widely available and are often outdated. Several cities also collect energy data according to end-use sectors (buildings, industry, transport).

Source: See endnote 24 for this chapter.



Buenos Aires, Argentina

RENEWABLE ENERGY OPPORTUNITY IN CITIES

The decentralised nature and scale of renewable energy technologies has made it possible to bring energy production closer to where the energy is consumed and to develop more distributed energy systems.²⁸ This has allowed other actors, such as municipal governments, private households and businesses, to take an active role in the energy system and to drive the transition towards renewables.²⁹ Through the uptake of renewables, cities have the opportunity to achieve a wide range of objectives, including fighting local air pollution to improve public health, mitigating climate change, supporting the local economy, promoting energy security, building resilient energy infrastructure, creating more liveable urban areas and enabling a better quality of life (→ see *Drivers chapter*).³⁰ Renewables have become the lowest-cost source of new power generation in a growing number of countries, resulting in cost savings compared with conventional energy supply options.³¹

Municipal governments are responsible for urban planning and for providing a range of urban services, including public housing, waste and wastewater management, and public transport. Considering these roles, they are well positioned to support the integration of renewable energy in their own activities and to encourage the deployment and use of renewables in cities more broadly. Municipal governments can support the integration of renewable energy in buildings, for example through the installation of solar PV and solar thermal systems. They also can link the development of renewables with other urban services, such as by using waste and wastewater to produce biogas and biomethane, simultaneously improving waste management and supporting renewables.³² As the electrification of transport gains momentum, some cities are facilitating the integration of electric vehicles (EVs) and renewable power supply, installing EV charging stations and other infrastructure that relies on renewable electricity.³³

Considering the multiple opportunities and benefits of renewable energy, many municipal governments and other urban players are actively engaged in advancing renewables. As of mid-2019, hundreds of city governments around the world had passed ambitious renewable energy targets for their municipal operations and/or city-wide, not just in the power sector but also for heating, cooling and transport (→ see *Targets and Policies chapter*).³⁴

CITIES' MULTIPLE ROLES IN THE ENERGY TRANSITION

The cross-sectional character of cities, coupled with their large energy use and the responsibility they have for their citizens, means that cities play multiple roles in the effort to address climate, energy and sustainable development issues; in addition, they must foster the integrated approaches needed to decarbonise energy use in all sectors (→ see *Figure 4*).³⁵ Many municipal governments have adopted specific targets for renewable energy

and/or energy efficiency, often as part of wider urban strategies to develop infrastructure and reduce air pollution and emissions. To achieve these targets, municipal governments have used their purchasing power to shift their energy use to renewables, or have become directly involved in renewable energy generation using solar, biomass and other sources (→ see *Urban Renewable Energy Markets chapter*).³⁶

Municipal governments have used their proximity and close ties to their constituents to engage local stakeholders in their energy and climate plans. Local policies are an important tool for encouraging greater uptake of renewables city-wide, helping to boost the involvement of residents, businesses and other urban actors in the energy transition.³⁷ Not only can this foster greater acceptance of renewables in cities, but it also is key to achieving public support for national renewable energy goals.³⁸ Cities can serve as trendsetters, influencing and advocating for more renewable energy policy making at the state/provincial and national levels. Cities also have joined together in national and global networks to exchange ideas, show city commitment and jointly drive renewable energy and climate action around the world.

Many municipal governments have the possibility to create incentives that influence choices at the local level, such as encouraging more efficient use of resources and reductions in overall energy demand. For example, cities can mandate the creation of urban green spaces and water bodies, as well as green roofs and cool pavements, to reduce the urban heat-island effectⁱ and minimise the need for air conditioning.³⁹ In the transport sector, they can use zoning policies to reduce the quantity and distance of transport trips while also improving walkability and cyclability and promoting public transport and shared mobility.⁴⁰

The specific roles that cities play in shaping the urban energy transition include:

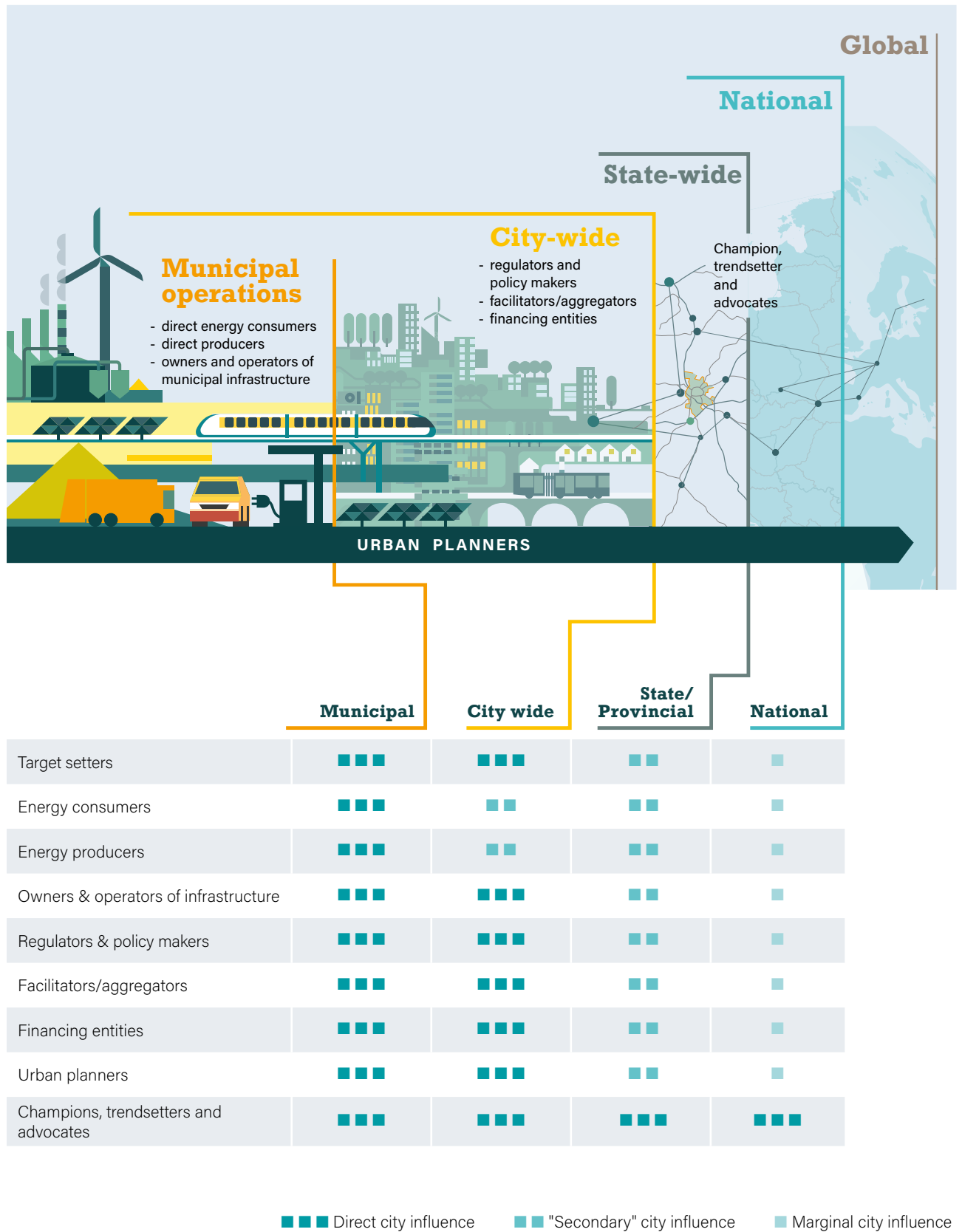
Target setters. Many municipal governments have adopted ambitious climate and energy targets, covering both municipal operations as well as city-wide emissions and energy use. For many cities, setting a target can act as a catalytic step in the shift to renewables, signalling ambition and helping to mobilise investments.⁴¹

Energy consumers. Municipal governments are major consumers of energy, including for public offices, schools, recreation facilities and street lighting.⁴² To transition these uses to renewables, many governments are using their purchasing power to contract a renewable energy supplier or to choose a renewable energy option. Some cities have aggregated city-wide electricity use to procure renewable power on behalf of residents and businesses, or have benefited from renewables deployment outside city boundaries – for example, by signing power purchase agreements (PPAs) with nearby wind and solar projects.⁴³

Energy producers. Building on their role as owners and operators of infrastructure (see below), municipal governments can become renewable energy producers, for example by installing solar PV and solar thermal on public buildings or tapping into local waste streams to create bioenergy.

i The heat-island effect describes urban areas that are hotter than nearby rural areas. See US Environmental Protection Agency, "Heat island effect", <https://www.epa.gov/heat-islands>, viewed 17 November 2019.

FIGURE 4. City Roles in Advancing Renewables Across Different Levels of Governance



Source: See endnote 35 for this chapter.

Owners and operators of infrastructure. A municipality's ownership and/or operation of infrastructure (including buildings, energy, transport, waste and wastewater) plays a decisive role in how it can respond to the opportunities presented by the energy transition. In the heating sector, for example, many cities manage district thermal networks (or grant concessions to private companies). When municipalities own their utilities, energy networks, transit fleets, grids and/or other energy infrastructure, they often have greater direct control over the speed of renewable energy deployment. In jurisdictions where the control over urban electricity infrastructure lies with national or state/provincial utilities, local initiatives have started to emerge to re-municipalise this infrastructure and allow for greater local control. Cities that own municipal utilities, whether for electricity or for district heating networks, can directly shape their energy mix by modifying their investments, operations and planning.

Regulators and policy makers. City authorities play an important role in the design, planning, zoning and permitting of city infrastructure. Many cities have made use of existing tax incentives, building codes, mandates, and various laws and regulations adopted at the state/provincial and national levels – such as feed-in tariffs and net metering policies – to increase the local deployment of renewables.⁴⁴ In some cases, city governments also have developed their own policies to encourage local renewables, complementing national- and state-level efforts.

Facilitators/aggregators. Cities play an important role in raising awareness about the benefits of renewable energy, contributing to knowledge sharing, dialogue and engagement from all parts of society, including directly from citizens, civil society groups and businesses.⁴⁵ City governments are uniquely positioned to act as facilitators and enablers of this dialogue, creating opportunities for citizens and other stakeholders to provide input and to help shape city plans and policies.

Financing entities. Generally, cities obtain income from tax collection, municipal bond issuance and a range of fee-for-service charges, among other sources.⁴⁶ City governments can use these funds to invest directly in renewables for their municipal operations, as well as to enable more direct investment among residents, businesses and other local stakeholders by providing low-interest loans, grants or rebates for different investment activities.⁴⁷

Urban planners. Cities have a role in co-ordinating urban planning both vertically (working with the national and sub-national levels of government) and horizontally (across city departments).⁴⁸ Good co-ordination of integrated energy planning across multiple levels of government can facilitate the coherent and efficient deployment of renewables.

Champions, trendsetters and advocates. City governments can act as trendsetters, leading by example to help drive change. They may act as laboratories of innovation for new policies and business models, testing out concepts and approaches. As such, the actions taken by cities can provide important learnings and influence change at the state/provincial and national levels, while providing valuable case studies for other peer cities around the world.

■ LIMITATIONS OF CITY ACTIONS TO DRIVE RENEWABLES

Despite these many points of leverage, key challenges remain to the uptake of renewables in cities. In many parts of the world, city governments still lack the financing, power and legal authority needed to pursue ambitious energy and climate strategies.⁴⁹ In Asia, Latin America and sub-Saharan Africa, many cities depend heavily on their national governments for funding and access to financial markets and have comparatively little rule-making authority.⁵⁰

A lack of co-ordination among city departments can impede progress, as can the absence of resources to engage local partners, and involve citizens and surrounding communities.⁵¹ Although city officials may want to do more, they may face opposition from colleagues and other city departments.⁵² Many city governments also lack the time and resources to focus on renewables or may face other constraints such as opposition from certain interest groups, making it difficult to drive change.⁵³

In general, cities cannot transition to sustainable, low-carbon models in isolation. Municipal efforts to scale up renewables are closely connected to the policies, regulations and incentives that are adopted at the state/provincial and national levels.⁵⁴ National governments must play an important role in aligning energy policies across different levels of government (referred to as vertical integrationⁱ or multi-level governance), supporting cities in scaling up finance for renewable energy projects and creating an enabling framework that stimulates private and civil society investment in cities.⁵⁵

Improved policies and regulatory frameworks are needed at all levels of government to support the energy transition. However, the degree of co-ordination among city, state/provincial and national governments varies by country or region. For example, cities in Europe and the United States (US) tend to have greater financial autonomy and regulatory authority than cities elsewhere, due in part to European prioritisation of the principle of subsidiarityⁱⁱ and to the importance of US state and local powers.⁵⁶ Integrating and harmonising policies and regulatory frameworks across jurisdictions would strengthen the opportunities for cities to advance sector coupling and overall progress towards renewable energy.

i Vertical integration refers to close co-operation and collaborative decision making between different levels of government. In this type of governance arrangement, national and state/provincial governments are able to work with cities to provide incentives, funding and larger policy mandates than cities could provide on their own.

ii Subsidiarity refers to the principle that issues that can be resolved at a local level should be resolved at that level. It aims to guarantee a degree of independence for local authorities in relation to higher levels of government. See European Parliament, "The principle of subsidiarity", <http://www.europarl.europa.eu/factsheets/en/sheet/7/the-principle-of-subsidiarity>, viewed 14 October 2019.

REGIONAL TRENDS

Although the opportunities to scale up renewables are widespread, a city's ability to engage these options and to take rapid action depends heavily on its local characteristics – for example, own financial resources, access to external financing, the size of the tax base, economic growth and the local administrative capacity and authority. These, in turn, are influenced by national and regional characteristics.

The differences among cities can be striking. Some cities – such as Amman (Jordan), Montevideo (Uruguay) and Ulaanbaatar (Mongolia) – have populations nearly as large as the rest of their respective countries, while others – including London (United Kingdom, UK), New York (US) and Tokyo (Japan) – boast economies larger than some Group of 20 countries.⁵⁷ Urban renewable energy development strategies are more effective when they take into consideration the broad diversity of local needs and constraints, within the larger regional context.

Asia is home to 60% of the world's population (4.3 billion people) and is the largest and most densely populated region, at over 43 million square kilometres (km²) and roughly 95 inhabitants per km².⁵⁸ Although Asia's overall urbanisation rate, at around 50%, is lower than in Latin America (81%) and Europe (74%), the region as a whole is rapidly becoming urban.⁵⁹ A range of social, political and economic factors are influencing this trend, stimulating local economies but also straining city infrastructures and fuelling environmental degradation. Fine particle air pollution and smog are growing concerns in cities across China, India and elsewhere.⁶⁰ Taken together, these factors are driving public demand for less-polluting mobility options and a cleaner energy mix.⁶¹

China is the leading actor in renewable energy deployment, both within Asia and worldwide. Despite a recent decline in renewables-related investment in the country, China still accounted for nearly a third (32%) of global investment in renewable power and fuels in 2018.⁶² China also had the largest cumulative renewable power capacity that year by far – at 727 gigawatts (GW), compared to 260 GW in the United States (the second largest capacity) – and was home to more than 95% of the global electric bus fleet and nearly half of all electric passenger vehicles.⁶³

India had the next highest installed renewable power capacity and investment in Asia in 2018 and is making a concerted push to



scale up EVs.⁶⁴ Other countries in the region, including Indonesia, Japan, Pakistan and the Philippines, have witnessed significant advancements in geothermal power, hydropower and solar PV capacity, while Thailand has seen substantial increases in ethanol production.⁶⁵

Europe is heavily urbanised, with around 74% of the region's population living in cities and an average population density of 73 inhabitants per km².⁶⁶ In contrast to many other regions, where urban centres are growing rapidly, European cities typically have a more settled urban form, shaped by buildings and local infrastructure that extend back centuries. Thus, the focus is more on refurbishing and improving existing infrastructure than on designing entirely new cities and regions.

Due to higher average income levels and a broader and more established tax base, European cities are in many ways better positioned to accelerate the energy transition than cities elsewhere in the world, although public opposition and more restrictive regulations around planning, permitting and project siting can present challenges.⁶⁷ Across Europe, the push for greater climate action – including through the Fridays for Future and Extinction Rebellion protest movements – is an increasingly powerful force for change.⁶⁸

Partly in response to this movement, the EU's recently published long-term energy strategy discusses an objective to be climate neutral by 2050.⁶⁹ After decades of focus on the electricity sector, attention is increasingly shifting towards greater use of renewables in the heating, cooling and transport sectors, as well as to sector coupling.⁷⁰ Germany tops the list for renewable capacity in the power, heating and cooling sectors in Europe, although Iceland, Denmark and Sweden lead in installed renewable power capacity per capita, and Austria, Cyprus and Greece have the most solar water heating capacity per capita.⁷¹

Latin America has a very high rate of urbanisation by global standards, and many of its major cities have experienced rapid growth.⁷² Since 1950, when only 40% of the region's population lived in cities, the urban share has more than doubled to 81% in 2018.⁷³ Due in part to public finance constraints, many municipal governments in Latin America are turning to public-private partnerships to implement key projects, including for renewables and public transit. Growing concerns about inadequate infrastructure as well as climate change are pushing many cities to invest heavily in public transit (including electric buses), and the opening of electricity markets in many countries is making it possible for cities to procure renewable electricity directly from local or nearby projects.⁷⁴

Urbanisation rates in the **Middle East and Northern Africa** vary widely, with nearly 100% urbanisation in Qatar and more than 80% in Kuwait versus 45% in Egypt and 30% in Yemen.⁷⁵ City governments in the region have comparatively little political autonomy and often lack financial and human resources as well as the ability to borrow independently from their national governments. This makes it difficult for cities alone to implement ambitious renewable energy projects or to invest in major infrastructure such as district cooling networks or public transit, relying instead on national governments or on direct partnerships with the private sector. National, rather than municipal,

governments largely drive efforts to deploy renewables, often influenced by the opportunities for job creation and economic diversification.⁷⁶

In **North America**, the urbanisation rate in both the United States and Canada is 82%.⁷⁷ However, the urban share varies widely by state and province, at less than 40% in Maine (US) and 48% in New Brunswick (Canada).⁷⁸ The distribution of cities and local governments also varies: for example, the US states of Illinois, Pennsylvania and Texas have more than 1,000 municipal governments each, while Hawaii has only 1.⁷⁹ Cities in Canada often rely on complex funding arrangements with higher levels of government to invest in major infrastructure projects. Such differences, as well as the varying legislative and financial powers that city governments possess, have an important impact on the role that they can play in driving renewables.

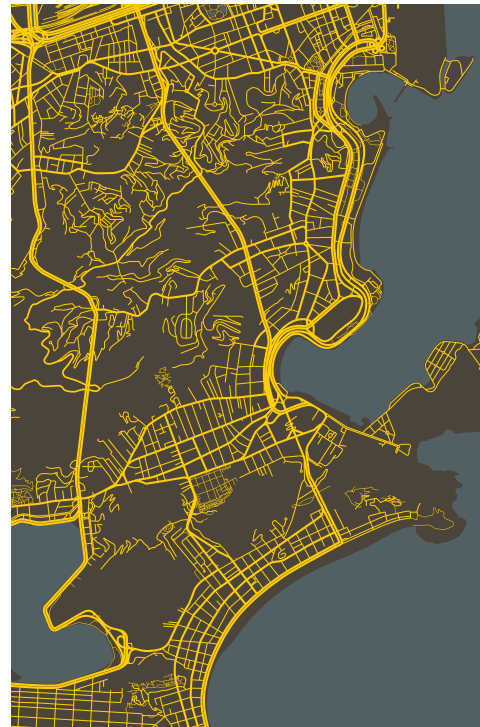
Historically, it was the states/provinces in North America that played the most important role in determining many aspects of energy and climate policy.⁸⁰ In recent years, however, cities have become increasingly influential, as seen in the range of city-led initiatives including the American Cities Climate Challenge, the Sierra Club's Ready for 100 campaign, the We Are Still In campaign and the Renewable Cities partnership.⁸¹ At a national level, in addition to having the world's second highest installed renewable power capacity in 2018, the United States has witnessed significant developments in the transport, heating and cooling sectors.⁸² However, the country also was the leading contributor to rising global oil and natural gas demand in 2019.⁸³

Sub-Saharan Africa is the world's most rapidly urbanising region, although urban shares range widely from 89% in Gabon and 56% in Ghana to 16% in Niger and 13% in Burundi.⁸⁴ Despite some promising economic indicators, poverty remains widespread in the region, and 55% of the urban population

lives in slum conditions.⁸⁵ In many countries, the speed of urbanisation exceeds the ability of local governments to adapt, leading to inadequate infrastructure and large numbers of informal settlements. The rapid rise of "primary cities" – whereby a country's largest city is several times bigger than its second largest city – together with low income levels has given rise to congestion, informal development patterns and the neglect of secondary cities by national governments.⁸⁶

As the influence of cities grows in sub-Saharan Africa, achieving ambitious climate and renewable energy targets hinges increasingly on city-level action.⁸⁷ Because much of the core infrastructure has not yet been built, the region faces a major opportunity to orient its growth along a more sustainable path.⁸⁸ However, the tax base of many African cities remains thin, and municipal governments often face tremendous difficulties collecting local taxes.⁸⁹ Moreover, the urgency of extending water and transport infrastructure and improving waste collection and recycling, among other challenges, makes it difficult for cities to allocate anywhere near the resources for energy and climate-related projects as in other parts of the world.⁹⁰ Financial, political and governance challenges deprive many cities of the capacity to invest in local renewable energy.⁹¹

Partly in response, the private sector is playing a growing role in accelerating the deployment of renewables in both urban and rural regions of Africa. Many of these efforts aim specifically at supporting energy access for previously unelectrified populations. During 2017 and 2018 alone, more than USD 500 million was invested in the off-grid solar sector, much of it in East and West Africa.⁹² Globally, sales of solar home systems increased 77% in 2018 compared to 2017, with some 108 million people – many of them in sub-Saharan Africa – now living in households that have achieved improved access to energy via solar power.⁹³





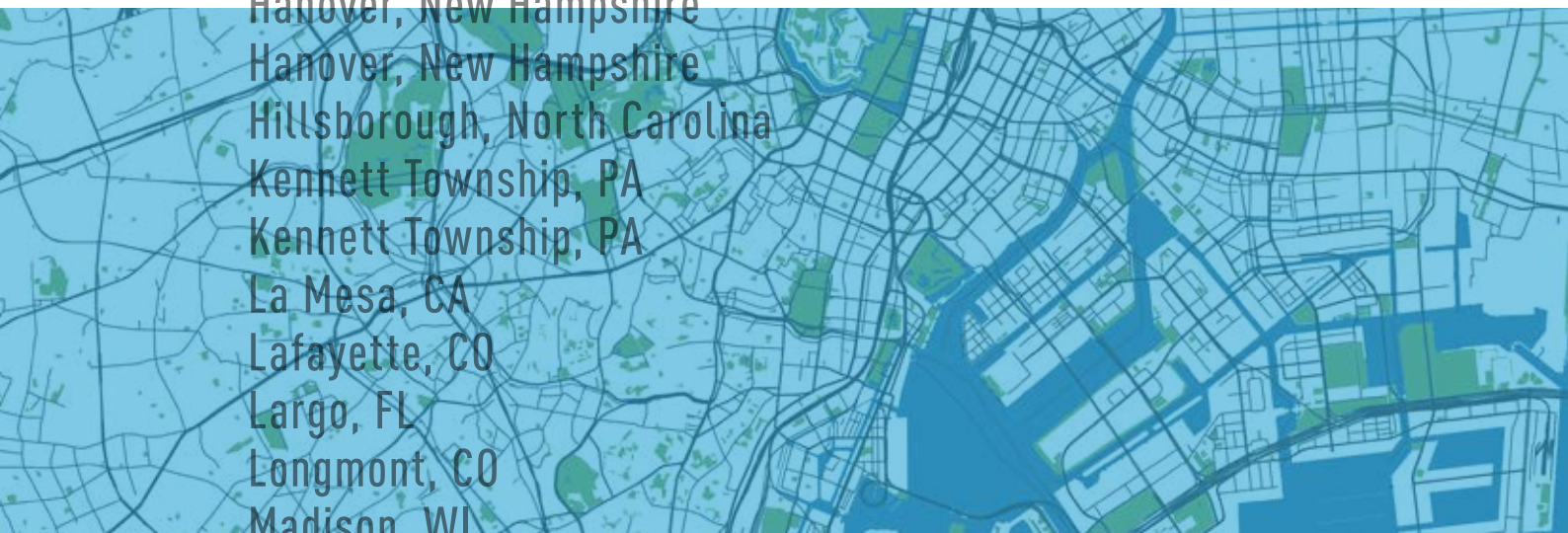
The Hague
 Abita Springs, LA
 Amherst, MA
 Angel Fire, NM
 Atlanta
 Berkeley, CA
 Blacksburg, VA
 Breckenridge, Colorado
 Chula Vista, CA
 Clarks Summit, PA
 Concord, NH
 Danvers, New Hampshire

2

DRIVERS

Del Mar, California
 Denton, TX
 Denver, CO
 Downingtown Borough, PA
 Eagle Nest, NM
 East Hampton, New York
 East Hampton, New York
 Eau Claire, WI
 Encinitas, CA
 Eureka, CA
 Goleta, California,
 Hanover, New Hampshire
 Hanover, New Hampshire
 Hillsborough, North Carolina
 Kennett Township, PA
 Kennett Township, PA
 La Mesa, CA
 Lafayette, CO
 Largo, FL
 Longmont, CO
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**FOR
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 IN CITIES**



DRIVERS FOR RENEWABLE ENERGY IN CITIES

When advancing renewables, cities are driven by a wide range of objectives, including mitigating climate change; advancing sustainable development; reducing air, water and soil pollution; improving citizens' health and well-being; stimulating economic development; reducing municipal energy costs; and improving energy access and security (→ see *Figure 5*).¹ The relative importance of the different drivers for renewable energy is very context specific, and most cities pursue renewables for a diversity of reasons.



■ AIR POLLUTION, HEALTH AND WELL-BEING

Air pollution is among the greatest environmental risks to health and well-being today. Increases in road transportⁱ, industrial activity, and heat and power generation, as well as the open burning of waste, contribute to elevated levels of outdoor air pollution in many cities worldwide. In developing countries, the use of charcoal and fuelwood for heating and cooking also contributes to poor indoor air quality in urban areas. Exposure is augmented by the absence of energy efficiency measures, such as building insulation, which results in the need for increased energy generation.²

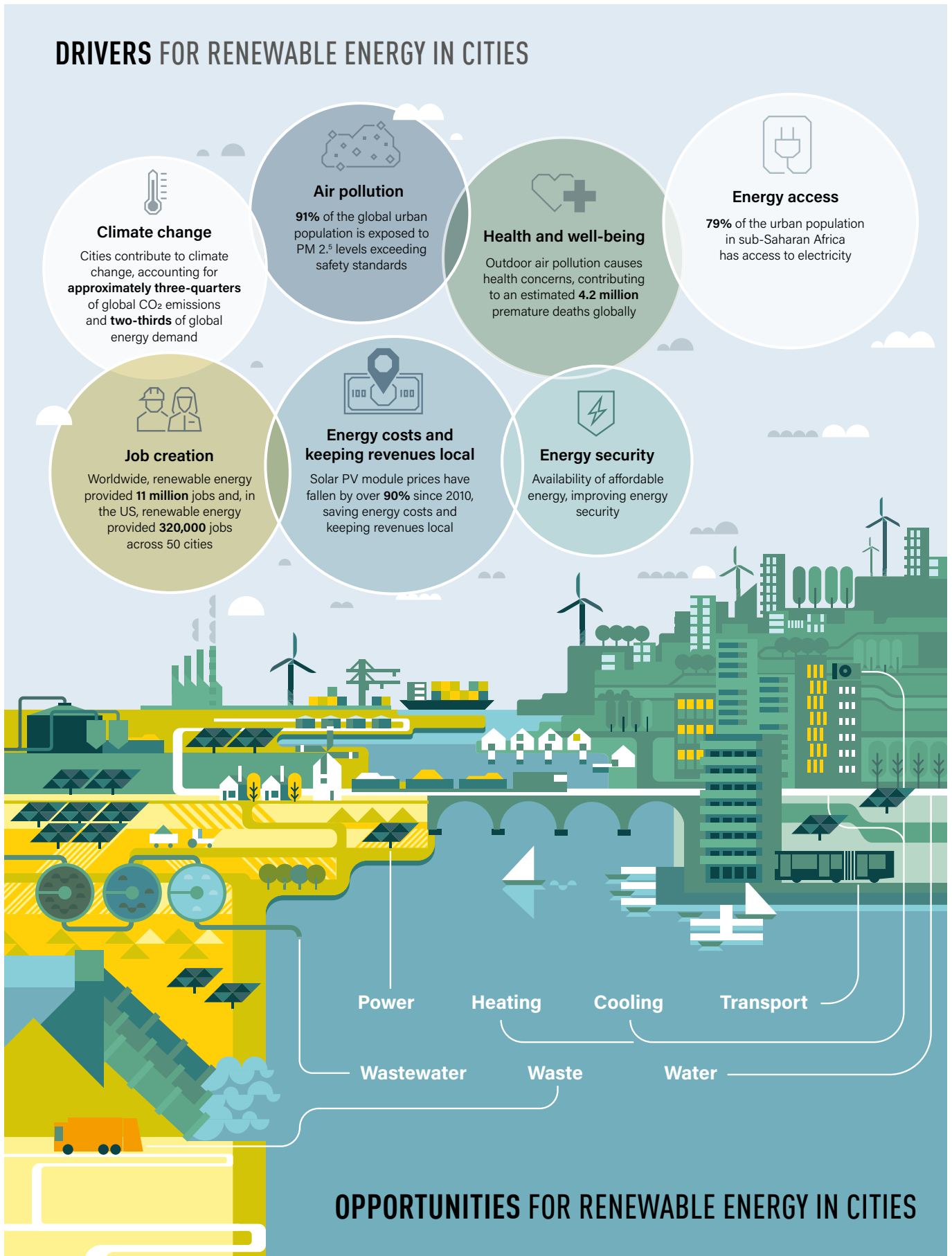
An estimated 9 out of 10 people worldwide regularly encountered polluted air in 2018.³ In 2016, as much as 91% of the global urban population was exposed to air pollution – measured in the form of fine particulate matter (PM_{2.5}) – and more than half of the urban population faced PM_{2.5} levels at least 2.5 times above the safety standard of the World Health Organization.⁴

Air pollution

is among the greatest environmental risks to health and well-being today.

ⁱ Fossil fuels power more than 95% of motorised transport worldwide, from REN21, *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf.

FIGURE 5. Drivers and Opportunities for Urban Renewable Energy



Source: See endnote 1 for this chapter.

Air pollution is particularly challenging in Asia, where it is triggered by rapid economic development, urbanisation and the widespread burning of coal for power and heat. In 2018, India and China were home to nearly all of the world's 50 most polluted cities (25 and 22 cities, respectively) but air pollution also is also a concern in Asian cities, including Dhaka (Bangladesh), Hanoi (Vietnam), Jakarta (Indonesia), Lahore (Pakistan) and Ulaanbaatar (Mongolia) (→ see Figure 6).⁵ In the Middle East, emissions from oil refineries, the open burning of waste and the high use of private vehicles and other transport contribute to polluted air in cities such as Dubai (United Arab Emirates, UAE), Kuwait City and Manama (Bahrain).⁶ While many cities in Africa suffer from air pollution, only 6% of the region's population lives near reliable monitoring stations (compared to 72% in Europe and North America), resulting in low awareness of air pollution impacts.⁷

Air pollution is the world's fourth-leading contributor to early mortality.⁸ In 2016, high levels of outdoor air pollution were responsible for the deaths of some 4.2 million people due to increases in cancer and in heart and lung disease.⁹ Most of the premature deaths occurred in low- and middle-income countries, particularly in Southeast Asia and the Western Pacific.¹⁰ Exposure to polluted air has been linked to mental illnesses such as depression and bipolar disorder, and socially disadvantaged groups often are exposed to disproportionate levels of pollution related to the siting of fossil fuel power plants and transport routes.¹¹

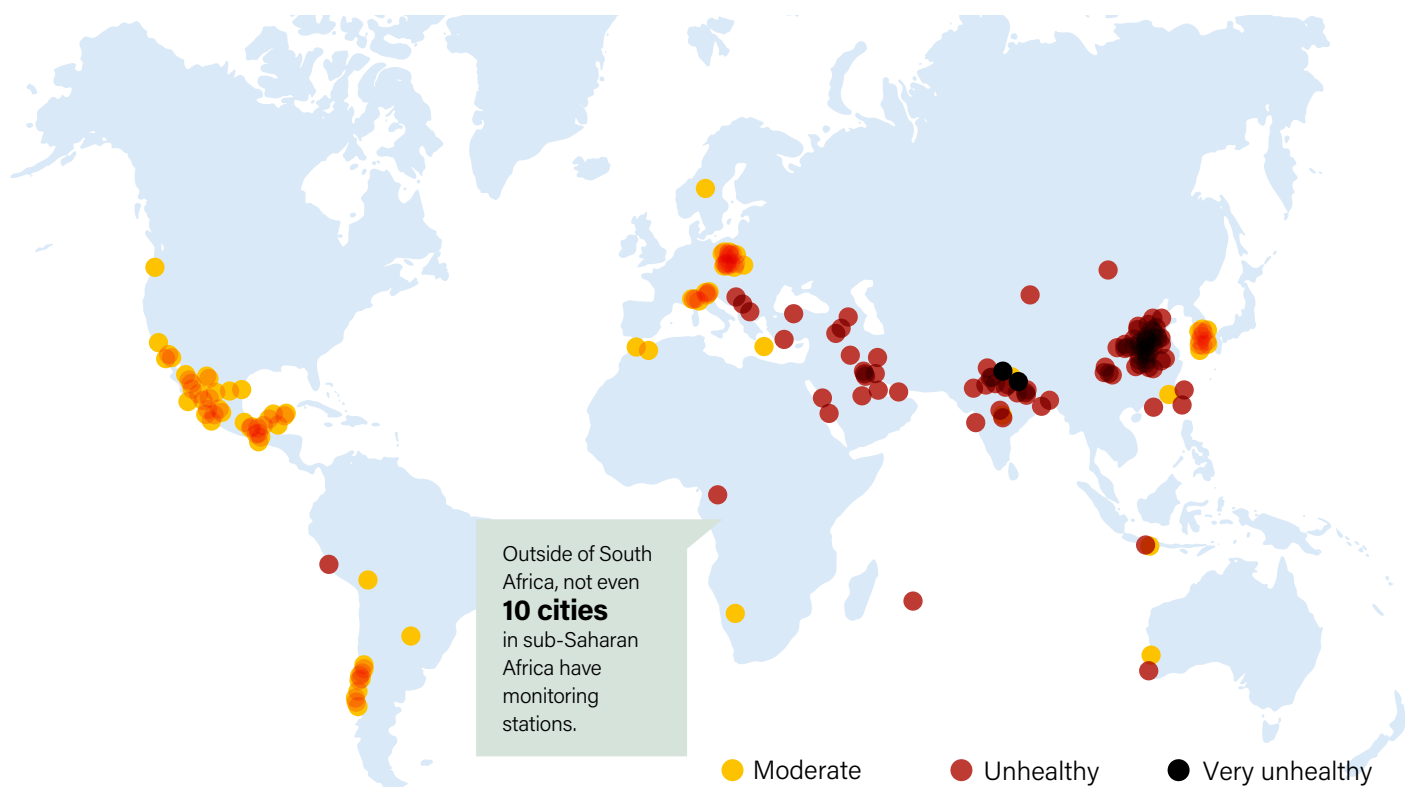
In the developing world, more than 3 billion people in both rural and urban areas burn charcoal and fuelwood to cook and heat their homes, contributing to poor indoor air quality caused by smoke and particulate matter.¹² Across sub-Saharan Africa,

730 million people, or more than 70% of the population, burned traditional biomass for energy in 2017.¹³ Each year more than 4 million people worldwide, primarily women and children, die prematurely from illness attributed to household air pollution and inefficient cooking and heating practices.¹⁴

Air pollution has a high economic cost. In member countries of the Organisation for Economic Co-operation and Development (OECD), death and illness caused by air pollution cost an estimated USD 1.8 trillion in 2015; among the so-called BRIICS countries (Brazil, the Russian Federation, India, Indonesia, China and South Africa) the cost was even higher, at USD 3 trillion.¹⁵ In Beijing, the economic costs related to hospital admissions and premature death due to respiratory disease, reduced lung function and chronic bronchitis from particulate air pollution neared 10-13% of the city's GDP in 2008-2012.¹⁶ India, Latvia and the Russian Federation lose more than 10% of GDP annually because of costs associated with air pollution, and Latin America and the Caribbean loses around 2% of its GDP annually to these costs.¹⁷

Cities also are concerned about pollution related to the extraction, refining and distribution of fossil fuels. Even when coal mines are located outside a city or country, mining can contribute to poor air quality because the wind carries particulate matter long distances.¹⁸ This is a concern in China, India and Germany as well as in Australia, where cities and towns in the Hunter Valley of New South Wales, such as Singleton and Muswellbrook, are located near the Upper Hunter coal mines.¹⁹ Petroleum refineries, frequently situated in urban areas, contaminate soil and waterways and negatively impact the air quality in neighbouring communities.²⁰ During extreme weather events, damage to



FIGURE 6. Air Pollution (PM_{2.5}) in Selected OECD and Non-OECD Cities

Note: OECD = Organisation for Economic Co-operation and Development; Data shown are air pollution levels in the 100 most polluted OECD cities and the 100 most polluted non-OECD cities.

Source: See endnote 5 for this chapter.

refineries can worsen soil, water and air pollution, as occurred in 2017 when Hurricane Harvey hit the US city of Houston.²¹

Driven by the need to reduce air pollution, many municipal governments have scaled up energy efficiency measures and the use of renewables in the power, heating and cooling, and transport sectors. In northern China, where air pollution is a rising concern, Beijing has taken steps to reduce or shut down coal-fired plants for electricity and heat generation.²² In 2018, the city announced a target to achieve an 8% renewables share in its total final energy consumption by 2020.²³ Overall, in surveyed Chinese cities, the deployment of renewable energy, along with energy efficiency measures, contributed to an estimated 12% reduction in average PM_{2.5} concentrations between 2017 and 2018.²⁴ In Europe, Kościerzyna (Poland) took steps to improve the city's air quality by installing 125 solar water heaters in residential buildings.²⁵

Cities also are advancing renewables in the transport sector, in addition to adopting technologies – such as electric vehicles (EVs) – that integrate the use of renewable energy. Such measures often complement measures to encourage public transport, bans

on polluting vehicles, and efforts to promote active modes of transport such as walking and cycling.²⁶ Many cities in China, Latin America and Europe have procured electric buses, and in the southern Chinese city of Shenzhen all buses have been electrified since 2017.²⁷ Mayors from 26 cities on 6 continents have committed to procuring only zero-emissionⁱ buses starting in 2025.²⁸ In the US state of Hawaii, four mayors jointly committed to 100% renewable energy in public transport by 2045.²⁹

Renewable energy generation has health co-benefitsⁱⁱ as well. For example, biogas systems can improve sanitation in homes by collecting animal and human waste in one location and reducing exposure to harmful pathogens.³⁰ Switching to renewable cooking solutions, such as electric cook stoves powered by solar PV, avoids the indoor air pollution associated with the use of solid fuels while helping to reduce more widespread pollution in the surrounding area.³¹ This helps to free users, particularly women, from the labourious job of collecting fuelwood, providing further co-benefits.³²

i “Zero-emission” vehicles do not produce tailpipe emissions. They include plug-in hybrids, which combine a conventional gasoline-powered engine with a battery that can be recharged from the grid; battery electric vehicles, which run entirely on electricity and can be recharged from the grid; and hydrogen fuel cell vehicles, which run on electricity from a fuel cell using hydrogen gas. See Union of Concerned Scientists, “What is ZEV?”, 12 September 2019, <https://www.ucsusa.org/clean-vehicles/california-and-western-states/what-is-zev>.

ii Renewables also can be associated with negative health effects, including the risks associated with the end-of-life disposal of solar PV panels and wind turbine blades, and emissions from bioenergy combustion in urban areas. See Otto Andersen, *Unintended Consequences of Renewable Energy: Problems to Be Solved* (Berlin: Springer Science & Business Media, 2013), <https://www.springer.com/gp/book/9781447155317>.

CLIMATE CHANGE

Cities are significant contributors to climate change: they account for two-thirds of total energy demand and for around three-quarters of global carbon dioxide emissions.³³ The contributions are not evenly distributed, however. In 2018, just 100 urban areas accounted for nearly a fifth of global CO₂ emissions from fossil fuel use, with Seoul (Republic of Korea), Guangzhou (China), New York (US), Los Angeles (US) and Shanghai (China) at the top of the list.³⁴

Meanwhile, cities are especially vulnerable to the impacts of climate change. Groundwater depletion, fires, food shortages, sea-level rise, spikes in energy use due to extreme temperatures, and the increased frequency of extreme weather events such as floods, droughts and storms affect city infrastructure and the livelihoods and health of residents.³⁵ More than 90% of the world's urban areas are located along coastlines, where rising sea levels and storms threaten inhabitants and infrastructure with flooding and strong winds.³⁶ The more than 1 billion people who live in urban slums and informal settlementsⁱ are particularly vulnerable to climate impacts, as many live along waterfronts and riverbanks that are prone to flooding.³⁷ In 2017, 70% of the 96 cities that belonged to the C40 network (which represents 700 million people worldwide) reported that they had experienced negative effects linked to climate change.³⁸

Cities increasingly recognise their critical role in climate change mitigation. By November 2019, more than 1,200 jurisdictions and local governments in 23 countries, representing over 280 million inhabitants, had declared a state of "climate emergency"ⁱⁱ, including cities such as Bacolod City (Philippines), Bochum (Germany), Christchurch (New Zealand), London (UK), Milan (Italy), Toulouse (France), Vancouver (Canada) and Warsaw (Poland).³⁹ Most of the signatories are from developed countries, primarily in Europe but also in North America and Oceania.⁴⁰

To mitigate climate change, cities have begun reducing their greenhouse gas emissions by integrating renewables into their decarbonisation strategies.⁴¹ In February 2019, Chicago (Illinois, US) presented its roadmap for urban resilience, which includes a transition to 100% renewable energy.⁴² Later that year, Berlin (Germany), motivated mainly by climate protection, adopted its Solarcity Berlin master plan, with a goal of 25% solar electricity by 2050.⁴³ Cities also are incorporating the use of renewables in heating, cooling and transport into their climate strategies. The climate roadmap of Helsinki (Finland) includes decarbonisation of the municipal district heating and cooling network by 2050, including scaling up geothermal and solar technologies; a similar plan exists in Linköping (Sweden).⁴⁴ For transport sector, several cities have strategies to decarbonise the sector, including Oslo (Norway) and Stockholm (Sweden).⁴⁵

Decentralised power generation from renewables has been key to climate change adaptation, helping to make energy systems more resilient while reducing risks associated with dependence on external energy sources (→ see *Energy Security* section). After Hurricanes

Irene and Sandy hit the US east coast in 2012, communities in the New York metropolitan area began investing in renewables and microgrids to minimise power shortages during storms and boost local energy resilience.⁴⁷ To empower local communities in this process, the State of New York launched the NY Prize competition, which provides funding and expertise for community microgrid development.⁴⁸ In one project to boost resilience while meeting rising energy demand, Marcus Garvey Village, a low-income housing complex in Brooklyn, installed a microgrid with a 400 kilowatt (kW) solar PV system, a 400 kW fuel cell system and a 300 kW battery storage system.⁴⁹ Boulder (Colorado) implemented a solar-plus-storage system in 2018 that enables municipal operations to continue during power emergencies.⁵⁰

In Japan, the Kashiwa-no-ha Smart City district installed a storage facility that can ensure vital services to the community in case of disaster. The facility includes a large-scale lithium-ion battery and a solar PV system that can supply 60% of the community's normal electricity consumption for three days.⁵¹ In addition, groundwater pumps are connected to the system to provide fresh water in case of a failure of the regular infrastructure.⁵²

By November 2019, almost **1,200** jurisdictions and local governments representing over 280 million inhabitants, had declared a state of "climate emergency".



i Informal settlements are defined as "residential areas where 1) inhabitants have no security of tenure vis-à-vis the land or dwellings they inhabit, with modalities ranging from squatting to informal rental housing, 2) the neighbourhoods usually lack, or are cut off from, basic services and city infrastructure and 3) the housing may not comply with current planning and building regulations, and is often situated in geographically and environmentally hazardous areas", from UN-Habitat, *Habitat III Issue Papers: 22 - Informal Settlements* (New York: 31 May 2015), http://habitat3.org/wp-content/uploads/Habitat-III-Issue-Paper-22_Informal-Settlements-2.0.pdf.

ii The call for declaring a climate emergency is an open "movement of movements", rather than a structured movement with specific guidelines and criteria. Individual city councils decide on their own priorities and actions. See endnote 39.

ENERGY COST REDUCTION

Cities are turning to renewables to reduce municipal energy costs, limit their exposure to volatile fossil fuel prices and attract local industries and businesses.⁵³ Many cities import most, if not all, of the energy they consume, typically in the form of fossil fuels and nuclear power.⁵⁴ Renewable energy cost reductions have enabled municipal governments to shift to renewables for municipal (or city-wide) energy consumption and have provided the opportunity for local energy consumption to lower and more easily control energy expenses.⁵⁵ For example, the levelised cost of electricity from solar PV fell 13% in 2018, and the costs of solar heating and cooling technologies are declining rapidly as well.⁵⁶ In the Pacific Island country of Kiribati, the South Tarawa city government installed grid-connected solar PV systems totalling 548 kW on four of its buildings in 2016, a move that was expected to save USD 290,000 in diesel fuel costs per year.⁵⁷ Mayors in Brandenburg (Germany) have supported the deployment of renewables because the systems bring additional business tax income to their local budgets.⁵⁸

In the United States, East Hampton (New York) has ambitious targets for 100% renewable electricity by 2020 and for 100% renewable energy use in heating and transport by 2030, with the aim of reducing municipal energy costs, boosting the local economy and creating jobs.⁵⁹ In 2015, Washington, D.C. installed solar panels on the roofs and parking lots of 34 government-owned facilities, driven by expected savings of USD 25 million over the 20-year duration of the power purchase agreement (PPA).⁶⁰ Three years later, in 2018, the city announced a broader goal of achieving 100% renewable electricity by 2032.⁶¹

Cities have further reduced their vulnerability to energy price volatility by accompanying renewable energy investments with market design and/or investments in technologies that increase system flexibility, such as energy storage and demand-response technologies.⁶² Such steps represent direct cost savings for governments and utilities and often allow energy consumers to benefit from lower energy prices.⁶²

To overcome space limitations for new renewable capacity, some urban authorities are investing in projects outside their own jurisdictions, using economies of scale to drive down the levelised costs of energy. Melbourne (Australia) led a consortium of 14 organisations to help finance the construction of a 39-turbine wind farm some 180 kilometres north-west of the city centre; the project now supplies town halls, bank branches and street lighting around the city.⁶³ Similarly, a public-private partnership between Calgary (Canada), a local wind power company and an environmental organisation resulted in the deployment of 12 wind turbines in southern Alberta to power Calgary's C-Train public transit system.⁶⁴

Some cities are developing renewable energy infrastructure to avoid having to invest in capital-intensive upgrades to local and regional power grids.⁶⁵ Installing distributed renewable generation systems such as solar PV, solar water heaters and micro wind

turbines can be especially economical when integrated into new construction or building retrofits alongside energy efficiency improvements. As early as 2000, Barcelona (Spain) introduced a solar thermal ordinance requiring that all new buildings and those undergoing major refurbishment supply at least 60% of their hot water from solar thermal systems.⁶⁶ Following the positive results of this policy, the national government as well as dozens of other cities in Spain and around the world have approved similar obligations.⁶⁷

SOCIO-ECONOMIC DEVELOPMENT

Economic benefits are a central driver for the transition to renewables in cities. Apart from reducing municipal energy costs and price volatility, renewables contribute to urban economic development by attracting new industries and providing opportunities to develop new business models that result in additional local income. This in turn leads to job creation and also contributes to cities' efforts to brand themselves as "green" and "sustainable", which helps to attract new residents, tourists and businesses.

Overall, investments in renewables and energy efficiency have strong positive impacts on employment, income and tax earnings at the city level.⁶⁸

The number of **jobs in renewable energy** worldwide increased to some 11 million in 2018, including jobs in research and development, project development, equipment manufacturing, installation, and operations and maintenance.⁶⁹ The employment opportunities related to renewables can be significant: in the United States, an estimated 14 jobs are created for every megawatt of distributed solar PV installed.⁷⁰ Jobs in renewables tend to be relatively well paid and offer a variety of low-, medium- and high-skilled opportunities.⁷¹ Provided that adequate professional education and training programmes are in place, investing in renewables is a particularly promising employment strategy for cities that have high youth unemployment or that have experienced losses in their traditional manufacturing sectors.⁷²

China leads the world in renewable energy jobs, and many Chinese cities have seen rapid growth in the sector. As of 2017, local policy support for solar power in Dezhou had resulted in the presence of some 100 solar companies in the city.⁷³ The United States had more than 320,000 jobs in renewables across 50 cities in 2018, led by Los Angeles (41,000) and New York (21,000).⁷⁴ In Ireland, the town of Daingean, previously at the centre of the country's peat industry, is now encouraging investment in wind and solar PV in partnership with the national peat company, Bord Na Móna.⁷⁵ In some cities, strategies explicitly link outdated fossil fuel structures with renewables. A district heating project launched in 2008 in the former Dutch mining town of Heerlen uses an abandoned coal mine for geothermal energy production and focuses specifically on training former coal industry workers.⁷⁶

ⁱ Demand response is the use of market signals such as time-of-use pricing, incentive payments or penalties to influence end-use electricity consumption behaviours. Usually used to balance electrical supply and demand within a power system. See GSR 2019.

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Cities with high shares of renewables are well positioned to **attract new industries**, creating direct and indirect jobsⁱ as well as additional tax income.⁷⁷ Renewable energy can be especially attractive to industries because of the comparatively low price, reliability and ease of access. As firms and

industries commit to emissions reductions and other climate-related goals, the ability of cities to guarantee “fossil-free energy” becomes increasingly valuable. In some cases, cities that wish to attract tech companies that run large data centres, such as Google and Facebook, are highlighting their ability to provide a consistent renewable electricity supply. For example, the high share of renewable generation in Fredericia (Denmark) was a determining factor for Google to locate its new data centre there.⁷⁸ Stockholm (Sweden) has attracted companies to local data parks that offer renewable power as well as the recovery of waste heat that is then fed into the city's district heating system.⁷⁹

Green city branding based on renewables has become a valuable marketing tool for cities aiming to position themselves as centres of sustainable development. This branding, which often occurs in well-established “green” cities with strong renewables policies, has several aims. Not only does it offer local residents an opportunity to engage in and benefit from the energy transition (→ see *Citizen Participation chapter*), but it also attracts skilled job seekers who are looking to resettle, tourists who visit the city to learn about green policies and technologies, and companies that could benefit from the city brand.⁸⁰

Freiburg (Germany) is among a growing number of cities that have used their renewable energy strategies as a marketing tool to attract workers, tourists and companies, thereby stimulating the local economy.⁸¹ Geneva (Switzerland) showcases its green agenda to promote tourism and attract international agencies and companies.⁸² Similarly, Vancouver (Canada) has publicised its efforts to become the “Greenest City in the World” by 2020.⁸³ In Scandinavia, cities such as Copenhagen (Denmark) as well as Malmö, Stockholm and Växjö (Sweden) all have established successful green city brands.⁸⁴ Japan's Kashiwa-no-ha Smart City in Tokyo focuses on combining energy efficiency, liveability and resource efficiency to attract businesses, policy tourists, and other visitors or potential residents.⁸⁵

ENERGY SECURITY

The transition to renewables can improve the energy security and energy autonomy of cities, making them less subject to external influences, including energy price instability. Energy security is a driver at the national level but is becoming a priority for cities as well, alongside efforts to boost resilience. Important factors determining energy security include the form and origin of the energy supplied, as well as ownership models and the characteristics of energy infrastructure. Energy security can be threatened by factors including geopolitical instability, climate change impacts, fuel shortages and price fluctuations.⁸⁶

To boost energy security and resilience, as of 2018 more than 30 cities worldwide had signed onto the 10% Resilience Pledge, which commits mayors to earmarking 10% of their annual city budgets for resilience-related projects, including local renewable energy investments.⁸⁷ As of July 2019, a total of 70 cities had published resilience strategies, and 89 had appointed Chief Resiliency Officers to oversee resilience planning and investments.⁸⁸

Energy security also ensures security of supply, which is a central concern for cities suffering from high volatility in energy provision. Many essential city services, such as street lighting and public transport, are dependent on a secure energy supply. In Ukraine, the city of Zhytomyr, motivated by the wish to become independent from fossil fuel imports, approved a plan in 2018 to achieve 100% renewable energy by 2050; a few months later, the cities of Kamianets-Podilskyi, Chortkiv and Lviv adopted the same target.⁸⁹ To attain its goal, Zhytomyr is investing in solar power, biofuel and micro-hydropower plants as well as reducing its overall energy consumption by retrofitting municipal buildings, installing LED (light-emitting diode) street lighting and switching to electric trolley buses.⁹⁰

In countries where the energy system struggles to deliver a stable and sufficient electricity supply, cities are investing in renewables to tackle shortages. Several South African cities are turning to renewables to gain energy security and independence while at the same time reducing costs. Cape Town is deploying solar PV panels on municipality-owned buildings, initiating campaigns to raise awareness of energy efficiency and procuring renewable electricity.⁹¹ Tshwane is developing a large waste-to-energy project, installing solar power heaters for 16,000 households and building a hydroelectric plant.⁹² Durban has developed the Durban Solar City framework to encourage the use of decentralised solar PV, and the municipality of eThekweni (of which Durban is a part) has built the eThekweni Landfill Gas-to-Electricity project and is creating a renewable energy development hub.⁹³

To increase the security of supply and to facilitate the integration of variable renewable energy sources such as solar PV and wind, some cities are more closely linking sectors of the energy system and of the economy for overall system efficiency and stability – for

i Also known as municipal aggregation programmes, such policies allow local entities to procure electricity as a group – by aggregating electricity demand – rather than as individuals. See National Conference of State Legislatures, “Community Choice Aggregation Programmes”, 1 December 2015, <http://www.ncsl.org/research/energy/community-choice-aggregation.aspx>.

ii Direct jobs are the primary output of the renewable energy project; indirect jobs include additional activities made possible by the project, for example equipment suppliers or service providers. See IRENA, *Renewable Energy and Jobs: Annual Review 2019* (Abu Dhabi: 2019), <https://www.irena.org/publications/2019/Jun/Renewable-Energy-and-Jobs-Annual-Review-2019>

example, coupling thermal with power systems to integrate and balance out variability.⁹⁴ Skive (Denmark) is building Europe's largest power-to-gas facility, which will convert surplus wind energy into carbon-free methane and contribute to the city's goal of CO₂ neutrality by 2029.⁹⁵ Experiments in Berlin (Germany) are testing the possibility of storing energy from wind and solar in nano-coated salt.⁹⁶ Cities also are investing in smart grids to optimise grid use on a local scale: the city government of Nice (France) collaborates with energy suppliers, distribution system operators and industrial partners to promote the grid integration of locally generated renewables.⁹⁷

Cities pursue renewables to provide safe access to energy and to eliminate risks associated with other forms of energy. The distribution and use of fossil fuels is associated with a wide range of dangers, including fatal fires from oil trucks and other transport accidents that have occurred in both low-income and wealthier countries.⁹⁸ In 2013, the derailment and explosion of a train carrying crude oil killed 47 people in the town of Lac-Mégantic in Quebec, Canada.⁹⁹ In developing and emerging countries, theft from oil and gas pipelines often leads to deadly explosions: 137 people in the town of Tlahuelilpan (Mexico) were killed when illegal tapping of a gas pipeline caused a major explosion in January 2019.¹⁰⁰ Such risks can be lessened if renewable energy is used to displace fossil fuels in urban energy systems.¹⁰¹

ENERGY GOVERNANCE

Thanks to their decentralised nature and scale, renewable energy technologies have made it possible to bring energy production closer to where the energy is consumed and to develop more distributed energy systems.¹⁰² However, potential conflicts may arise with renewable energy production at the local level, related to land requirements for production, the demand for minerals and metals used in renewable technologies, or logging for biomass energy in an unsustainable manner.¹⁰³ A community-owned wind farm in Oaxaca (Mexico) was specifically designed

to avoid conflicts over land by minimising the impact on local agriculture and using half of the income to compensate landowners and to fund community programmes.¹⁰⁴

For many cities, energy independence is an important motivation for investing in renewables. Self-sufficiency in energy provision can be supported by promoting energy efficiency in combination with a firm move towards a 100% renewable energy supply. Cities can boost their independence by investing in infrastructure such as smart grids and buildings in preparation for city-wide electrification, including supplying renewable electricity to EVs and for heating and cooling applications.

Energy independence improves a city's (and country's) trade and debt balances, avoids unexpected costs, and reduces vulnerability to price volatility. In the United States, Austin (Texas) has been able to reduce and stabilise city-wide energy prices through its GreenChoice programme, which sends a strong message to suppliers regarding local demand for renewable power. Customers sign a multi-year electricity supply contract with the city utility, Austin Energy, which then purchases a large volume of renewable energy certificates (RECs) from certified suppliers in the state.¹⁰⁵

Groups of citizens within cities may strive for energy independence as well. Many so-called prosumers – people who own and operate small-scale energy systems, such as rooftop solar PV – are adopting renewables out of a desire to be more independent from the central grid. At a global scale, the Transition Town movement connects residents across cities who want to build an alternative way of living that does not involve fossil fuels (→ see *Citizen Participation* chapter).

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ACCESS TO ENERGY

Many cities, mainly in the developing world, are adopting renewable energy policies and targets to expand energy accessⁱ to more residents, including people living in urban slums and informal settlements and in suburban and peri-urban areas. In 2017, the global electricity access rate in urban areas reached 97.4%, up from 94.7% in 2001 (in rural areas, the rate was 78.7%).¹⁰⁶

Urban electricity access is generally high in Latin America (99.6%) and in the Asia Pacific (99%) region, and the access rate in sub-Saharan Africa increased from 60% of the population in 2000 to nearly 79% in 2017.¹⁰⁷ However, more than 109 million urban residents worldwide (and 840 million people in total) still lacked electricity as of 2017, and maintaining high levels of access remains a challenge in rapidly urbanising cities.¹⁰⁸ Also, many urban residents continue to suffer from unreliable electricity access due to power outages and low energy access: in Lagos (Nigeria), the power is out for an estimated one-third of the time in an average month.¹⁰⁹ Because data on access to adequate heating, cooling and transport services are more limited than data on electricity access, estimating overall energy access in cities worldwide is difficult.¹¹⁰

Electrification rates tend to be higher in the world's urban areas. However, in many developing country cities, a large share of the population continues to rely on the direct burning of available fuels such as charcoal and scrap wood for cooking and heating, affecting both indoor and outdoor air quality.¹¹¹ In San Carlos de Bariloche (Argentina), a programme was launched in 2016 to weatherise 100 low-income houses that use wood for heating and cooking and that lack thermal insulation and proper ventilation; the programme was later expanded to target 1,000 homes.¹¹²

Unlike with fossil fuels, which are geographically concentrated in certain areas, renewable energy often can be generated from localised resources, allowing for greater flexibility in their use.

Many cities have embraced distributed renewables to provide access to modern energy services, including for electricity, space and water heating, and cooking fuel.¹¹³ In 2012, Kasese district in western Uganda set a target for universal electricity access by 2020 based on a transition to 100% renewables using a combination of micro-hydropower, solar PV, biomass and geothermal electricity. As of 2015, even though only 7.6% of the district's 134,000 households were grid connected, tens of thousands more residents had gained access to electricity (many off-grid), and renewables were powering 26.8% of the district.¹¹⁴

Numerous other efforts in Africa and worldwide support the deployment of distributed renewables for energy access in urban areas. In Johannesburg (South Africa), the University of Witwatersrand developed a 420 kW solar district heating

system in 2018 to service 14 student residence buildings.¹¹⁵ In the Kamenge commune of Bujumbura (Burundi) – where 95% of the population does not have access to electricity and the national power supply cannot keep up with growing demand – the city has installed a 260 kW solar PV system at the Hospital University Centre of Kamenge to provide a more reliable energy supply.¹¹⁶

Urban energy access is closely related to **ensuring energy affordability**. Urban energy poverty is determined by expenditures on items such as transport, housing, electricity and cooking and tends to be concentrated in lower-income, suburban neighbourhoods.¹¹⁷ On average, the urban poor have less access to energy – and typically spend a higher share of their income on energy – than the urban rich.¹¹⁸

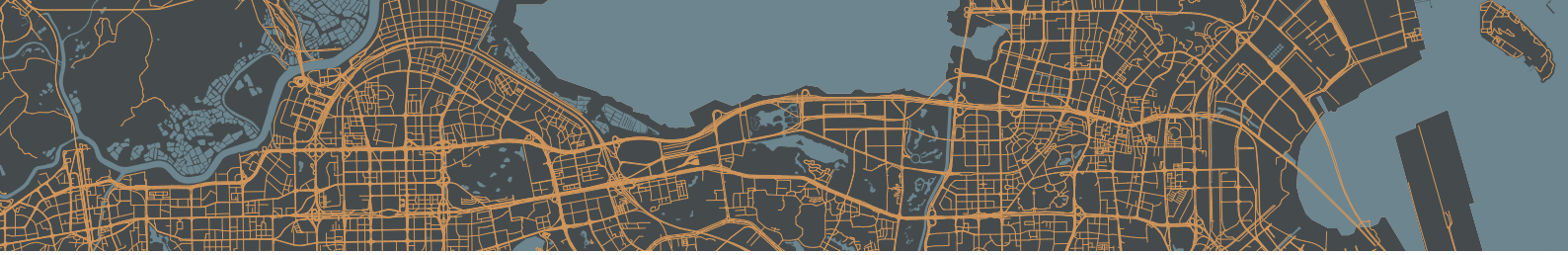
Energy poverty is not exclusively a developing country phenomenon. Depending on the data source used, an estimated 50 million to 125 million people in the EU experience energy poverty.¹¹⁹ Renewables are a central solution to addressing energy poverty in cities, particularly as technology costs decline and in combination with measures to promote energy efficiency and accessibility.¹²⁰ Porto (Portugal) tackled energy poverty directly by renovating public buildings to make them more energy efficient and by installing renewable heating and cooling facilities and solar hot water systems, resulting in annual energy savings of 286 kilowatt-hours (kWh) per square metre (m²).¹²¹ Elsewhere, Rajkot (India) has installed solar PV in connection to social housing developments, with the potential to reduce 35 tonnes of CO₂-equivalent emissions per year.¹²²

Energy poverty is best measured by assessing the quality of energy sources and the ability to purchase energy for essential uses and basic human needs. Urban dwellers may, for instance, limit the number of meals they eat in order to save money on fuels and food.¹²³ Under conditions of energy poverty, the price inelasticity of energy drives people to prioritise energy over other expenditures such as education.¹²⁴ In such contexts, renewable energy solutions bring vast benefits by providing fast and inclusive access to basic energy needs, allowing future generations to escape the poverty trap and thereby promoting sustainable development. Renewables also may allow grid-connected households to make additional income by selling electricity back to the grid, although such opportunities are rare in developing countries.¹²⁵

Access to energy for urban populations is greatly influenced by the **reliability of the energy supply**. While energy network failures happen in cities around the world, they are more frequent in developing countries.¹²⁶ Introducing and expanding the use of renewables in urban energy systems, especially via distributed solutions, can reduce the risk of sudden, large blackouts and increase the overall reliability of supply, supporting the income-generating activities of low-income households.¹²⁷ Lagos (Nigeria) established the Lagos Solar Project to provide a reliable supply of renewable power to critical public infrastructure, such as schools and health facilities.¹²⁸ To decrease pressure on the grid, Nairobi (Kenya) introduced a regulation requiring large buildings to harness the city's solar potential.¹²⁹

In 2017, the
global
electricity
access rate
in urban areas reached
97.4%, up from 94.7% in
2001.

ⁱ Here, energy access is understood as the opportunity for users to legally achieve connectivity, to be able to afford energy and to have reliability in energy provision. Access to energy facilitates access to many basic human rights such as water, good nutrition, health, shelter and education.

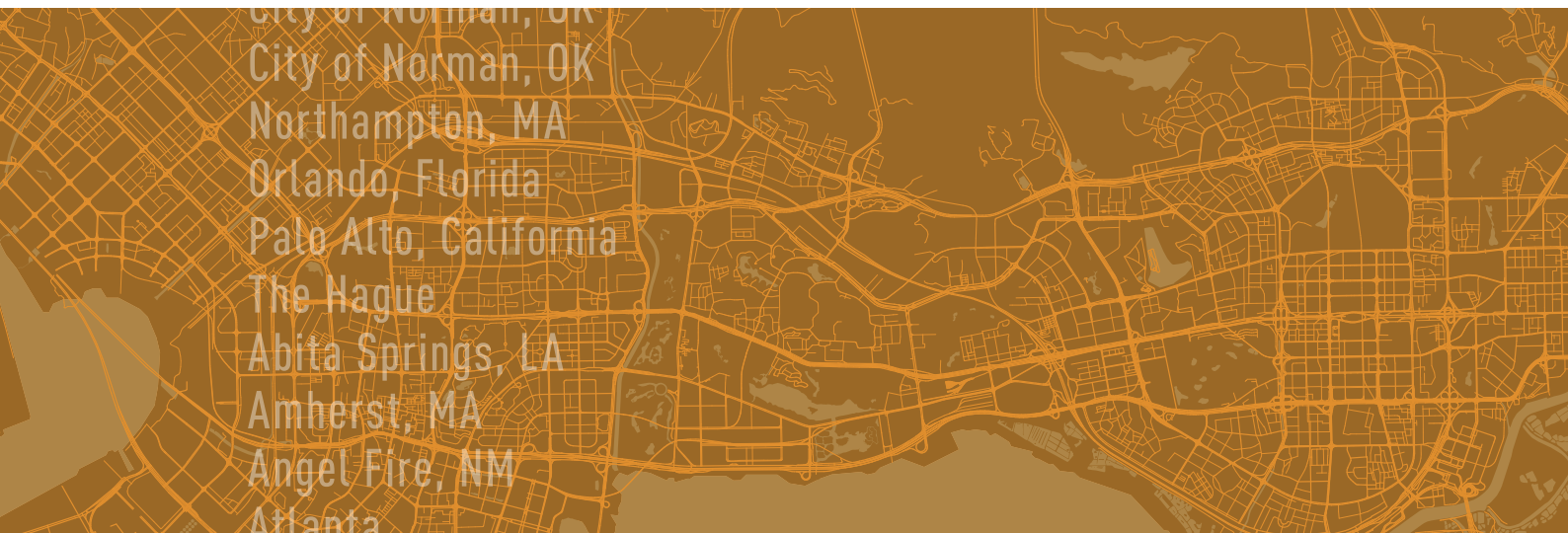


3

URBAN POLICY LANDSCAPE:

TARGETS AND POLICIES

- East Hampton, New York
- Eau Claire, WI
- Encinitas, CA
- Eureka, CA
- Goleta, California,
- Hanover, New Hampshire
- Hanover, New Hampshire
- Hillsborough, North Carolina
- Kennett Township, PA
- Kennett Township, PA
- La Mesa, CA
- Lafayette, CO
- Largo, FL
- Longmont, CO
- Madison, WI
- Menlo Park
- Middleton, WI
- Minneapolis, MN
- Moab, Utah
- Monterey City, CA
- Nederland, Colorado
- Nevada City, California
- Nevada City, California
- New Brunswick, NJ
- City of Norman, OK
- City of Norman, OK
- Northampton, MA
- Orlando, Florida
- Palo Alto, California
- The Hague
- Abita Springs, LA
- Amherst, MA
- Angel Fire, NM
- Atlanta



URBAN POLICY LANDSCAPE: TARGETS AND POLICIES

Many city governments around the world have committed to ambitious targets and policies to advance renewables, both within municipal operations and city-wide. These measures often are part of wider climate mitigation and adaptation strategies and include improving energy efficiency. In other cases, renewable energy targets and policies are developed primarily to reduce local air pollution and to achieve other municipal goals such as job creation and economic diversification (→ see *Drivers chapter and Figure 7*).

As the costs of renewable energy technologies fall, the policies being used to advance renewables continue to evolve and adapt.¹ In addition, many cities are making it easier to integrate growing shares of renewable energy into local energy systems by supporting key enabling technologies such as electric vehicles and district energy networks. As at the national level, most of the support for renewables at the city level has been directed towards the power sector.² However, targets and policies in the heating, cooling and transport sectors are gaining momentum.³

Municipal renewable energy (and climate) targets vary widely in their target years, their monitoring and compliance frameworks, and their overall structure, with some focused on either electricity, heating and cooling, or transport, and others focused on two or all of these. Most existing renewable energy targets at the city level are aspirational (i.e., non-binding) in character, and in most cases no clear penalties exist for failing to achieve them. This contrasts with many state-level renewable energy targets, notably in the United States, Canada and the UK, which are accompanied by enforceable penalties for non-compliance.⁴

Strong resource endowments and higher shares of renewables in the state/provincial and national energy mixes make it easier for cities to achieve renewable energy or decarbonisation targets. For cities in regions with abundant hydropower, such as Seattle (Washington, US) and Quebec City (Canada), it may be easier to achieve their targets by electrifying their transport and heating systems with renewable electricity sources.⁵ Achieving renewable energy and climate targets also may be easier in cities like Munich (Germany) or Vienna (Austria) than in emerging-country megacities such as Lagos (Nigeria) or New Delhi (India), due to differences in local infrastructure and institutional capacity.⁶ However, even cities starting from less supportive geographical and institutional circumstances – such as Durban (South Africa), Kigali (Rwanda) and Taiyuan (China) – have made measurable progress towards achieving their targets.⁷

City governments often have been trendsetters in establishing innovative policy mechanisms for renewable energy deployment, for instance by pioneering ambitious feed-in tariffs in the 1990s and 2000s and by introducing ordinances mandating solar thermal use in new or existing construction.⁸ However, municipal governments alone cannot achieve the transition to sustainable, low-carbon cities. Decision making at the city level can be constrained by a host of jurisdictional issues (influenced by supra-national, national and state/provincial governments) and by the limited power and authority that many cities have in practice.⁹

Decision making

at the city level can be constrained by host of jurisdictional issues and by the limited power and authority that many cities have in practice.



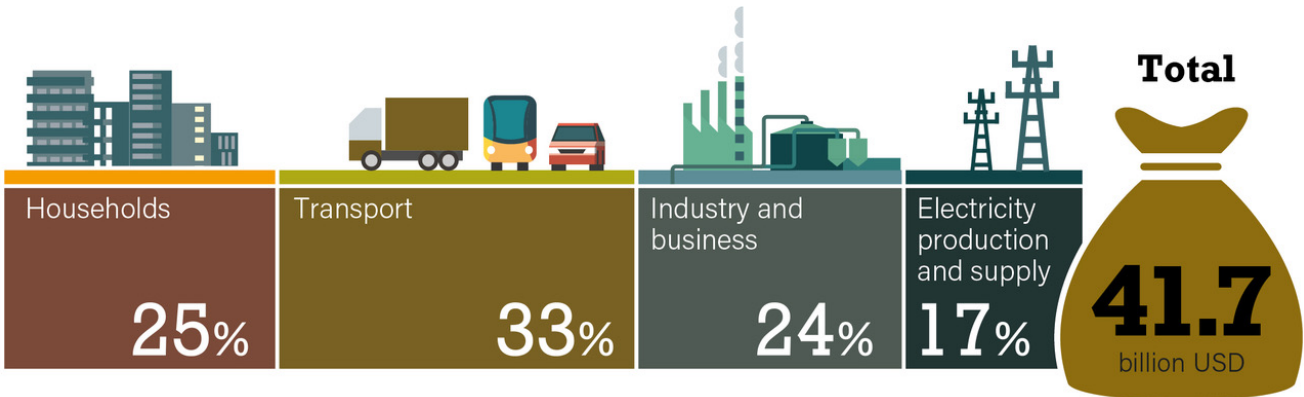
Policies at the national or state/provincial levels, such as national building codes and regulations on vehicle or appliance efficiency, have a direct influence not only on municipal strategies and operations, but also on city-wide energy use.¹⁰ Other areas, such as taxation, environmental regulation and electricity market structure, often are determined largely by national or state/provincial policies, limiting the possibility for local authorities to directly support investment in renewables.¹¹ This is particularly the case in regions where sub-national control is weaker, as in parts of Africa, Asia, Latin America and the Middle East.¹²

Energy policies set at the national level also affect energy consumption in cities. In particular, national subsidies supporting the use of fossil fuels can hinder the deployment of renewable technologies.¹³ In 2015-2016, identified fossil fuel subsidies in urban areas of the six BRIICS countries (Brazil, Russian Federation, India, Indonesia, China and South Africa) and of most countries in the Organisation for Economic Co-operation and Development (OECD) averaged an estimated USD 13.8 billion for transport, USD 10.6 billion for households, USD 10.3 billion for industry and business, and USD 7.0 billion for electricity production and supply (→ see Figure 8).¹⁴

Although an equivalent analysis for non-OECD and non-BRIICS countries is not available, it is likely that the total subsidies awarded in other countries are comparable in size.¹⁵ In 2018, global subsidies for fossil fuel consumption totalled USD 400 billion,¹⁶ if the hidden subsidies associated with fossil fuel use – related to air pollution, climate change and other environmental and social externalities – were included, the total would be considerably higher.¹⁷

Some national governments are promoting National Urban Policies (NUPs) as a way to align policies in different sectors, complementing municipal policies and creating an institutional framework that integrates cities into overall national development plans; this helps to implement and monitor progress.¹⁸ As of 2018, 76 countries had adopted explicit NUPs and another 72 had adopted partial elements of NUPs; many are still in the feasibility stage.¹⁹ Several countries have designated specialised urban agencies in charge of implementing NUPs.²⁰

FIGURE 7. Average Annual Subsidies for Fossil Fuel Use in Urban Areas, by Sector, in the OECD and BRIICS Countries, 2015-2016



Note: Subsidies for fossil fuel consumption in urban areas were identified for most countries. OECD = Organisation for Economic Cooperation and Development; BRIICS = Brazil, Russian Federation, India, Indonesia, China and South Africa. A further USD 27.7 million in subsidies in urban areas of the selected countries goes to fossil fuel use in social and public services (too small to be included in figure).

Source: See endnote 14 for this chapter.



In addition, some national governments have built on cities as a tool to leverage and achieve goals set at the international level, such as the United Nations' Sustainable Development Goals (SDGs) and countries' Nationally Determined Contributions (NDCs) for reducing global greenhouse gas emissions, submitted under the Paris Agreement.²¹ More than two-thirds (113 out of 164) of the submitted NDCs indicate an urban dimension, although only 23 of these explicitly address climate mitigation in cities.²² Many more of the NDCs highlight urban adaptation and resilience and include targets to decarbonise specific sectors such as buildings, energy, transport and waste, which also apply to urban areas.²³

Many cities have demonstrated their leadership on climate and energy issues by committing to verifiable emissions reductions within the framework of other national, regional and/or international initiative (→ see Sidebar 2).²⁴



ⁱ Only seven countries have both an NUP and an NDC that explicitly refer to climate change mitigation in cities. See endnote 22.

SIDEBAR 2: City Leadership on Climate and Energy

Cities around the world are contributing to national commitments to reduce greenhouse gas emissions and taking important steps to develop their own energy, climate and sustainable development strategies. At the landmark 1992 UN Conference on Environment and Development (“Rio Earth Summit”), several important agreements and commitments for sustainable development emerged, including the Rio Principles and Agenda 21. Since then, cities have adopted various targets related to climate change and other concerns, with thousands of cities committing to reducing their carbon emissions. Such city-level commitments often have exceeded the ambition of country-level NDCs.

In 2015, 193 national governments adopted the UN’s 2030 Agenda for Sustainable Development, which defines 17 Sustainable Development Goals and establishes a framework for measuring progress towards sustainable development worldwide. The SDGs are deeply interconnected – integrating multiple policy objectives – and energy is relevant for reaching a large majority of them. Advancement in SDG 7, which aims to achieve universal access to affordable, reliable, sustainable and modern energy by 2030, has the potential to spur progress in other SDGs, for example the goals of reducing air pollution-related deaths and illnesses; climate change mitigation and adaptation; and poverty reduction. National governments also have embedded the importance of cities in SDG 11, which is dedicated to making human settlements inclusive, safe, resilient and sustainable.

Cities play a key role in reaching the SDGs as well as national and international climate goals. By one estimate, 65% of the SDG targets will not be achieved without the engagement of cities and local governments, given their roles and core competencies in underlying issues such as energy, infrastructure, transport, housing, water and land use. Cities also are key to achieving SDG 7, since the generation and use of renewable energy in cities is critical in achieving sustainable communities. Local actors can critically advance renewables through their various roles as regulators and policy makers, owners and operators of energy infrastructure, energy consumers and facilitators of the energy transition (→ see *Cities in the Renewable Energy Transition* chapter).

Although the SDGs were agreed on at the national level, multiple organisations have advanced initiatives to “localise” these goals. In many cases, cities have joined together in networks to strengthen their voice. At the national, regional and international levels, municipal governments are networking to increase their advocacy capacity, to share learning on climate and energy solutions, and to inspire other cities to act.

- As of mid-2019, nearly 10,000 cities and local governments had committed to jointly reducing CO₂-equivalent emissionsⁱ through the Global Covenant of Mayors for Climate & Energy, representing some 770 million people or nearly 10% of the global population. More than 6,000 of the cities, mostly in Western Europe, had prepared detailed strategic climate action plans with targets that are in line with the Paris Agreement. City-level commitments also have grown in Asia (including Central Asia), Eastern Europe, Latin America and sub-Saharan Africa.
- As of mid-2019, more than 1,750 local and regional governments (representing more than a quarter of the world’s urban population) had committed to sustainable urban development under the ICLEI–Local Governments for Sustainability network.
- As of mid-2019, the C40 Cities Climate Leadership Group connected 94 cities (representing one-twelfth of the world’s population, a quarter of the gross world product and 70% of global CO₂ emissions) that are committed to delivering the Paris Agreement at the local level and to reducing air pollution in their cities.
- As of late 2018, of the more than 650 cities reporting to CDP, over 400 had adopted emission reduction targets, most of them in North America, Europe and Latin America. More than 206 of these cities had city-wide emissions reduction targets, including 76 in the United States alone. In early 2019, ICLEI began collaborating with CDP to streamline the process of city climate reporting, including on renewable energy.
- More than 400 cities have joined WWF’s One Planet City Challenge since its inception in 2011, reporting over 5,700 actions that have the potential to reduce total greenhouse gas emissions by 3.9 gigatonnes by 2050.
- As of mid-2019, more than 280 city leaders in the United States had joined the We Are Still In movement (alongside businesses, states, universities and others), representing 155 million people across all 50 states. These leaders have committed to taking action consistent with the goals of the Paris Agreement as a way to counter the lack of commitment at the national level.
- As of October 2019, nearly 100 local governments in Japan, in addition to local governments, businesses, non-governmental organisations and research institutions in other countries, signed the Nagano Declaration, committing to accelerate the transition to 100% renewable energy cities.

ⁱ The cities committed to reduce emissions by 1.4 billion tonnes by 2030 and 2.8 billion tonnes by 2050.

Source: See endnote 24 for this chapter.

TARGETS

RENEWABLE ENERGY TARGETS

Municipal renewable energy targets provide greater long-term certainty to residents, companies and investors about a city's plans and priorities, and can help mobilise both stakeholders and financing.²⁵ They can play an important role in shaping city planning, influencing what kind of infrastructure gets built and how cities grow over time.²⁶ In addition, renewable energy targets foster accountability and provide a measurable basis to monitor progress, enabling cities to contribute in a quantifiable way to achieving broader national or state-level targets.²⁷ Targets can be designed to apply strictly to municipal operations, or to city-wide energy use; renewable energy targets often also are part of wider climate targets.²⁸

The lack of baseline data on urban energy use and generation, particularly city-wide, remains an important barrier for many cities. To develop clear targets and strategies, some cities have undertaken assessment of their baseline data and renewable energy potential. In Sydney (Australia), city officials developed a range of scenarios based on the city's demand for electricity, heating and cooling, including detailed maps of the various districts, building types and energy usage.²⁹ The officials mapped these data in relation to local renewable energy potentials, including from waste and wastewater facilities, to develop a comprehensive strategy for renewable energy and decarbonisation.³⁰ In the UK, Bristol was the first city to develop a comprehensive solar map for homes and businesses, an exercise that led the city to set a target for 1 GW of solar PV installed capacity by 2020.³¹

In practice, municipal renewable energy targets vary in several ways:

- **Scope:** Some cities have adopted targets to increase the use and/or share of renewables in their municipal operations, including public transport networks, public buildings and in some cases municipal utilities.³² City-wide targets, in contrast, look beyond municipal operations to include all energy use (in all sectors or only a specific sub-sector) that occurs throughout the city. Because they require action from a wider range of stakeholders and, possibly, sectors, city-wide targets are more challenging to achieve.
- **Sector:** Many cities have adopted sector-specific targets in the electricity, heating and cooling, or transport sectors. Although targets focused on the electricity sector are more widespread, a growing number of jurisdictions have adopted targets in other sectors. Fewer cities have passed targets that address all city-wide energy use (→ see Reference Tables R1 to R4).
- **Renewable energy consumption:** Typically, these targets are presented as percent (%) shares of total municipal operations and/or city-wide energy and/or electricity consumption.

- **Renewable energy generation and capacity:** Targets can be designed to increase a city's own renewable electricity capacity (in MW) or its total renewable generation (in MWh).³³ These targets can be set in different ways:

- *Share of energy demand versus fixed amount:* Targets can be set as a percentage (%) of the urban final energy/electricity consumption or as a fixed amount supplied (often in GWh).
- *Technology-specific versus technology-neutral:* Capacity targets can be technology-specific (for example, 500 MW of solar PV by 2020) or technology-neutral (500 MW of renewable electricity capacity by 2020).

- **Binding versus aspirational:** Targets differ depending on how binding they are and what penalties (if any) apply in the event that they are not met.³⁴ While some state-level renewable energy targets are legally binding (as in the United States and Canada) and levy substantial financial penalties for non-compliance, most targets adopted by cities are aspirational in nature and are not accompanied by fines or penalties. Where targets are not supported by legislation or other binding regulations, they can more easily be overturned or diluted by subsequent mayors or city councils.

- **Simple versus stepped:** As city governments work to achieve their overall targets, they often break them down into interim, shorter-term targets to facilitate monitoring (for example, 50% by 2020, 70% by 2025, 95% by 2030). By contrast, simple targets (for example, 80% renewable electricity by 2050) may be more difficult to reach, as local governments may not be required to report on progress as frequently.³⁵

- **Generic versus specific:** Rather than adopting generic targets that do not detail how the targets will be met (for example, 75% renewable electricity by 2030), some local governments break down their targets into quantifiable measures. To achieve its transport-related targets, San Sebastian (Spain) specifies investing in EV charging infrastructure and transitioning to a fully electric bus fleet by 2030.³⁶ The city also has adopted supporting measures such as a pledge to ban diesel cars starting in 2020.³⁷ The contribution of each measure can be quantified and integrated into the city's strategy. By targeting specific actions, city governments can better assign departmental responsibilities for achieving them.³⁸

Renewable energy and climate targets often are thought of as discrete, long-term objectives to be achieved by some date in the future. However, some cities have adapted their targets over time, expanding them to more sectors and increasing their level of ambition. Breckenridge (Colorado, US) and Malmö (Sweden) both first set targets for shares of renewable power in municipal operations, then later extended them to city-wide targets.³⁹ Similarly, after adopting a target in 2016 for 50% renewable electricity by 2030, Sydney (Australia) doubled this target and moved it a decade earlier, pledging in 2019 to meet 100% of its electricity needs from renewable sources starting in January 2020.⁴⁰

ⁱ While detailed modelling and analysis can be helpful in setting targets, such analyses tend to be conservative, resulting in targets that may be modest relative to what is achievable because they do not consider important technical, economic, behavioural and business model-related changes that are likely to occur in the coming decades. From Hans-Josef Fell, Energy Watch Group, personal communication with REN21, 10 April 2019.

Globally, thousands of city governments have adopted renewable energy targets.⁴¹ While most of these are for renewable power, many cities also have set comprehensive targets covering two or all of the end-use sectors of power, heating and cooling, and transport (→ see Reference Tables R1-R4). Although global data on city-specific energy and climate targets are lacking, several key commitmentsⁱ can be highlighted.

- As of mid-2019, nearly 10,000 cities had committed to reducing their greenhouse gas emissions through the Global Covenant of Mayors for Climate & Energy.⁴² As part of their commitment, more than 6,300 cities had submitted city action plans; of these, nearly 5,000 specified local renewable electricity generation and use, and more than 1,700 also included renewable heat production.^{ii,43}
- As of late 2018, of the more than 650 cities reporting to CDP, over 190 had adopted targets for renewable power consumption as a share of municipal operations or city-wide consumption, with target years ranging between 2020 and 2050.^{iii,44}
- Of the more than 1,000 cities disclosing to ICLEI (which has a total network of over 1,700 cities), more than 350 had adopted renewable power targets as of mid-2019.⁴⁵

The movement toward 100% renewable energy also has gained traction. As of mid-2019, more than 250 cities had adopted a target for 100% renewables, either for municipal operations or city-wide. While most of these targets apply to the power sector, the 100% movement also has expanded to the heating, cooling and transport sectors (→ see Sidebar 3 and Figure 10).⁴⁶

In the **power sector**, with the exception of jurisdictions with municipal utilities, most local governments do not gather comprehensive data on renewable power capacity or electricity generation.

Partly as a result, most cities set their power targets based on final electricity consumption, reflecting the percentage of retail electricity sales derived from renewables, either for municipal operations or for the city as a whole.⁴⁷

Some city governments have opted to use targets based on renewable power capacity instead, which can be easier to monitor^{iv} (→ see Reference Table R5). Capacity-based targets are prominent in China: for example, by the end of 2020 Beijing aims to add 1.16 GW of solar PV and 650 MW of wind power capacity; Shenzhen aims to add 150 MW of rooftop solar PV; and Tianjin plans to add 800 MW of solar PV, 1,160 MW of wind power and 155 MW of bio-power capacity.⁴⁸ Capacity-based targets also exist in Bologna (Italy; 10 MW of solar PV by 2020) and Seoul (Republic of Korea; 1 GW by 2022).⁴⁹

In the **heating and cooling** sector, a growing number of cities are adopting specific targets, often bundled with broader renewable energy targets covering all energy sectors.⁵⁰ As with power sector targets, some are designed to apply strictly to municipal operations while others apply city-wide.

For example, Täby (Sweden) has committed to using renewable heat to meet the needs of all local government operations by 2020, whereas Stockholm's targets apply city-wide.⁵¹ Beijing (China)

i Because some cities may be reporting to several entities, some overlap may exist.

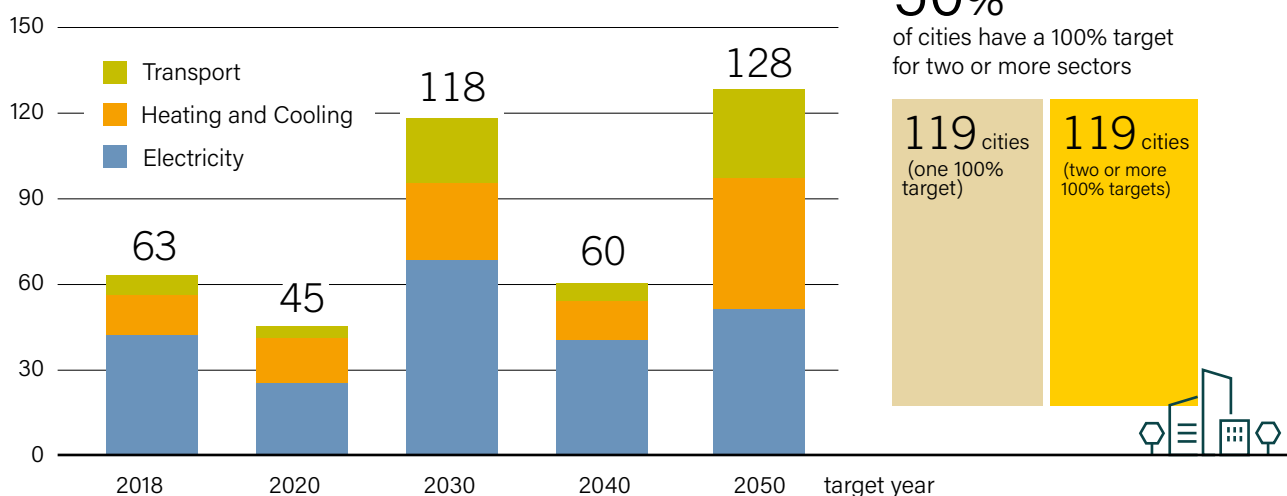
ii The data and questionnaire of the Global Covenant of Mayors for Climate & Energy does not account for how much of the local electricity generation/use and heat production comes from renewables; thus, some plans may also include non-renewable sources.

iii Several of the cities disclosing to CDP also have capacity-based targets, and some cities have already achieved their targets.

iv Uncertainties remain about whether the added renewable capacity actually contributes to altering the electricity mix, due mainly to curtailment, differences in local renewable energy potentials, and the effects of smog and other forms of air pollution on, for example, solar PV output.

FIGURE 8. 100% Renewable Energy Targets in Cities, As of Mid-2019

Number of 100% targets
(10-year period aggregate)



Note: Data included in this figure were compiled by ICLEI and The Global 100% Renewable Energy Platform with material provided by a variety of stakeholders, including CDP, CAN, C40, IRENA, Sierra Club, Renewable cities (2018); and may not be comprehensive.

Source: see endnote 102.

SIDEBAR 3: The Rise of 100% Renewable Energy Targets

Growing numbers of cities and towns (as well as regions and countries) are committing to a 100% renewable energy future. Targets for 100% renewable power are widespread, and many cities also have adopted comprehensive 100% targets that cover two or more of the end-use sectors of power, heating and cooling, and transport.

By mid-2019, more than 250 cities worldwide had committed to a total of 370 100% targets in either power, heating and cooling, transport or all sectors – with target years ranging between 2020 and 2050 – up from half a dozen or so targets in 2010. Most of these cities are in North America and Europe. In Germany, more than 150 districts and cities have adopted 100% renewable electricity targets, including Hamburg and Munich by 2025 and Frankfurt by 2050. Targets for 100% renewable power also exist in Frederikshavn and Sønderborg (Denmark) and in Gothenburg, Lund, Malmö and Stockholm (Sweden), among other European cities.

In the United States, more than 100 cities and towns, including Cincinnati (Ohio), Grand Rapids (Michigan), Minneapolis (Minnesota) and Washington, D.C., had established targets for 100% renewable electricity by mid-2019. Several cities already have transitioned to 100% renewable power, including Aspen (Colorado), Burlington (Vermont) and Greensburg (Kansas). 100% targets also have emerged in cities in Australia (including Adelaide, Canberra and Lismore), Japan (Fukushima and Yokohama), Kenya (Kisumu), South Africa (Durban) and Uganda (Kasese). While such targets remain rare in Latin America, several cities in the region boost already high shares of renewable power, mainly from hydropower.

In many cases, adopting a 100% renewable electricity target has fuelled further ambition, mainly by expanding the target to apply to more sectors. Some cities first achieved their targets for 100% renewable electricity, then expanded to the heating, cooling and transport sectors. Hassfurt (Germany) achieved 100% renewable electricity in 2017 and now aims to scale up renewables in other sectors, including by expanding its district heating capacity and adding a local biogas facility, a power-to-gas installation and a combined heat and power (CHP) plant to generate renewable hydrogen for local use.

Portland (Oregon), the first US city to adopt a Climate Action Plan (in 1993), committed in 2017 to sourcing 100% of its electricity from renewable sources by 2035 and to meeting its total final energy demand in all sectors with renewables by 2050. Key to Portland's ability to set such a comprehensive target has been engagement and support from local citizens and businesses, affirmed by city elections that prominently featured climate and energy issues. By the end of 2018, around 50 cities worldwide had committed to 100% renewables in all sectors.

Additionally, more than 110 cities and municipalities had adopted targets for 100% renewable heating and cooling by year's end. Most of them are in the United

States (including San Francisco, California; Hanover, New Hampshire; and Pittsburgh, Pennsylvania), Canada (including Calgary, Vancouver and Victoria in British Columbia) and Northern Europe (including Linköping, Sweden; Oslo, Norway; and Ulm, Germany). Examples also exist in Australia (Canberra, Oxford County and Uralla), China (Foshan and Shenzhen) and Japan (Fukushima and Yokohama). Curitiba (Brazil) and Msunduzi municipality (South Africa) both aim to achieve 100% renewable heating and cooling.

By the end of 2018, more than 70 cities and municipalities had adopted targets to transition to 100% renewable energy in the transport sector, including Athens (Greece) and Mexico City (Mexico). Some of these targets apply strictly for municipal operations, as in Brighton (UK), Oslo (Norway) and Pittsburgh (Pennsylvania, US), while others apply city-wide, as in Concord (Massachusetts, US), Honolulu (Hawaii, US) and Ulm (Germany). Uncertainty remains whether these targets will be met by using biofuels or renewably powered EVs.

In addition, several cities have adopted fossil fuel-free targets. Växjö (Sweden) pioneered this approach in the mid-1990s, adopting the world's first fossil fuel-free target. While many such targets are equivalent to a 100% renewables target, they also may include non-fossil fuel alternatives like nuclear power.

Source: See endnote 46 for this chapter.

has a target to install 9 million m² of solar hot water collectors by 2020, an area equivalent to roughly 1.5% of the cumulative solar collector capacity installed worldwide in 2018.⁵²

In the **transport** sector, the primary way to increase the share of renewables has been through specific targets or mandates for the share of biofuels (mainly ethanol and biodiesel) in fuel consumption or production (either in percentage terms or by volume, such as millions of litres). Such targets or mandates have been enacted mainly at the national levelⁱ, although more are emerging at the city level (→ see *Reference Table R4*). Helsinki (Finland) introduced targets to transition its bus systems to run on advanced biofuels, produced mainly from forestry and agricultural wastes.⁵³ Targets for biofuels in municipal and public transit vehicles exist in Brighton (UK), Oslo (Norway) and Pittsburgh (Pennsylvania, US).⁵⁴

Driven in part by efforts to improve local air quality, cities are passing targets to increase the share of EVs in their municipal fleets. Globally, most municipal EV targets are not linked directly to renewable energy (whether through direct EV charging with renewables or parallel efforts to increase renewables in the electricity mix). Of the more than 50 cities worldwide with identified e-mobility targets as of mid-2019, only 8% had an

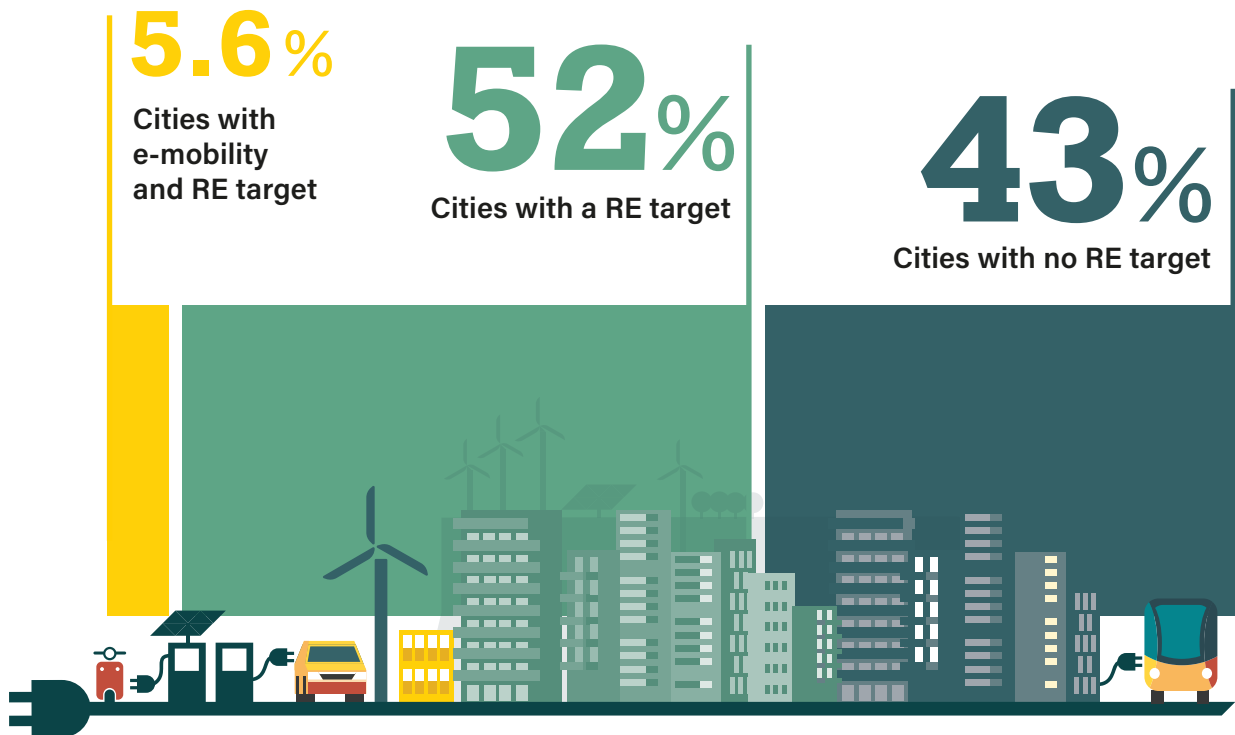
e-mobility target that was directly linked to a renewable energy target, although several cities had independent targets for renewable power (→ see *Figure 11 and Reference Table R6*).⁵⁵ Auckland (New Zealand) aims to reduce emissions from the transport sector by increasing locally generated wind and solar PV power and by setting a target for 40-50% of vehicles to be EVs by 2040.⁵⁶ Münster (Germany) has committed to 100% e-mobility in its transport system by 2050, relying fully on renewable power.⁵⁷

Most cities do not yet couple their efforts to scale up the use of EVs with growing shares of renewables, although many have ambitious EV targets. By 2019, the mayors of more than 30 cities worldwide – including Birmingham (UK), Cape Town (South Africa), Jakarta (Indonesia) and Medellín (Colombia) – had committed through the C40 Fossil-Fuel-Free Streets Declaration to purchase only electric transit buses after 2025.⁵⁸ In China, several cities including Dongguan, Foshan, Guangzhou, Hangzhou, Nanjing, Shaanxi, Shandong, Zhongshan and Zhubai have outlined plans to achieve 100% electrified public transit by 2020, and Wuhan has a target to have 60,000 EVs on the road that year.⁵⁹ Among other cities, Kerala (India), Porto (Portugal) and Seoul (Republic of Korea) also have adopted EV targets.⁶⁰

i Most transport sector targets at the national level include biofuel blending rates of 5% to 20%. See GSR2019.

ii In addition, the municipal government promotes more walking and cycling routes and boosting the use of public transit.

FIGURE 9. Cities with E-mobility Targets and Renewable Energy Targets



Source: See endnote 55 for this chapter.

CLIMATE AND AIR POLLUTION TARGETS

Climate and air pollution targets are proliferating at the city level as concerns about climate change grow and as awareness of the economic and human costs of pollution spreads (→ see *Table 1 for an overview of target types and examples*).⁶¹ Increasing the use of renewables in municipal operations and city-wide, and increasing urban renewable energy generation, often are part of efforts to achieve these targets.

Emissions reduction targets, aimed at cutting emissions from a baseline level by a specific date, are the most common city-level climate target worldwide. Such targets vary in scope, with the goal of decarbonising, for example, municipal operations, city-wide electricity consumption, city-wide energy supply (in the power, heating and cooling, transport and/or cooking sectors) or city-wide emissions from sectors such as waste management or large industry.

Some city governments have introduced stepped targets with clearly defined interim goals, which facilitate monitoring, reporting and identifying deviations from long-term goals; they also allow for introducing additional policy or regulatory interventions to keep progress on track.⁶² For example, Riga (Latvia) has targets

to reduce the city's CO₂ emissions 55-60% by 2020, 70% by 2030 and 85-90% by 2050 (all from 1990 levels).⁶³ Stepped emissions reduction targets also exist in Abasan al Kabira (State of Palestine), Athens (Greece), Bornova (Turkey), Brasília (Brazil), Cainta (Philippines), Cape Town (South Africa), Minneapolis (Minnesota, US), Providencia (Chile) and Taipei (Chinese Taipei), among other cities.⁶⁴

Several cities are going further by adopting **net zero carbon targets**ⁱ (or carbon-neutral targets) that commit them to reducing carbon emissions to zero, whether community-wide or for specific districts or buildings.⁶⁵ As of mid-2019, 21 cities in Australia, Europe and North America had adopted community-wide net zero targets.⁶⁶ At the Global Climate Action Summit in September 2019, another 100 cities announced goals to achieve net zero carbon emissions by 2050.⁶⁷ Adelaide (Australia) and Copenhagen (Denmark) both have articulated plans to become the world's first carbon-neutral city.⁶⁸ Byron Shire (Australia) plans to transition to zero emissions by 2025, and net zero targets also exist in Boston (Massachusetts, US), Heidelberg (Germany), Montreal (Canada) and Oslo (Norway).⁶⁹

ⁱ Such targets at the city level often rely on a combination of targeted emissions reductions from local sources combined with investments in negative-emissions projects such as afforestation and certified carbon offset programmes

TABLE 1. Overview of Urban Climate and Air Pollution Targets

Target Type	Description	Examples
Beyond business-as-usual target	Target for emissions reduction beyond a given business-as-usual forecast, which is typically based on projecting the historical growth in emissions forward into the future.	Buenos Aires (Argentina); Perth (Australia); Belo Horizonte, Cioeste, Recife (Brazil); Taichung (Chinese Taipei); Bogotá (Colombia); Copenhagen (Denmark); Quito (Ecuador); New Delhi (India); Jakarta (Indonesia); Oristano, Rimini, Verbania (Italy); Nakuru (Kenya); San Isidro (Peru); Changwon (Republic of Korea); Singapore (Singapore); Cape Town, Johannesburg (South Africa); Bangkok (Thailand); Durham (New Hampshire, US); Louisville (Kentucky, US)
Emissions reduction target	Target to reduce emissions by a certain amount by a specific date (for example, 50% below 1990 by 2020).	More than 10,000 cities worldwide have such targets.
Net zero emissions target (also called carbon-neutral target)	Target based on reducing the city's emissions as much as possible and investing in offsetting measures to cover any remaining emissions, for example by ensuring that any net emissions are offset or sequestered elsewhere. Interchangeable with carbon neutrality.	Adelaide, Melbourne, Sydney (Australia); Montreal (Canada); Copenhagen (Denmark); Helsinki (Finland); Paris (France); Heidelberg (Germany); Oslo (Norway); Barcelona (Spain); Stockholm (Sweden); Bristol, London, Manchester, Nottingham (UK); Austin, Boston, Los Angeles, New York City, San Francisco, Seattle, Washington, D.C. (US)
Air pollution reduction target	Target to reduce air pollution in cities.	Buenos Aires (Argentina); Sydney (Australia); Medellin (Colombia); Copenhagen (Denmark); Quito (Ecuador); Paris (France); Berlin, Heidelberg (Germany); Bengaluru, New Delhi (India); Jakarta (Indonesia); Tel Aviv-Yafo (Israel); Milan (Italy); Tokyo (Japan); Amman (Jordan); Guadalajara, Mexico City (Mexico); Rotterdam (Netherlands); Oslo (Norway); Lima (Peru); Quezon City (Philippines); Warsaw (Poland); Lisbon (Portugal); Seoul (Republic of Korea); Durban (South Africa); Barcelona, Madrid (Spain); Stockholm (Sweden), Dubai (UAE); London (UK); Austin, Houston, Los Angeles, Portland, Washington, D.C. (US)

Source: See endnote 61 for this chapter.

In a similar approach, in 2018 Greater Springfield (Australia) adopted a target to become a **net zero energy city**ⁱ by 2038.⁷⁰ The initiative aims to ensure that by 2038 the six suburbs of Greater Springfield will generate more energy than they consume, drawing on a range of investments in renewable energy capacity as well as energy storage infrastructure, district energy systems and green mobility.⁷¹

In 2018, Manchester (UK) became one of the first European cities to adopt a comprehensive carbon budget, which is monitored on an annual basis and is allocated within a series of five-year plans.⁷² To stay within the budget, the city aims to reduce its emissions to near zero by 2038.⁷³

Another type of target, used primarily in rapidly urbanising cities in emerging countries, is a “beyond business-as-usual” target. As of mid-2019, at least 23 cities worldwide had adopted such targets.⁷⁴ For example, Cape Town (South Africa) aims to reduce its energy-related emissions 37% below business as usual by 2040.⁷⁵

In October 2019, 35 cities worldwide signed the C40 Clean Air Cities Declaration, committing to air pollution reduction targets and clean air policies by 2025.⁷⁶ Among the participating cities are Amman (Jordan), Bengaluru (India), Guadalajara (Mexico), Tel Aviv-Yafo (Israel) and Warsaw (Poland).⁷⁷

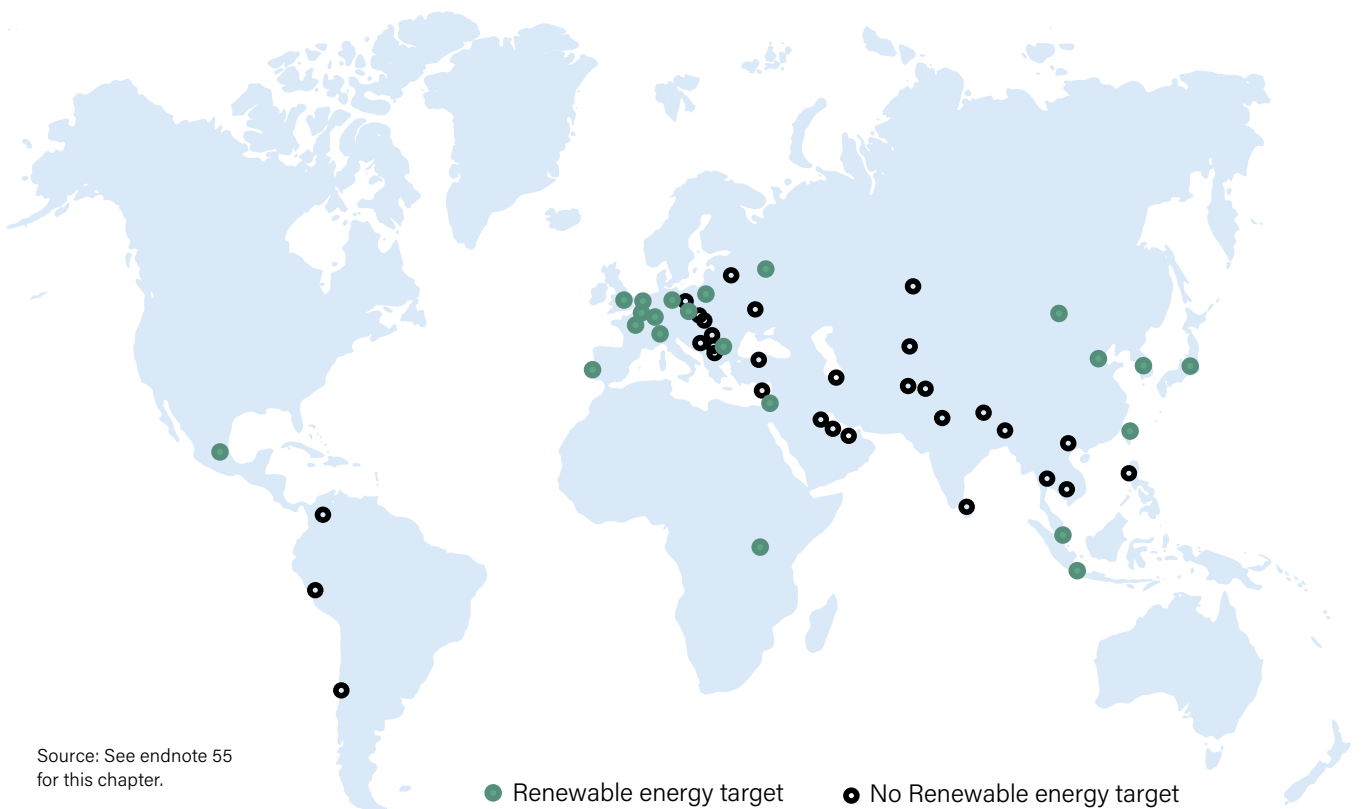
Through the uptake of renewables and the development of cleaner transport, cities have the opportunity to combat local air pollution and improve public health. Although no global review has been conducted on the link between air pollution and renewable energy targets, data suggest that municipal governments are using renewables to address this challenge. In 2018, 53 of the world’s capital cities with air pollution monitoring stations registered PM_{2.5} levels exceeding the World Health Organization’s safety standard; of these, nearly half had adopted targets for renewables as of mid-2019 (in either the power, heating and cooling, or transport sector, or for all three; → see *Figure 12 and Reference Table R7*).⁷⁸

■ POLICIES

Targets are converted into action through the adoption and implementation of policies and regulations (→ see *Table 2*). As at the national level, most of the policy support for renewables at the city level has been directed towards the power sector. However, policies supporting the use of renewables in the heating and cooling and transport sectors, as well as measures linking renewables and energy efficiency, continue to gain momentum at the city level.⁷⁹ Some cities also have developed integrated policy approaches to the energy transition (→ see *Sidebar 4*).⁸⁰

i A net zero energy city refers to a city that generates more energy within its borders than it consumes.

FIGURE 10. Overview of Existing Renewable Energy Targets in the Most-Polluted Capital Cities, As of Mid-2019



SIDEBAR 4: Integrated Policy Approaches to the Urban Energy Transition

A growing number of cities have realised that integrated approaches that harness a range of renewable energy sources are critical to accelerating the energy transition. This shift can be seen as a move from a single-technology approach to a whole-systems approach to urban energy planning. As part of this shift, cities are working with a wide variety of stakeholders to develop and implement ambitious policies and strategies that integrate the power, heating and cooling, and transport sectors.

Burlington, Vermont (US): In 2014, Burlington (42,000 residents) achieved its 100% renewable electricity target, set three years prior, by using a diverse mix of local energy resources (for example, wind energy, solar PV and biomass, including landfill gas), buying renewable energy certificates and facilitating the purchase of a local hydropower plant by the city's municipal utility, a measure that 80% of city voters supported in a local ballot. In partnership with the utility, Burlington also has undertaken multiple initiatives to promote energy efficiency (including establishing an energy efficiency fund in 1990) and to encourage the adoption of EVs, including offering utility-funded rebates and a special electricity rate for EV charging. To increase the share of renewables in the heating sector, the city passed a resolution in April 2018 authorizing the development of a district heating network to serve local residents and businesses, using waste heat from a nearby biomass facility.

Cape Town, South Africa: Cape Town (4.5 million residents) has taken several measures to increase the share of renewables in its power mix and to improve overall energy efficiency. In 2006, the city was a pioneer in signing South Africa's first bilateral PPA with a local wind power project. To scale up distributed generation projects, Cape Town developed a small-scale generation programme that enables residential, commercial and industrial customers to generate their own electricity on-site from renewable technologies and to sell their surplus to the grid. The city also has invested in four micro-hydropower turbines at its water treatment plants that supply 5% of the municipal government's electricity demand. In addition, Cape Town offers a marketing and accreditation programme for solar water heaters and is exploring the use of a special tariff category for EV charging to reduce transport-related emissions and promote cleaner mobility.

Hamburg, Germany: Hamburg (1.8 million residents) has developed an integrated strategy that includes the use of a wide range of renewable technologies in an increasingly interconnected regional energy system. The city and surrounding areas already produce enough renewable power to meet around 160% of regional electricity demand (mainly from wind power projects along the coast), and plans are in place to expand wind power output threefold, linking the extra output to end-uses including heating, cooling, and electric and hydrogen-based mobility. The local district heating network has been connected to electric

heating technologies, enabling it to use surplus electricity from nearby renewable power projects. Hamburg also is supporting related innovations including promoting the ability of renewable energy and storage to provide ancillary services, piloting demand response in local industrial facilities and deploying energy storage technologies.

Seoul, Republic of Korea: In Seoul (9.9 million residents), the metropolitan government has made rapid progress in improving energy efficiency and scaling up renewable energy. It has invested in district heating projects that provide heating and cooling to residents and businesses and has supported more than 200 MW of distributed solar PV in the city. The local government has established a special agency, Seoul Energy Corporation (SEC), to oversee implementation of the city's energy policies. The development of renewables in the city is supported by national measures including a renewable energy mandate, a renewable fuel standard and a requirement that public buildings meet 30% of their electricity demand with on-site renewables by 2020. The SEC has increased the city's EV procurement to 10,000 vehicles, offers a low-interest loan for EV purchases and provides dedicated charging facilities powered by solar PV to ensure that the vehicles can be charged using renewable power.

Sydney, Australia: Sydney (5.2 million residents) has developed a detailed strategy to tap into the city's large potential for renewable heating and cooling and other distributed technologies. The city recently committed to procuring 100% of its electricity needs from local and regional renewable energy sources by 2020, a decade ahead of its original 2030 target. To accelerate the deployment of renewable power, it has harnessed local hydro and wind resources and invested in rooftop solar PV and solar thermal installations at more than 30 public facilities, including swimming pools, libraries and the city's Town Hall. Sydney also has engaged with private sector partners to develop a large-scale battery storage system to improve the integration of variable renewable energy sources such as wind and solar PV and to supply this power during peak hours.

Uppsala, Sweden: The municipality of Uppsala (168,000 residents) has a far-reaching strategy to make the city fossil fuel-free and to power it with 100% renewable electricity by 2030. A key focus is on using locally available renewable energy resources, including biomass and food waste, to transition to a more circular economy (one in which waste is minimised or eliminated and the flow of resources is circular rather than linear). To achieve its objectives, the city has developed a biogas project using household organic waste, a biomass gasification project using forestry waste, and a range of solar PV projects. Uppsala aims to improve the flexibility of demand, both for electricity and for heating, to improve the integration of renewable sources into the energy system.

Source: See endnote 80 for this chapter.

Having supportive policies in places is key to accelerating the pace of renewable energy deployment, particularly at the city level.⁸¹ Cities often face challenges in rapidly scaling up renewables due to space constraints, planning restrictions, historical preservation requirements, high land costs, stringent inspection requirements, local opposition and a lack of direct control over major areas of policy making (such as tax policy).⁸² In addition, most residents of major cities live in multi-unit buildings, where the barriers to adopting renewables tend to be higher.⁸³ In Toronto (Canada), 30% of dwellings are in high-rise apartment buildings, and in New York City (New York, US) 40% of all residential units are in multi-unit buildings; the shares are even higher in certain cities in Asia and Latin America.⁸⁴

Several factors determine the policy and regulatory options available to municipal governments. They include whether the city owns the municipal utility (electric, district energy, transit or other) and whether the relevant jurisdiction allows for competition among suppliers. Another key determining factor is whether customers are allowed to connect any electricity that they generate on-site to the grid and export the surplus, and whether third parties (such as private solar leasing companies) can own or lease customer-sited generation, such as rooftop solar PV projects.

Cities often face challenges in rapidly scaling up renewables.

City policies can be divided into two main categories:

- **Policies targeting a municipality's own operations:** Such approaches often focus first and foremost on **city procurement**, which refers to the kinds of investments that city governments and local operators make in municipal fleet vehicles, bus and transit systems, and renewable electricity or heating from local and regional projects, among others. City procurement also refers to efforts by city governments to boost their **own renewable energy production**, such as through direct investments in rooftop solar PV and solar thermal, in biogas at local landfill sites and in wastewater treatment plants. In addition, city procurement here refers to actions by city governments to support the provision of **key enabling infrastructure** such as EV charging stations and district energy systems.⁸⁵
- **Policies targeting city-wide energy use:** Such approaches typically focus on encouraging private investment in renewables (and in key enabling infrastructure such as district energy systems and EVs) among residents, businesses, industries, utilities, and airport and harbour authorities. To increase the uptake of renewables city-wide, municipal governments serve as policy makers and regulators, using tools such as mandates and obligations (for example, solar PV or solar thermal ordinances) as well as fiscal and financial mechanisms, including tax exemptions, grants, fees and rebates. City governments also can introduce Property Assessed Clean Energy (PACE) financing, which allows residents and businesses to invest in renewable energy technologies via the municipal government and to repay the loans through an increase in their annual tax assessments.

Beyond these two broad categories, city governments are taking steps to improve the overall enabling environment in which residents and businesses operate, including by increasing awareness; reducing administrative, permitting and inspection-related barriers to investment; establishing bulk buying programmes; and creating supportive zoning and other laws. Improving the enabling environment involves updating existing laws or creating new ones, for example facilitating the emergence of supportive business models such as solar leasing, bulk buying and the development of community-funded solar projects (→ see *Finance chapter*).



TABLE 2. City-level Policies by Sector

		Electricity Sector	Heating and Cooling Sector	Transport Sector
Municipal Operations	City Procurement	<ul style="list-style-type: none"> Direct city investment in renewable power capacity on public buildings (for example, rooftop solar PV) Buying renewable electricity from, for example, the existing utility, local residents and businesses (such as through special tariff structures for customer-sited generation) and third-party suppliers 	<ul style="list-style-type: none"> Direct city investment in renewable heating and cooling technologies and infrastructure (for example, solar thermal for city buildings, or renewably driven district thermal networks) Buying renewable heat from existing district networks Aggregating the city's heat demand to enable the construction of new district networks 	<ul style="list-style-type: none"> Direct city investment in the production of biofuels, renewable electricity or electro-fuels Direct city investment in renewable transport (for example, renewably powered transit, biodiesel buses, renewably powered hydrogen vehicles or trains; etc.) Procuring key enabling technologies for renewable transport, such as EVs and hydrogen vehicles
	City-wide	<ul style="list-style-type: none"> Mandates to purchase electricity from renewable options, or to install renewable energy systems for new and/or existing buildings Aggregating the city's electricity demand and seeking new suppliers (for example, through community choice aggregation) 	<ul style="list-style-type: none"> Mandates to purchase heating and cooling from renewable options, or to install renewable energy systems for new and/or existing buildings Adopting net zero emission/energy standards 	<ul style="list-style-type: none"> City fleet mandates to buy only electric cars or, for example, biodiesel/biofuel buses Mandates for specific sectors (for example, logistics companies) to use biofuels or to use EVs to enable renewables Mandates to install EV charging infrastructure in new and/or existing construction (for example, shopping centres) to enable renewables
	Fiscal and Financial Mechanisms	<ul style="list-style-type: none"> Property Assessed Clean Energy (PACE) financing Rebate programmes Low-interest loans Revolving loan funds Etc. 	<ul style="list-style-type: none"> Property Assessed Clean Energy (PACE) financing Rebate programmes Low-interest loans Revolving loan funds Etc. 	<ul style="list-style-type: none"> Eliminating or reducing fees (for parking, ferries, road tolls, electricity, etc.) for certain vehicles, including EVs Attractive rate structures for smart charging to improve the integration of renewables Congestion zones with preferential rules for EVs and renewably powered vehicles

Source: REN21

Key Elements of the Enabling Policy Environment

Streamlined permitting and approval procedures, supportive zoning rules and building regulations, streamlined inspections, making public land available for renewable energy projects, registries of certified installers, public awareness campaigns, bulk buying programmes, co-ordination among relevant city departments (waste management, water treatment, planning, etc.) and among different levels of government, etc.

MUNICIPAL UTILITIES

Municipal utilities that have ownership over local energy supply or distribution infrastructure are central actors in many cities around the world, shaping the pace and scale of the energy transition at the city level (→ see *Figure 13*).⁸⁶ Significantly, municipal utilities have different accountability mechanisms than do investor-owned and nationally owned utilities; in particular, they are accountable to the local city council and/or to the municipality's residents. Also, staff at municipal utilities typically are members of the community. In light of these and other factors, it is often argued that municipal ownership can provide greater responsiveness to local needs and priorities.⁸⁷

While municipal utilities frequently have control over local energy supply and distribution, many have responsibilities that range beyond the energy sector to include water, waste management, emergency services, public transit and in some cases the management of the local airport. Each city's unique ownership structure, in turn, impacts the policy and regulatory tools it has at its disposal to accelerate renewable energy adoption. Whereas municipal electric utilities (including local co-operatives) are common in Europe, Japan, the Philippines, South Africa and the United States, national utilities are predominant in most other regions of the world.⁸⁸

In cities like Nairobi (Kenya) and Tunis (Tunisia), for example, direct municipal control over the electricity supply is limited because neither city has a municipal utility, buying instead from national suppliers.⁸⁹ By contrast, in the United States, more than 1,800 municipal utilities supply over 15 million electricity customers, or roughly 10% of all electricity customers.⁹⁰ In the EU, an estimated

1,500 local and regional energy companies, most of which are publicly owned, serve around 85 million electricity and natural gas customers, making them important actors in many cities.⁹¹

In an attempt to gain greater control over the energy supply, several cities have taken steps to create their own municipal utilities. In the case of Nottingham (UK), Robin Hood Energy, established in 2015, was the first municipal energy company created by a local council in the UK in more than 75 years.⁹² In July 2019, the new municipal utility in Barcelona (Spain), Barcelona Energía, started supplying locally produced renewable energy to city council buildings and facilities and other local customers.⁹³ Efforts to municipalise are being discussed in US cities such as Bangor (Maine), Chicago (Illinois) and San Francisco (California).⁹⁴

Cities also can purchase local energy infrastructure such as distribution grids in part or in full, as in Hamburg (Germany) and Nottingham (UK).⁹⁵ In recent years there has been a trend of re-municipalisation, or buying back the energy supply infrastructure, enabling cities to pursue more ambitious policies for renewable energy adoption and integration (→ see *Citizen Participation chapter*).

Those cities that do not directly control their energy mix (for the electricity, heating and cooling, or transport sectors) may seek to influence state-level and utility-level policy making by taking part as intervenors in regulatory hearings.⁹⁶ Such cities also can engage with the relevant utility to push for more ambitious renewable energy goals, or to encourage the procurement of more EVs or electric buses, for example. In addition, cities can renegotiate their franchise agreementsⁱ – long-term contracts that cities sign with electricity suppliers to provide reliable power supply (used mainly in North America).

ⁱ Franchise agreements often range from 20 to 40 years, and the contract renewal process can provide a valuable opportunity for the city (on behalf of its residents and businesses, or in concert with them) to require utilities to deliver on more ambitious energy and climate commitments. Franchise agreements are sometimes referred to as “concessions” or “concession agreements.”

FIGURE 13. Spectrum of Ownership of Municipal Electric or Heating Utilities

Full ownership		→ No ownership	
100% city ownership of the municipal utility	Partial city ownership of the municipal utility	Privately owned, but still structured as a municipal utility that the city can influence as a key “city stakeholder”	No municipal electric/thermal energy utility; all city residents and businesses buy their electricity or thermal energy from a regional or national supplier
Examples: 1,843 utilities in the United States, including Oak Ridge (Tennessee), Burlington (Vermont), and Austin (Texas), Sacramento (CA); Munich (Germany); Olongapo (Philippines); Nottingham (UK); Barcelona (Spain)	Examples: Freiburg (Germany)	Examples: Meralco serving Metro Manila (Philippines); Boulder (Colorado, US)	Examples: Denver (Colorado, US); Chicago (Illinois, US); Nairobi (Kenya); Tunis (Tunisia); London (UK)

Source: See endnote 86 for this chapter.

POWER

In many parts of the world, cities are assuming greater control over their own energy and climate policy as well as over the ownership and operation of electricity sector assets, including local generation plants and distribution grids.⁹⁷ A key

trend in electricity markets worldwide that has helped cities gain greater control and influence has been the separation of control over electricity transmission and distribution, also known as “**unbundling**” (→ see *Box 2*).⁹⁸

Another part of the shift towards greater access to renewables is the emergence of **green power programmes**, which enable customers in urban areas, including renters, to actively support

In the US, more than 1,800 municipal utilities supply over 15 million electricity customers.

the development of renewable power by opting into renewable electricity sources provided by their utility. For many urban residents, green power programmes may be the only way for them to actively determine their electricity mix. The first such programme was launched in the US state of New Hampshire in 1996.⁹⁹ By 2017, more than 5.5 million electricity retail customers across the United States participated in voluntary renewable power programmes, purchasing 112 TWh of electricity, or roughly 3% of US electricity sales that year.¹⁰⁰

The opening up of electricity markets also has enabled city governments (and businesses) to sign **power purchase agreements** or **solar leasing** agreements with specific renewable electricity generators (→ see *Finance chapter*). Such innovations enable city governments and residents to lock in their renewable electricity supply and price with developers of projects located both within and outside city limits, making it possible for urban areas to achieve far more ambitious renewable energy targets.

BOX 2. Unbundling of Electricity Markets

Unbundling refers to the process through which traditional electric utilities (many of which were nationalised in the mid-20th century) are required to separate control over generation (i.e., power plants) from control of the transmission and distribution system.

As electricity markets are opened up to competition, more customers can choose their supplier and have greater say over their electricity mix. In particular, cities that do not own their own municipal utilities have benefited directly from the process of unbundling and retail competition, enabling them to directly control their electricity mix. However, cities can still face challenges. Cape Town (South Africa) is currently in legal proceedings to secure its right to procure electricity directly from third-party suppliers, including renewable electricity suppliers, rather than having to buy from the national utility, Eskom.

Although the development of competitive electricity markets has been patchy, their emergence has made it possible for independent power producers (including renewable electricity generators) to generate and sell their electricity. Around 70% of countries worldwide have introduced varying degrees of private sector participation and competition in the electricity sector and offer small-scale producers the ability to connect to the grid to sell their surplus electricity.

The ability to choose suppliers (for example, to choose a utility or supplier that offers a higher share of renewable energy or electricity) is now guaranteed in the EU as well as in Australia, Canada, the Russian Federation, Switzerland, the United States and some countries in Eastern Europe and Latin America (Argentina, Brazil, Chile, Guatemala, Peru). This shift has sparked innovations in the sector, including the emergence of new business models (→ see *Finance chapter*).

Source: See endnote 98 for this chapter.



CITY PROCUREMENT

City procurement here includes cities' efforts to purchase renewable electricity to power municipal operations, such as by developing renewable energy projects to meet the local government's own energy needs. City governments also can procure renewable electricity directly from others, whether through tenders or auctions that result in PPAsⁱ, or through policies that encourage customer-sited generation, such as net metering initiatives and feed-in tariffs.¹⁰¹ Efforts to increase the share of renewables used for municipal operations are at the heart of cities' role as champions and trendsetters.

A growing number of Indian cities have started to procure renewable electricity directly for on-site use. In 2018, the South Delhi Municipal Corporation (SDMC), one of three municipally run entities in New Delhi, became the first public body in India to generate a substantial profit from the sale of electricity from publicly owned solar PV systems, specifically rooftop arrays on 55 municipal buildings.¹⁰² In 2019, SDMC committed to installing rooftop PV systems on all of its municipal buildings, including local schools, by year's end.¹⁰³ New Delhi's police force also has committed to installing several MW of rooftop solar PV at police buildings throughout the city.¹⁰⁴ Chennai (India) issued tenders for the installation of solar PV on 662 municipal buildings, including government offices, schools and hospitals.¹⁰⁵ Building on the success of its March 2018 tender, Tumakuru (India) issued a new tender in late 2019 to install solar PV on government buildings to supply municipal power needs.¹⁰⁶

In the Middle East, the Dubai Electricity and Water Authority (UAE) signed a memorandum of understanding with the Dubai Future Foundation in early 2019 to design, build and operate a solar PV plant to generate 4,000 MWh of renewable energy annually for the city's Museum of the Future.¹⁰⁷ Abu Dhabi (UAE) is investing heavily in a few large-scale solar PV and concentrating solar thermal power (CSP) projects to achieve its renewables targets.¹⁰⁸ In Africa, Harare (Zimbabwe) aims to reach its target of 25% renewable energy mainly by procuring and developing a 60 MW solar PV project and a biogas plant that will use local waste streams to generate electricity.¹⁰⁹

In their efforts to scale up renewables, many cities are turning to power purchase agreements. PPAs are increasingly common in US cities including Cincinnati (Ohio), Georgetown (Texas) and Palo Alto (California).¹¹⁰ In Georgetown, the municipal utility Georgetown Utility Systems relies on PPAs to meet 100% of its electricity needs from two wind projects and a solar PV project.¹¹¹ Several cities in Washington state have joined together to sign direct PPAs for electricity from a local wind power project that will enable them to supply 100% of the electricity needs of their city governments with renewables.¹¹²

In another PPA approach involving multiple parties, Melbourne (Australia) joined with cultural institutions, universities, local companies and municipalities in the area to collectively purchase renewable electricity from a newly built 80 MW wind farm.¹¹³ The project enabled the operations of the Melbourne City Council to be powered by 100% renewable electricity, and the city councils of Moreland Council, Port Phillip and Yarra have committed to purchasing electricity from the same project.¹¹⁴ In July 2017, the Sunshine Coast Council (Australia) entered a long-term PPA for its municipal electricity consumption with the 15 MW Sunshine Coast Solar Farm, which generates enough electricity to meet all of the local government's electricity needs and will provide an estimated USD 22 million in savings.¹¹⁵

As part of plans to scale up its renewable energy procurement, Cape Town (South Africa) aims to purchase the electricity generation from more than 520 MW of renewable capacity over a 15-year period; the city envisions meeting a large share of this through PPAs with independent producers and via small-scale generators located near households and businesses.¹¹⁶ Leading drivers behind the city's efforts are securing lower-cost power for customers and reducing reliance on the national utility Eskom, which has increased its electricity rates in recent years.¹¹⁷

In this vein, cities have introduced a wide range of policies to allow residents and local businesses to develop their own renewable electricity projects. Among the most common policy tools supporting the development of distributed renewables are feed-in tariffs and net metering policies, both of which are evolving in response to the rapid decline in renewable electricity generation costs and other factors.¹¹⁸

Although **feed-in tariffs** (FITs) have been implemented mostly at the national levelⁱⁱ, a number of cities (particularly those that own their municipal utility) have designed and implemented them for renewable energy projects. Illustrating city governments' role as champions and trendsetters, the first FITs to provide cost-based compensation emerged at the municipal level in the early 1990s in German cities such as Aachen, Freising and Hammelburg.¹¹⁹ By the mid-1990s, more than 40 municipal utilities across Germany had adopted some variation of these FITs.¹²⁰

US cities, including Fort Collins (Colorado), Gainesville (Florida) and Los Angeles (California), followed suit, adopting FITs to

Although FITs have been implemented mostly at the national level, some cities have used them for renewable energy projects.

ⁱ Another innovation that is used mainly in the corporate sector but could soon be adopted by cities is the rise of so-called virtual PPAs. Virtual PPAs are similar in many ways to conventional PPAs, but the resulting contract is strictly financial and does not require the physical delivery of electricity. See US Environmental Protection Agency Green Power Partnership, "Introduction to Virtual Power Purchase Agreements," webinar, 2016, https://www.epa.gov/sites/production/files/2016-09/documents/webinar_kent_20160928.pdf, and Rachit Kansal, Introduction to the Virtual Power Purchase Agreement (Snowmass, CO: Rocky Mountain Institute, 2018), <https://rmi.org/wp-content/uploads/2018/12/rmi-brc-intro-vppa.pdf>.

ⁱⁱ As of 2018, 111 countries, states and provinces had feed-in policies. See GSR 2019.

drive solar PV deployment.¹²¹ The LA Department of Water and Power's FIT policy encourages the development of both solar PV and landfill gas projects, and the department relies on financial instruments such as rebates to further encourage uptake.¹²² As of early 2019, the local utility had supported the installation of more than 440 MW of solar PV capacity within city limits.¹²³

Net metering policies were present in at least 66 countries as of the end of 2018.¹²⁴ Although such policies typically are adopted at the state or national level, a number of cities have introduced these policies (often via their municipal utilities) to encourage more distributed generation in the network. Of South Africa's 164 municipal electric utilities, 34 had adopted rules to allow small-scale electricity generators to connect to the grid as of late 2017; more than half of these (18) had adopted special tariffs governing the compensation of excess generation exported to the grid, including Cape Town, Durban and Johannesburg.¹²⁵ Driven in part by these policies, an estimated 700 MW of solar PV capacity was installed on customer's premises in cities and municipalities nationwide by mid-2019.¹²⁶

A related policy that has emerged to support the development of urban renewable energy projects is **virtual net metering**ⁱ (also referred to as electricity wheeling). Virtual net metering is available in jurisdictions in Jordan, Pakistan and the United States, among others.¹²⁷ The idea also is spreading in India: in 2019, New Delhi expanded its solar PV policy to allow customers to engage in virtual net metering, mainly to enable customers that do not have suitable roof space to participate in solar PV generation.¹²⁸

City governments (and local businesses) also are using **renewable energy certificates** (RECs) to achieve their renewable electricity objectives.¹²⁹ A REC represents 1 megawatt-hour of renewable electricity and can be bought and sold separately from electricity and used for compliance purposes.¹³⁰ Because RECs can be purchased and traded, city governments (and businesses) are able to buy the certificates in the exact quantities they need, providing a way to meet their renewable electricity targets without having to generate their own renewable power.¹³¹

To achieve its 100% target, the municipal utility of Burlington (Vermont, US) meets a portion of the city's electricity demand with a local bio-power plant (in which it has a 50% ownership share) and the rest through the purchase of RECs from wind, solar and small-scale hydropower facilities in the region.¹³² In Austin (Texas, US), the local utility Austin Energy uses RECs to buy renewable energy from certified sources in the state to meet its needs.¹³³

Another procurement approach that is gaining ground in some US cities is community choice aggregation (CCA).¹³⁴ In CCA, an actor (often the city government) aggregates all of the electricity

demand in a given area and tenders out a contract to supply the electricity for that group of customersⁱⁱ. Through CCA, cities are able to actively take control of their electricity supply, giving preference to suppliers that meet the city or community's preferences. In a growing number of cases, CCA is being used to procure higher shares of renewable electricity than are available from existing suppliers and to lock in lower rates.¹³⁵ In Cambridge (Massachusetts, US), all customers of the local utility are automatically enrolled in a CCA programme that provides 25% more solar PV than is mandated by the state.¹³⁶ Residents and businesses also have the option to enrol in a "100% Green" package supplying electricity only from local renewable energy projects.¹³⁷

Although CCA programmes are created at the local level, their emergence often requires enabling laws and regulations at the state level. At least eight US states have adopted such legislation, including California, Illinois, Massachusetts, New Jersey, Ohio, Rhode Island and Virginia.¹³⁸ While CCA is found mainly in the United States, related approaches are used elsewhere.¹³⁹ In Brčko (Bosnia and Herzegovina), the municipal government re-tenders out the supply contract for meeting the municipality's electricity needs each year, giving it the ability to determine annually the local electricity supply.¹⁴⁰

MANDATES AND BUILDING CODES

The use of mandates and stricter building codes has become an important tool for city governments to reduce greenhouse gas emissions and accelerate renewable energy use.¹⁴¹ Mandates in the renewable power sector generally include a technology-specific requirement (for example, to adopt solar PV on all public buildings by 2025), whereas building codes typically are technology-neutral, setting out the standard or level of energy performance that needs to be attained.

In many emerging market cities, particularly rapidly growing cities in Africa, Asia and Latin America, enforcing building codes and mandates can be a key challenge. Often, municipalities lack the capacity to conduct inspections and to verify that codes and standards are being complied with.¹⁴² City governments can address some of these challenges by investing in better permitting and inspection regimes (→ see *Elements of the Enabling Environment* section).

In an example of how cities act as trendsetters, in 2016 several municipal governments in California adopted mandates for solar PV in new construction, including Lancaster, San Francisco, Santa Monica and Sebastopol.¹⁴³ Two years later, the state of California followed suit, passing a state-wide mandate requiring that all new single-family homes integrate solar PV starting in

i Virtual net metering refers to the ability to generate power at a location that is different from the location where the electricity meter is located, and to use the output of that facility to offset one's own consumption. The electricity generation is not consumed directly on-site (as under traditional net metering) but is produced elsewhere and "netted" virtually. Like traditional net metering, customers receive a credit on their bills that is equivalent to their share of the total renewable electricity generated.

ii CCA first emerged in the United States in the late 1990s as a mechanism to help cities and customers reduce their utility bills. In 2017, the estimated 750 active CCA programmes nationwide procured 42 TWh of electricity on behalf of 5 million customers. See Eric O'Shaughnessy et al., *Community Choice Aggregation: Challenges, Opportunities, and Impacts on Renewable Energy Markets* (Golden, CO: National Renewable Energy Laboratory, 2019), <https://www.nrel.gov/docs/fy19osti/72195.pdf>.

2020.¹⁴⁴ Tübingen (Germany) introduced a mandate in 2018 that requires the installation of solar PV on all new buildings in the city, a move that New York City followed in 2019.¹⁴⁵

Instead of issuing technology-specific mandates, some cities are tightening their building codes to support renewables. While building codes often are focused on improving energy efficiency by, for example, requiring better insulation and reducing energy waste, codes also can be used to require that a certain share of a building's energy use comes from on-site renewable power generation.¹⁴⁶

Many building codes apply strictly to new construction, but some jurisdictions are using them to influence existing construction as well, mainly when buildings undergo renovations. Singapore's Building Control Act includes a special category for "zero energy buildings" that applies to both existing and new construction in the commercial, industrial and institutional sectors.¹⁴⁷ To achieve the standard, all electricity used within the building must be sourced from renewables, whether onsite or offsite.¹⁴⁸

In the UK, the so-called Merton Rule (named after the London borough of Merton that initiated the measure in 2003) enables local authorities to set higher energy standards in buildings than those established at the national level.¹⁴⁹ In practice, the Merton Rule requires all new developments greater than 1,000 m², including residential complexes, public buildings, supermarkets and a range of commercial buildings, to generate at least 10% of their electricity from on-site renewables.¹⁵⁰ At a broader scale, signatories of the Covenant of Mayors for Climate & Energy have committed to adopt city building codes and energy performance requirements that are more stringent than those at the national level.¹⁵¹

Zaragoza (Spain) took a different approach through its provision ensuring that buildings owners retain a "**right to the sun**" by fixing a maximum height for surrounding buildings and regulating the distance between buildings.¹⁵² The provision is explicitly designed to ensure that residents' ability to generate on-site solar energy, whether from solar thermal or PV systems, is protected.¹⁵³ This highlights the role of city governments in promoting integrated urban planning, shaping the overall development of cities in ways that enable or facilitate the urban energy transition.

FISCAL AND FINANCIAL INCENTIVES

Fiscal and financial incentives include grants, rebates, tax exemptions, and the use of fees and levies to encourage or discourage certain types of behaviour and investment choices. Many cities – including municipal governments in Europe, Japan and the United States – use grants to encourage the adoption of renewable power technologies. In Japan, the prefectures of Aichi, Hiroshima, Itabashi, Kitakyushu and Sumida offer grants directly to consumers for purchasing renewable energy systems.¹⁵⁴ Itabashi, in central Japan, provides grants for installing solar PV systems and solar water heaters.¹⁵⁵

With regard to **tax incentives**, Medellín (Colombia) offers five-year tax exemptions of 20% to 100% for companies that manufacture solar, wind and geothermal generation equipment (and efficient lighting technologies) to encourage growth in the city's renewable energy sector.¹⁵⁶ Darebin City Council (Australia) launched its Solar Saver programme in 2017 to help residents finance small-scale (1 kW to 5 kW) solar PV systems interest-free over a 10-year period.¹⁵⁷ The Council is able to buy the solar panels without paying the local sales tax, and the programme enables residents to repay their system gradually from the savings on their electricity bills.¹⁵⁸ By the end of 2018, Darebin residents had installed 18 MW of solar PV capacity, and the city aims to double this by the end of 2022.¹⁵⁹

Property Assessed Clean Energy (PACE) financing, first launched in the United States in 2008, is another policy and financing innovation available at the city level to encourage the adoption of renewables. Like community choice aggregation, PACE programmes often require enabling legislation at the state or provincial level. PACE financing provides participants with access to low-interest loans for investments in eligible renewable energy technologies, repayable through an increase on their annual property tax bill.¹⁶⁰ Under such programmes, a city in effect uses its taxation powers (namely, its control over municipal property taxes) to encourage renewables.¹⁶¹

As of early 2019, more than 200,000 US homeowners had invested a total of USD 5 billion in energy efficiency and renewable energy improvements through PACE financing.¹⁶² Programmes focused specifically on the development of renewables via PACE financing were available in 17 major US citiesⁱ, and PACE programmes also were catching on in Australia, Canada and Europe.¹⁶³

ENABLING POLICIES

Renewable energy projects, whether owned by residents, businesses, community groups, or utilities or city governments themselves, rely on more than procurement policies, mandates, and fiscal and financial incentives. They typically depend on the presence of other measures including permitting and procurement guidelines, zoning rules and municipal bylaws. These measures generally are not thought of as part of the renewable energy policy toolkit, yet they are important to the overall enabling environment, particularly at the city level.

For cities with insufficient capacity to enforce building codes and mandates, investing in better permitting procedures and in more staff to conduct site inspections can play an important role. Several cities in India have stepped up their enforcement of national-level building codes, in part to improve the energy performance of commercial and other buildings.¹⁶⁴

i The government offers JPY 25,000 (USD 230) per kW, with an upper limit of JPY 100,000 (USD 921) for solar PV systems and 5% of the initial cost, to a maximum of JPY 45,000 (USD 414) for solar water heating systems.

ii Nationwide, 36 states plus Washington, D.C. had laws to enable the development of PACE, and programmes were operating in more than 20 states, most of them focused on projects in the commercial sector. See PACENation, "PACE Programs", <https://pacenation.us/pace-programs/>, viewed 21 November 2019.

Cities also can lead by introducing specific requirements on the use of public space, or by introducing **procurement guidelines**. For Copenhagen's flagship Middlegrunden offshore wind power project, the city hosted several meetings to engage stakeholders and introduced special terms of collaboration between the municipal utility and co-operative members to support the project, making it the world's first offshore wind farm to be financed on a co-operative basis.¹⁶⁵

Some cities are pro-actively addressing barriers related to the visibility and aesthetics of renewable energy projects (particularly solar energy systems) by introducing **solar zoning guidelines**.¹⁶⁶ For example, several historic Swiss cantons have adopted guidelines clarifying where and how solar PV projects can be installed.¹⁶⁷

The absence of such guidelines has been cited as a key reason why cities with far-reaching preservation laws, such as Rome and Florence (Italy), have seen comparatively little solar PV adoption.¹⁶⁸ In Doha (Qatar), a project to regenerate the downtown using solar PV and solar thermal systems required adjusting zoning and building bylaws.¹⁶⁹

City zoning rules can introduce additional costs for households and businesses, limiting the market for renewable technologies.¹⁷⁰ Simple measures such as defining thresholds for the size of eligible solar PV systems can help residents and businesses better understand whether zoning review is required before a building permit is issued. Santa Monica (California, US) made it easier to install solar PV systems by streamlining its review and permitting process, clarifying many of the issues that had caused delays in project approval.¹⁷¹ In 2018, Kfar Sava (Israel) launched the New Under the Sun project to overcome barriers that impede residents of multi-unit residential buildings from adopting solar power.¹⁷²

In many cities, the process for deploying new solar PV projects is hindered by planning and permitting issues as well as by challenges in acquiring customers.¹⁷³ One approach that has emerged to help boost customer acquisition (and reduce upfront costs) is **bulk buying programmes**, also known as "solarise" campaigns.¹⁷⁴ In addition to volume discounts, benefits for participants may include access to certified installers, guarantees that high-quality products will be installed, free site evaluations, and simplified permitting and inspection requirements, all of which can save municipal governments, residents and businesses time and resources.¹⁷⁵

Solarise campaigns are available in a number of US cities, including Athens, Atlanta and Middle Georgia (all in Georgia) and Roswell (New Mexico).¹⁷⁶ Bulk buying programmes also are available in Vancouver (Canada) and several Australian cities, including Darebin, Stonington and Strathbogie Shire.¹⁷⁷ Darebin initiated bulk buying as part of its effort to double the city's installed solar PV capacity between 2018 (18 MW) and 2022, and the programme helps residents save 10-15% on their solar system purchases.¹⁷⁸ Darebin also is exploring ways to get renters involved through innovative partnerships with local landlords.¹⁷⁹

HEATING AND COOLING

As awareness of the heating and cooling sector's contribution to final energy use grows, interest in using renewable technologies in the sector is rising on the policy agenda.¹⁸⁰ Globally, energy use for space cooling tripled between 1990 and 2016, and developing more sustainable forms of cooling is a growing priority, particularly in cities located in or near equatorial regions.^{ii,181} The cost-competitiveness of renewable heating and cooling technologies is being supported by economies of scale, restrictions on the use of high-carbon technologies and fuels, and carbon pricing policies that make fossil fuel-based heating and cooling more expensive.

Worldwide, a few dozen cities in China, Europe, Japan and North America have begun to rapidly transition to renewable heating and cooling sources.¹⁸² However, the vast potential of these technologies, and of key enabling technologies such as electric heat pumps (which can be powered by renewable electricity), remains largely untapped.¹⁸³

City governments are supporting the use of renewable energy in the heating and cooling sector in various ways, including by deploying renewables in municipal operations and public facilities and advancing key enabling infrastructure such as district energy networks. Although the renewable share in district heating and cooling remains low, these systems provide an entry point for renewables to reach many end-users and make it possible to meet urban heating and cooling needs more efficiently. City governments also are mandating the adoption of individual renewable heating and cooling systems on new and/or existing buildings, coupling this with financial incentives such as grants and rebates. In addition, cities have introduced bans and restrictions on fossil fuels and technologies, helping to accelerate renewable energy adoption in the sector.



i Bulk buying programmes can be run by city governments as well as by other groups and stakeholders. In some cases, city governments participate in the programmes themselves, while in others the programmes are set up mainly for the benefit of residents and businesses. Since such policies do not involve introducing mandates, or the use of fiscal or other incentives, here they are considered among the measures that can support the overall enabling environment.

ii In warmer climates, cities are on average 5-9 degrees Celsius hotter than rural areas, making cooling a growing policy priority. See endnote 181.

CITY PROCUREMENT

Although renewable heating and cooling options can have higher upfront costs than fossil fuel technologies, some cities have started to unlock long-term energy savings for themselves and for residents by investing in renewable technologies. Such efforts to increase the use of renewables in heating and cooling play an important role in raising awareness, particularly when they save governments and residents money. The city government in Alice Springs (Australia) saves thousands of dollars in annual energy costs after investing in solar thermal systems at public swimming pools and athletic facilities and at the local hospital.¹⁸⁴

In 2018, Zagreb (Croatia) completed a series of investments in solar thermal technologies at all hospitals and healthcare-related buildings owned by the city.¹⁸⁵ Lerum (Sweden) added solar thermal systems to act as a sound barrier along a stretch of railroad in the city, improving quality of life for residents while reducing local energy costs by injecting the solar energy into the city's district heating network.¹⁸⁶ In 2017, a prison near Varaždin (Croatia) became the first in the country to use renewable heat sources, replacing fossil fuels with biomass energy from local wood chips to meet around half of the prison's heating-related energy demand.¹⁸⁷

Many cities have made major commitments to invest in renewables for district heating (→ see *Markets chapter*). In Austria, biomass-based combined heat and power (CHP) plants are connected to district energy networks in Graz, Linz, Salzburg and Vienna.¹⁸⁸ Stockholm (Sweden) worked with a local company in 2016 to develop a CHP plant that runs on local forest biomass and that connects to the city's district energy system, raising the share of renewables in the network from 45% to 70%.¹⁸⁹ Similarly, Amsterdam (Netherlands) announced substantial new investments in 2019 to modernise the city's district energy system and boost its reliance on renewable energy sources.¹⁹⁰

In hotter climates, city governments are adjusting their planning and procurement strategies to encourage greater use of renewables for cooling.¹⁹¹ Virtually non-existent two decades ago, district cooling networks have spread to cities around the world.¹⁹² Dubai (UAE) invested in a district energy system that now meets around 20% of the city's total cooling demand.¹⁹³ Rajkot (India) announced in 2019 its first major district network to providing cooling to buildings, reducing peak electricity demand and providing energy savings and emissions reductions.¹⁹⁴ Medellín (Colombia) has invested in district cooling for public buildings since 2013.¹⁹⁵

District cooling systems are not limited to warmer countries. Toronto (Canada) has operated a district cooling system since 2004 using water from Lake Ontario, unlocking substantial cost savings.¹⁹⁶ Advanced district cooling systems also exist in Barcelona (Spain), Lisbon (Portugal) and Paris (France).¹⁹⁷

Mandates are an important policy to drive market demand and to reduce the costs of renewable heating and cooling systems.

MANDATES AND BUILDING CODES

City mandatesⁱ and obligations in the heating and cooling sector take various forms and can apply to existing buildings, strictly to new builds or exclusively to public buildings.¹⁹⁸ As in the renewable electricity sector, it is possible to distinguish between mandates, which are usually technology-specific, and building codes, which tend to be technology-neutral.

In some cases, mandates are imposed only for buildings that exceed a certain size or that have particularly high heating demand. Mandates sometimes require that urban businesses and residents purchase heating fuels blended with a certain share of biofuel, such as biodiesel. While mandates vary in scope, timing and coverage, they have become an important part of the renewable energy policy toolkit for city governments, helping to drive market demand and to reduce the costs of renewable heating and cooling systems.¹⁹⁹

In 2000, Barcelona (Spain) became the first city to approve an ordinance targeting solar thermal systems.²⁰⁰ The city requires all new and renovated buildings to supply a minimum of 60% of their running hot water needs through the use of solar energy, without stipulating the exact technology to be used.²⁰¹ As awareness of solar hot water ordinances has grown, similar approaches were taken in other cities in Spain, and the policy was adopted at the national level in 2006.²⁰²

In 2013, Chandigarh (India) introduced a mandate for the use of solar hot water in buildings including industries, hotels, hospitals, prisons, canteens, housing complexes, government buildings and new residential construction.²⁰³ Numerous cities in Brazil have adopted solar mandates, including São Paulo, where 40% of the energy for heating water in new residential, commercial and industrial buildings must come from solar water heaters.²⁰⁴ Elsewhere in South America, solar thermal ordinances have been introduced in Montevideo (Uruguay) and Rosario (Argentina).²⁰⁵ In the United States, San Francisco (California) and Tucson (Arizona) mandate the use of solar water heaters.²⁰⁶ Similar mandates or ordinances exist in Bangalore (India), Beirut (Lebanon), Loures (Portugal), Vellmar (Germany) and Vienna (Austria), among other cities.²⁰⁷

Some cities are exploring the use of **zero emission** or **net zero energy** building standards. In zero emission buildings, the entire energy supply comes from non-CO₂ emitting sources.²⁰⁸ Similarly, a net zero energy building generates as much (or more) energy on-site as it consumes.²⁰⁹ In 2016, Santa Monica (California, US) became the world's first city to adopt a net zero energy ordinance, which requires all new single-family homes to generate as much energy from renewable sources as they consume.²¹⁰ In the EU, the latest Energy Performance of Buildings Directive requires that all new public buildings in the region be "nearly" zero energy.²¹¹ Net zero emission standards also are being considered in Cape Town and Durban (South Africa).²¹²

Another regulatory measure that cities are implementing is "**solar-ready**" guidelines, which specify various design features that builders can integrate into their plans in anticipation of the

ⁱ Among city planners, mandates are also frequently referred to as "ordinances".

future integration of solar technologies.²¹³ Solar-ready guidelines can be developed for both solar thermal and solar PV projects (→ see *Electricity Sector Policies* section) and can help reduce the costs and administrative barriers of adopting solar technologies. Such guidelines have been adopted in municipalities across the United States, including Kansas City (Kansas) and Minneapolis (Minnesota).²¹⁴

In another form of mandate, some cities have obligated residents and businesses in certain districts to **connect to district energy** networks. Since 2012, Belgrade (Serbia) has required all public buildings and all new private buildings to connect to the local district heating system, a move that was key to unlocking investments, including those required to boost the share of renewable heat in the district network.²¹⁵

In Tartu (Estonia), the district energy system relies mainly on heat produced from local biomass energy (wood chips) combined with smaller shares of solar thermal energy as well as heat pumps and natural gas.²¹⁶ The city adopted a **purchase obligation** that prioritises renewable heat, and the district heating operator is allowed to use natural gas only when the heat from renewable sources (or from heat pumps) is insufficient.²¹⁷ Cities and regions across Germany also have adopted purchase obligations for renewable heat.²¹⁸

FISCAL AND FINANCIAL INCENTIVES

At the city level, fiscal and financial incentives – including grants, rebates, tax incentives and low-interest loans – are being used increasingly to spur the adoption of renewable heating and cooling technologies.²¹⁹

Itabashi (Japan) offers **grants** for the installation of solar thermal systems, covering up to 5% of the initial cost.²²⁰ To achieve its target for 100% renewables in all sectors, Boulder (Colorado, US) launched a residential **rebate** programme to support the installation of electric heat pumps in place of natural gas heating

systems.²²¹ Electric heat pumps in the city provide both space heating and cooling and will rely on growing shares of renewable electricity as the city transitions to 100% renewables.²²²

In cases where municipal governments may not be able to allocate substantial sums for renewable energy installation, partnerships with other levels of government can play an important role. Between 2005 and 2019, the EU's CONCERTO initiative, which aims to develop high-efficiency, renewably powered urban districts, provided grants to 58 cities and communities to support renewable energy projects.²²³

As in the power sector, city governments in the United States and Canada, as well as in Cape Town (South Africa) and parts of Australia and Europe, have introduced **PACE** programmes that enable residents and businesses to borrow from the municipal government to finance investments in renewable heating and cooling technologies. A PACE programme in Shelburne (Nova Scotia, Canada) enables homeowners to invest in solar thermal installations up to CAD 8,000 (USD 5,860) per home.²²⁴

Another popular approach is the use of **low-interest loans**, or concessional finance, to support renewable heating and cooling, as in Amsterdam and Delft (Netherlands) and Brussels (Belgium).²²⁵ In 2017, Grenoble (France) established a local heating fund to support small-scale renewable heat projects.²²⁶ Some cities also offer tax exemptions to encourage the uptake of renewables. Washington, D.C. (US) introduced a personal property tax exemption in 2012 for investments in various renewable energy systems, including solar thermal (and solar PV).²²⁷

Other cities have established **research and development funds** to support renewable technology innovation in the heating and cooling sector. In April 2019, Helsinki (Finland) offered EUR 1 million (USD 1.14 million) to a company or person that could find a way to replace coal-fired heating in the city, specifying that the solution should use the least biomass possible.²²⁸



ENABLING POLICIES

The enabling environment for heating and cooling includes elements such as streamlined permitting procedures, simplified technical inspections, and changes in laws and zoning regulations to support the development of renewable heat projects.

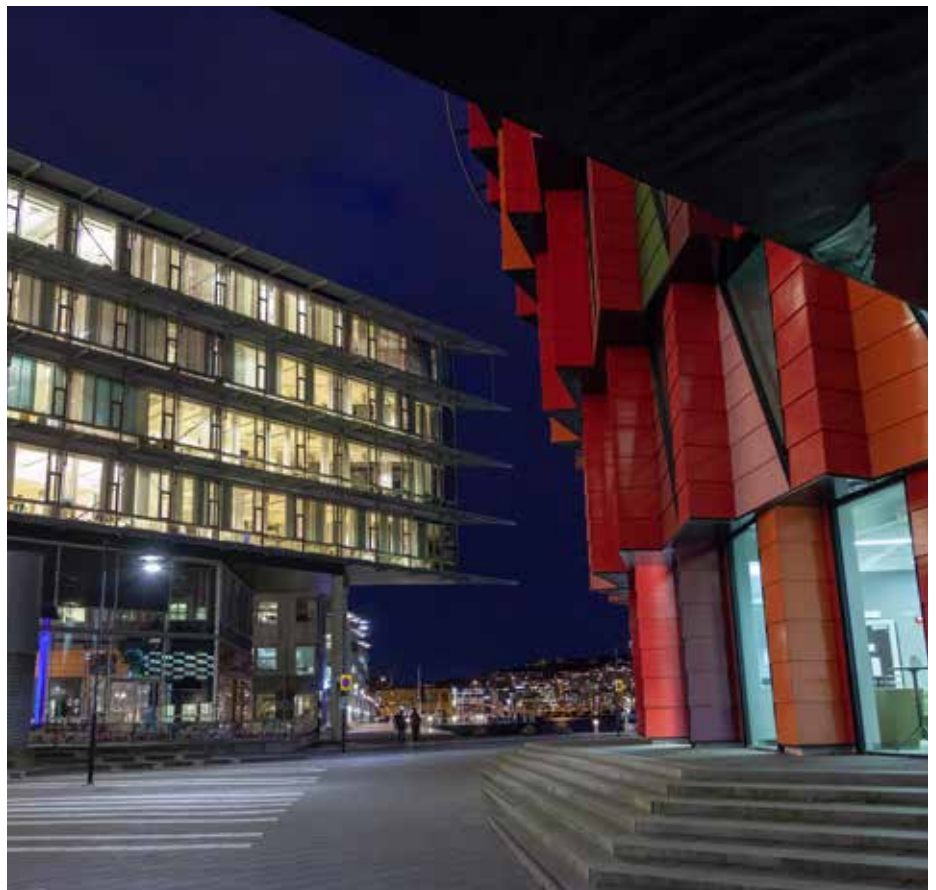
Supportive **planning, zoning and permitting** requirements can be particularly important for encouraging investment in district heating networks, which require detailed mapping and forward planning as well as citizen and business engagement and support.²²⁹ Such planning and zoning processes have been used in Gram (Denmark), Paris Saclay (France) and Tartu (Estonia).²³⁰

Cape Town (South Africa) is supporting the renewable heating and cooling market by setting up online portals that enable residents and business owners to obtain quotes for solar hot water systems from certified installers.²³¹ Creating such portals, along with registries of certified installers, can help maintain quality in the market and ensure that renewable heating solutions garner the trust of local citizens and businesses.

As in the power sector, some cities have established **bulk buying programmes** for renewable heating and cooling technologies to help reduce the upfront costs of such systems. In Australia, communities including Darebin, Healesville, Stonnington and Sutherland Shire have used bulk buying for solar water heating.²³² Bulk buying programmes can operate in conjunction with city procurement efforts or can be run as stand-alone programmes to encourage residents and businesses to invest in renewable heat technologies.

Several cities have issued **bans** on specific technologies and fuels to drive the adoption of renewable alternatives. In September 2019, Krakow became the first city in Poland to prohibit the burning of coal and fuelwood in boilers, stoves and fireplaces.²³³ Some Chinese cities, including Handan, Taiyuan and Xingtai, have banned coal for residential heating.²³⁴ The mayor of Helsinki (Finland) pledged in 2019 to ban the use of coal in the city's heating and electricity sectors entirely by 2029.²³⁵ In 2017, London (UK) launched a strategy to phase out the installation of fossil fuel heating in the 2020s.²³⁶

As of January 2020, Berkeley (California, US) is banning the connection of natural gas pipes to most new residential and commercial buildings.²³⁷ San Jose (California, US) has adopted a similar ordinance that would prohibit the use of natural gas in new single-family and low-rise multi-family buildings (but not high-rise buildings) starting in 2020.²³⁸ In Europe, the Climate Strategy of Gothenburg (Sweden) calls for the city to phase out fossil fuels in its district heating system by 2030 and to investigate climate-neutral alternatives, including renewable energy, waste heat and thermal storage.²³⁹



■ TRANSPORT

Historically, most of the focus on increasing the share of renewables in transport has been on promoting biofuels (mainly ethanol and biodiesel) and has occurred at the national and state/provincial levels. In some cases, cities have been involved in the production and use of biogas and biomethane in the transport sector, taking advantage of locally available resources. Increasingly, however, cities have become interested in electric mobility, primarily to reduce local noise and air pollution, but also to capitalise on the potential of e-mobility to power vehicles using renewable electricity. In general, cities have started to play a more central and pro-active role in issues around mobility (→ see *Markets chapter*).

Policies to encourage the uptake of renewables in the transport sector include mandates, grants and rebates, financial incentives, restrictions on certain fuels (such as diesel) or technologies (such as internal combustion engines) and the implementation

EVs offer potential for greater penetration of renewables and reduced emissions.

of low-emission zones. City governments in Europe and North America also have adopted policies to prioritise the procurement of renewables in the transport sector, such as the use of biodiesel, biogas and biomethane in municipal buses.²⁴⁰ However, given the growing trend in electrification of transport, many city-level policies in the sector are increasingly oriented towards technologies such as EVs and electric buses and the associated charging infrastructure.

The exact contribution that EVs can make to the uptake of renewables depends on the renewable share in a region's electricity mix and on whether policies are in place to simultaneously increase renewables in the power sector and/or require the use of renewable electricity for charging. By themselves, policies supporting EVs and hydrogen fuel cell vehicles are not renewable energy policies. Similarly, while "zero emission vehicles" typically refer to vehicles that produce no atmospheric pollutants during operation, they are not necessarily fuelled by renewable sources; in most cases, they refer to EVs but without specifying the electricity source. While EVs and hydrogen fuel cell vehicles do not necessarily increase the renewable share in transport, they offer significant potential for greater penetration of renewables and reduced emissions.²⁴¹

Because most renewable energy-related policies for transport at the city level focus on road transport, this section focuses mainly on that sector.



CITY PROCUREMENT AND DIRECT INVESTMENT

Many cities have used their purchasing and investment power to directly increase the use of renewables in transport. Cities are doing this in a variety of ways, including by adopting performance standards that influence municipal procurement decisions. Cities also can prioritise investments in vehicles that run on renewable fuels, in local production of biogas and biomethane from solid waste and wastewater, in local EV charging or hydrogen refuelling infrastructure, and in renewable electricity or hydrogen for city fleets.

Skåne (Sweden) has made significant progress towards its energy and climate goals by introducing strict environmental criteria in the procurement of public bus fleets; as of 2015, renewable fuels (mainly biogas and biodiesel) accounted for more than 53% of the fuel mix used in the city's 1,000-plus public buses.²⁴² Jämtland (Sweden) has a similar focus on cleaner buses, setting out detailed procurement rules requiring that new buses use between 30% and 50% renewable fuels, mainly biodiesel.²⁴³ Linköping (Sweden) began investing in local biogas production in the 1990s and has since run all city buses on biogas.²⁴⁴ In Tartu (Estonia), the local government has undertaken direct investments to enable the use of renewables in the transport sector, including purchasing buses that run on locally produced biogas.²⁴⁵

In Spain, the city of Barcelona (with co-funding from the EU) has invested in an energy-efficient wastewater treatment system to produce biomethane for transport, and Vilasana has invested in biogas production from pig slurry plants for use in vehicles.²⁴⁶ In 2017, Kolkata (India) invested in a pilot project for buses running on locally produced biogas from animal and human waste, with the low cost of the fuel being a main driver of the initiative.²⁴⁷ Vaasa (Finland) purchased 12 public buses to run on biogas from sewage sludge from its wastewater treatment facility and separately collected biowaste, highlighting the co-benefits of local job creation across the biogas value chain.²⁴⁸

San Francisco (California, US) committed in 2017 to purchasing renewable electricity from two local projects – including a 61.7 MW wind project and a 45 MW solar PV project – to power

its rapid transit system.²⁴⁹ Dubai (UAE), under its Smart Dubai 2021 strategy, is working to increase renewable power and EVs through diverse public investments, including in electric boats running on solar power.²⁵⁰

In many cities, government procurement decisions that focus on specific enabling technologies and infrastructure are not based strictly on scaling renewables, but rather on related goals such as reducing carbon emissions and air pollution. This includes, for example, decisions to increase investments in charging infrastructure for EVs and electric buses, often for fleet vehicles used in municipal operations. However, because transport-related energy consumption is often far smaller for municipal operations than it is citywide, city governments are starting to directly invest in infrastructure for wider constituencies, including residents, businesses, logistics companies and electric utilities.

Wellington (New Zealand), capitalising on the fact that around 82% of the city's electricity comes from renewable sources, has promoted EVs as a way to increase the use of renewables in the transport sector.²⁵¹ Wellington City Council has committed to switching its entire fleet to EVs as vehicles become due for replacement and is also investing in charging infrastructure, including in new homes and multi-unit buildings.²⁵² Dunedin (New Zealand) has developed an integrated transport strategy that includes a significant expansion of EV charging infrastructure.²⁵³

City governments also are promoting cleaner transport and driving the procurement of enabling technologies through **bulk buying programmes**. Through such initiatives, city governments, citizens and local businesses are able to pool their purchasing power to reduce the costs of buying EVs or renewable

power.²⁵⁴ Under a US bulk buying initiative launched in 2018, some 127 cities and 15 counties in 38 states have pooled their purchasing power to obtain more-competitive and lower-cost EVs.²⁵⁵ Efforts are under way to expand the initiative to public electric school buses.²⁵⁶

MANDATES AND OBLIGATIONS

A variety of **mandates and obligations** have been used to advance the use of renewables in transport, including biofuel blending mandates and mandates focused on the use of EVs. Mandates can be designed to apply to all actors or to specific segments of the transport sector, such as owners of fleet vehicles, transit operators and auto dealerships.

Biofuel blending mandates, which require that transport fuels are blended with a minimum percentage of biofuel, such as ethanol or biodiesel, remain the most common type of mandate in the transport sector. Most biofuel mandates are set at higher levels of government, and as of 2018 they were being used in 70 countries at the national and/or state/provincial level.²⁵⁷ In some cases, cities have supported the implementation of these higher-level mandates by adopting their own: for example, Kisumu (Kenya) has its own 10% ethanol blending requirement.²⁵⁸

Cities also can take advantage of local biogas production to meet mandates set at the national or state/provincial levels. As part of its efforts to comply with Germany's obligatory biofuel quota, the public waste collection company in Berlin collects local organic waste separately from other waste and then uses it to produce biogas, which fuels around half of the company's 330 collection



Wellington (New Zealand)

In Europe, 236 cities have low-emission zones.

trucks.²⁵⁹ This results in roughly 2.5 million litres of avoided diesel fuel consumption each year.²⁶⁰

Many cities that have adopted energy-related mandates in the transport sector have focused on EV charging infrastructure. Although these mandates do not directly stimulate the uptake of renewables in the sector, they target technologies that enable higher shares of renewable energy in the transport sector, through electrification and the continued increase of renewables in the local power mix.

Since May 2018, delivery companies operating in Shenzhen (China) have been required to purchase “new energy vehicles” (including electric, hydrogen and other zero emission vehicles) when procuring new lightduty trucks.²⁶¹ In a similar approach, an ordinance in Lola (Ecuador) states that new taxi permits will be issued for electric taxis only.²⁶² To ensure that the policy leads to quantifiable emissions reduction, the city has combined it with a measure requiring that for every new taxi that enters into service in the city, one conventional fossil fuel taxi permit must be withdrawn.²⁶³

In an example of how city actions are supported by actions at other levels of government, some states and provinces such as

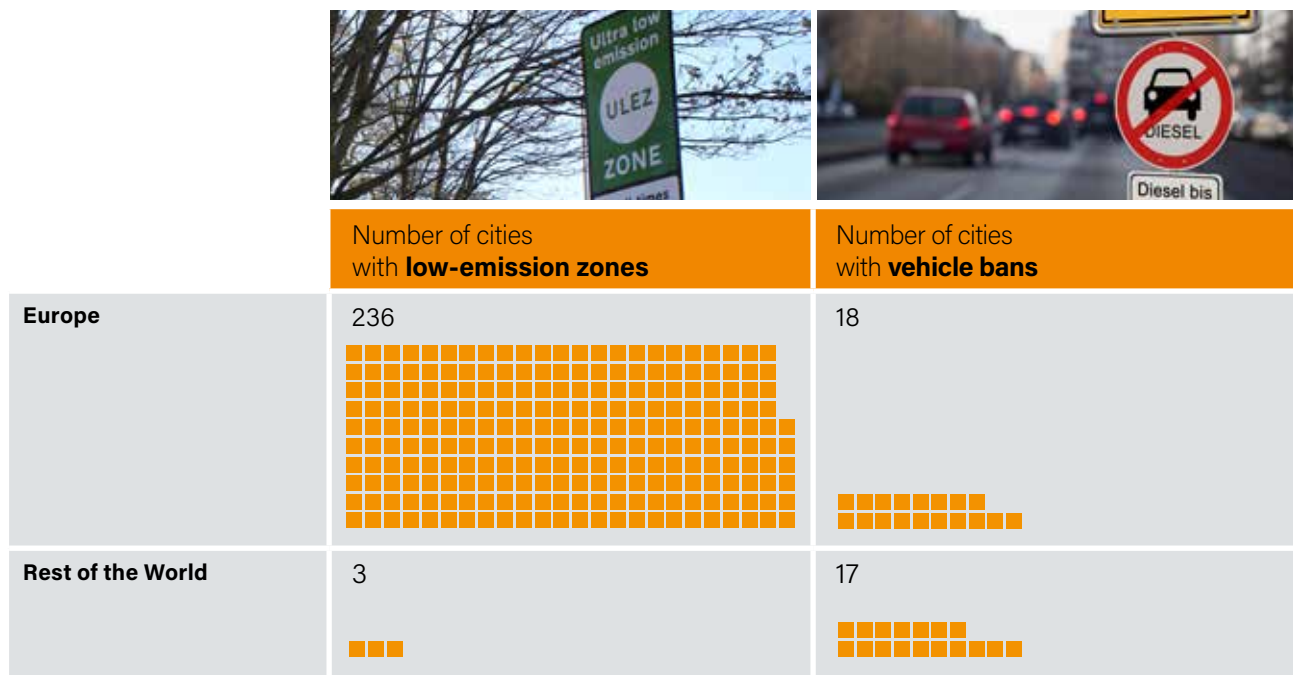
Colorado (US) and Quebec (Canada) have introduced mandates that require local auto manufacturers, retailers and dealerships – or owners and operators of fleet vehicles – to sell or procure a specified minimum share of EVs by a certain date.²⁶⁴ Some cities require that certain establishments (such as grocery stores or shopping centres) above a certain floor area (for example, 300 m²) offer EV charging facilities on premises.²⁶⁵ A few cities also now require that new buildings be “EV ready”, which entails installing the appropriate electrical infrastructure to enable EV charging stations to be added.²⁶⁶

In addition, cities have introduced **bans and restrictions** to encourage citizens and businesses to adopt cleaner transport modes, either through restrictions on obtaining new licence plates for conventional vehicles, or more commonly by restricting internal combustion engine vehiclesⁱⁱ, especially diesel ones (→ see Figure 14).²⁶⁷ In addition to incentivising increased EV uptake, these restrictions can stimulate interest in biogas and biomethane vehicles that result in fewer emissions, as well as interest in greater use of biofuels in hybrid vehicles.²⁶⁸ Such measures often are considered part of a transition towards complete electrification of transport, where bans on internal combustion engine vehicles are envisioned.²⁶⁹

i Such efforts include a requirement for appropriate electric cabling infrastructure to enable EV charging to occur on-site.

ii Unless special exemptions are introduced, bans on internal combustion engine vehicles will also affect the use of ethanol and biodiesel, both of which are considered renewable fuels.

FIGURE 11. Number of Cities with Low-Emission Zones and Vehicle Bans, Europe and Rest of World, As of Mid-2019



Note: Although most vehicle bans in cities are for diesel vehicles, many cities also ban petrol motors, and some specifically ban older vehicles. Most bans are not yet in effect but will enter into effect between 2020 and 2030.

Source: See endnote 267 for this chapter.

As of early 2019, at least 35 major cities (18 in Europe) had plans to ban or heavily restrict the use of diesel vehicles, and several cities had adopted restrictions on the circulation of petrol and/or diesel-powered vans.²⁷⁰ For most cities (and countries), the bans apply starting only in 2030 or 2040, although Madrid (Spain) has already banned most non-zero-emission vehicles from its city centre, and Rome (Italy) intends to ban all diesel cars from its roads by 2024.²⁷¹

In China, many cities have banned the use of internal combustion engine motorcycles and mopeds, and as of July 2019 several local governments in the country no longer allow sales of light-duty vehicles that do not comply with the country's strict new vehicle emission standards.²⁷² Starting in January 2020, all new buses and other heavy-duty diesel vehicles in some Chinese cities will be required to meet the new rules, and the emissions standards take effect nationwide in July 2020.²⁷³ Hainan announced in March 2019 that it would be the first city in China to fully phase out the sale of internal combustion engine vehicles in the city, a goal it aims to achieve by 2030.²⁷⁴

FISCAL AND FINANCIAL INCENTIVES

Cities have used fiscal and financial incentives to encourage greater adoption of cleaner transport options. Such measures include tax exemptions or reductions, the waiving of certain fees and charges, feed-in tariffs for biomethane injection into local natural gas grids, smart charging tariffs, and free parking or free access to special traffic lanes normally reserved for high-occupancy vehicles such as buses. Although these incentives occasionally require co-operation from other levels of government (particularly the national government), their use is spreading at the city level.

In some cases, city policy can complement national policy. For example, in addition to local government investment in biogas for transport, Sweden's national government has provided **tax exemptions or reductions**, such as waiving the CO₂ tax on biogas until 2020 and providing a fixed bonus for manure-based biogas production.²⁷⁵

In an example of the interdependency between city- and national-level policy making, the French national government provides **feed-in tariffs** for biomethane injection into the natural gas grid (covering production costs) and has a target for 10% renewable gas in the country's gas network by 2030, which is complemented by local investment in biomethane production and infrastructure.²⁷⁶ Consequently, biomethane fuelling stations are now available in at least 58 French cities.²⁷⁷ In October 2019, as part of its campaign to tackle air pollution, Paris granted the winning bid in a tender for 409 new city buses to a company that will supply buses fuelled by biomethane from recycled organic waste.²⁷⁸

To encourage the uptake of EVs, a common incentive is **free vehicle charging**, whereby users do not have to pay to charge their EVs. In cities with large EV shares and with a municipally owned utility, an alternative approach is to offer **"smart charging tariffs"**, or special electricity rate categories designed to minimise the synchronicity, or simultaneity, of EV charging.²⁷⁹ Such tariff structures encourage users (or charging station operators) to charge their vehicles when electricity prices are lower or when

wind and solar PV supply is abundant. Some cities offer lower-cost or free charging during the daytime (to correspond with solar PV output) or overnight (to correspond with higher average wind power output), combined with peak pricing during times of higher electricity demand.²⁸⁰ Some municipal utilities and others are exploring "deadlinebased" EV charging plans that enable customers to choose among different charging durations (between 2 and 12 hours), providing utilities with greater flexibility over when loads occur (→ see *Sidebar 7 in Markets chapter*).²⁸¹

Many cities in Sweden provide **free parking** for vehicles that use biomethane, as well as toll exemptions for biogas vehicles and **free access to special traffic lanes** for biogas taxis.²⁸² Stockholm offers preferential access at its airport for "low-emission taxis" including biogas/natural gas, electric and hydrogen fuel cell vehicles.²⁸³ Other jurisdictions worldwide provide free parking for EVs in urban areas, and several cities in China offer exemptions for "new energy vehicles" from road tolls, public ferries and other fees.²⁸⁴ To reduce congestion in the city centre, Shanghai (China) provides free parking for EV car sharing operators and subsidies for both the charging infrastructure and related electricity costs.²⁸⁵ Canberra (Australia) is among many cities offering free access to "fast track" traffic lanes (high-occupancy lanes, bus lanes, etc.) for EVs and other zero emission vehicles.²⁸⁶

Oslo (Norway) **reduced vehicle import taxes** for EVs to lower the cost gap between internal combustion engine vehicles and EVs.²⁸⁷ Buenos Aires (Argentina) reduced taxes for the first 6,000 light-duty EVs and 350 electric buses sold, based on a quota in order to encourage rapid uptake while simultaneously controlling the total costs of the policy.²⁸⁸ Ras Al Khaimah (UAE) has agreed to exempt EVs from registration, renewal and ownership transfer charges through December 2021.²⁸⁹

At the national level, some governments provide financial incentives such as **rebates and investment grants** to stimulate the production of biogas for vehicles, as in Scandinavia.²⁹⁰ At the local level, however, such incentives are becoming more prevalent for EVs. A small but growing number of city governments is offering grants and rebates for purchases of EVs, plug-in hybrids and/or zero emission vehicles, and for investments in related infrastructure such as charging facilities.

Although the costs of EVs and charging stations continue to decline, grants, rebates and other direct incentives have played an important role in EV adoption. In the United States, 9 of the 11 major metropolitan areas with the highest annual purchases of EVs offered rebates in 2018, ranging from USD 2,000 to USD 5,000.²⁹¹ US cities also are providing financial incentives to increase the number of charging stations available to residents: for example, both Fresno and Sacramento (California) provide rebates for investments in EV charging stations.²⁹²

ENABLING POLICIES: URBAN PLANNING AND ZONING

City governments can accelerate the energy transition in the transport sector through their urban planning and zoning authority. The many different policy measures in this context include designating low-emission zones with differentiated pricing policies, and levying congestion charges that offer exemptions or reduced fees for certain vehicle types. Cities also can revise **zoning and other bylaws** to encourage the development of enabling infrastructure such as biogas and biomethane fuelling stations and EV charging stations. In 2017, the City Council of Richmond (California, US) adopted an amendment to its zoning bylaws that requires all new residential parking spaces to include an outlet capable of charging an EV.²⁹³

Related ways that cities can directly support infrastructure include making **public land** available either for free or at a discounted rate specifically for renewable fuel stations and EV charging companies (as is being done in Stockholm, Sweden), and investing in the construction of depots or re-purposing old warehouses where hundreds if not thousands of EVs can be charged at once.²⁹⁴

Cities also are enabling the use of biomethane in the transport sector – whether for direct use in vehicles or for injection in the natural gas grid – by supporting infrastructure such as fuelling stations and the location of production plants near solid waste and wastewater facilities. Biomethane is available in at least 900 fuelling stations in cities across Germany, and in Sweden at least 212 cities collect food waste for biogas production for transport.²⁹⁵ Many cities in Europe are interested in tapping into the large potential to use urban organic waste for biogas production, injecting biomethane into the gas grid and using it in local transport. Under the EU UrbanBiogas programme, Abrantes (Portugal), Graz (Austria), Rzeszów (Poland), Valmiera (Latvia) and Zagreb (Croatia) all have participated in training for biogas project planning and implementation.²⁹⁶

Interest in EVs among cities has increased greatly in recent years. However, because EVs and charging infrastructure are only as

“renewable” as the electricity used to supply them, some city governments are taking further steps to support direct linkages between vehicle charging and renewable power. In a pilot project in Austria’s Vorarlberg Valley Region, the local government allocated 20 m² of solar PV capacity (roughly 4 kW) for each EV used, to ensure that the vehicles’ electricity consumption was coupled with increased renewable energy generation.²⁹⁷ A growing number of Austrian cities are directly linking their transitions to EVs with 100% renewable electricity, ensuring that charging stations are fully powered by additional renewable capacity.²⁹⁸

To encourage greater interest in EVs, Berlin and Stuttgart (Germany) and Paris (France) have created lowemission zones that restrict the use of more-polluting vehicles, imposing fines for non-compliance while in many cases offering incentives for cleaner biogas, biomethane, electric and hydrogen fuel cell vehicles.²⁹⁹ In a related approach, cities are using congestion charges in designated areas or during certain times that impose different fees for vehicles with different emission profiles.³⁰⁰ London (UK), Singapore and Stockholm (Sweden) all have congestion charges in place, and New York (New York, US) plans to enforce one in 2021.³⁰¹ The schemes often include exemptions for residents living inside the target area and for bicycles, motorbikes, and electric and zero emission vehicles, including biogas/biomethane vehicles.

Since its adoption in 2003, the congestion charge in London (UK) has reduced the number of cars driving in the city centre by roughly 30%.³⁰² In early 2019, London revamped its congestion charge into an “ultra-low emissions zone” (ULEZ), removing the exemption for private-hire vehicles (such as taxis), increasing the fees for most vehicle types, raising the thresholds and expanding the zone 18-fold.³⁰³ In response, some London firms have retrofitted their vehicles to run on biogas to avoid the additional ULEZ charge; meanwhile, EV sales in the city have surged, and sales of diesel vehicles have plummeted.³⁰⁴





City of Malmö
 Helsingborg Municipality
 Kristianstad Municipality
 Lund Municipality
 Piteå Municipality
 Södertälje Municipality
 Sollentuna Municipality
 Täby Municipality

4

URBAN

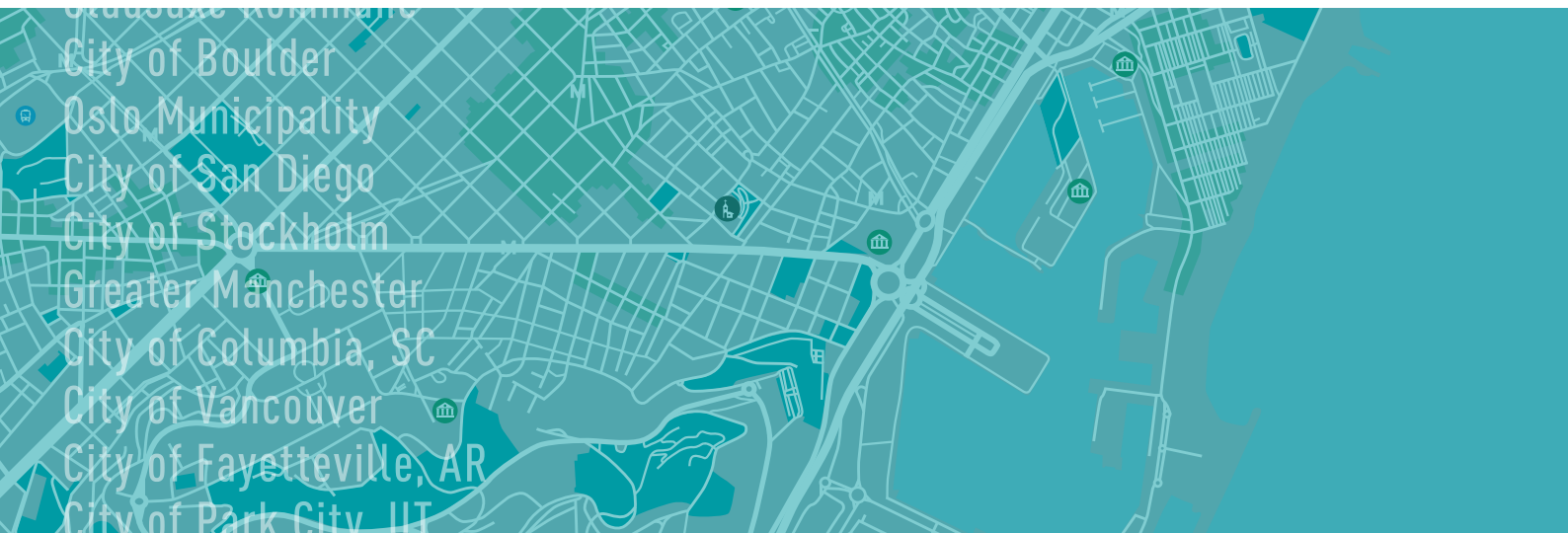
RENEWABLE

ENERGY

MARKETS



Upplands Väsby Municipality
 Uppsala Municipality
 City of Calgary
 City of Austin, TX
 City of Cincinnati, OH
 City of Evanston, IL
 City of Glendale, CA
 City of Hillsdale, OR
 City of Minneapolis
 City of Seattle
 City of Santa Barbara, CA
 Basel, Switzerland
 City of Irvine, CA
 Salt Lake City
 City of Santa Monica
 City of Copenhagen
 Gladsaxe Kommune
 City of Boulder
 Oslo Municipality
 City of San Diego
 City of Stockholm
 Greater Manchester
 City of Columbia, SC
 City of Vancouver
 City of Fayetteville, AR
 City of Park City, UT



URBAN RENEWABLE ENERGY MARKETS

In cities around the world, there is growing recognition of the diverse economic, environmental, social and other benefits that renewable energy can deliver, as well as of the tremendous opportunities for increasing the local production and consumption of renewables (→ see *Drivers chapter*). This awareness is accelerating renewable energy-related activity in urban energy markets, supported by policies at various levels of government, by increasingly attractive economics and by new business models.¹

City governments as well as businesses, residents and other urban actors rely on a variety of mechanisms to source renewable energy.² In many cases, they contract for renewable electricity from third-party providers through power purchase agreements (PPAs), or they invest directly in solar, wind and other technologies, deploying them on buildings or urban land to produce heat for buildings and industry, fuels for transport, and electricity for a range of uses.³

As at the national and state/provincial levels, most of the tracking of renewable energy developments in cities has occurred in the power sector; however, urban renewables are gaining momentum in the heat (in buildings and industry) and transport sectors as well.⁴ City actors are tapping a wide range of technologies depending on the local circumstances and resource potential as well as on the policy environment, which is influenced by local, state/provincial and/or national policies.⁵

In addition, many municipal governments and urban players are advancing enabling technologies and infrastructure – such as district heating networks, heat pumps, electric vehicles and energy storage systems – that can ease the integration of rising shares of renewables in the energy system. These technologies can increase system flexibility, in part by enabling sector coupling, or the interconnection of sectors such as electricity, heat and transport that have been largely isolated from one another.⁶

Municipal governments also are linking energy supply with other municipal activities to find cost-effective solutions to multiple challenges. For example, by developing waste-to-energy, cities can generate renewable energy from urban waste and wastewater streams – including the organic portion of municipal solid waste, restaurant waste, wastewater sludge, and waste from surrounding agri-businesses – while improving waste management and minimising landfilling. (→ see *Sidebar 4*).⁷

In general, data on renewable capacity and generation are tracked at the national level (and often the state/provincial level) but not at the local level.⁸ As a result, although many municipal governments, residents, businesses and other actors source renewables to meet their energy needs, comprehensive statistics on urban energy markets are lacking.⁹ This chapter focuses on renewable energy technologies – as well as enabling technologies and infrastructure – that are particularly relevant for cities or that require some degree of population density to be feasible and viable. Given the tracking constraints, however, global and even regional or national data on the use of these technologies in urban settings are limited.

POWER

City governments and other urban actors are shifting to renewable power for applications such as street and indoor lighting, appliances, cooking, cooling and heating (via heat pumps and combined heat and power (CHP) or cogeneration plants). In many cases, they are contracting their renewable electricity supply via PPAs, relying on centralised generation from solar PV plants, wind farms and other renewable generation facilities that are located elsewhere (usually outside city boundaries).¹⁰

While global data on renewable power use are more widely available, they typically are not broken down by urban/non-urban usageⁱ. However, several municipal governments track renewable electricity use within their areas of jurisdiction. Of the more than 570 cities that self-reported their energy consumption to CDPⁱⁱ in 2018, 340 cities cited some share of renewables in the urban electricity mix during 2017 (→ see *Figure 14*).¹¹ At least 100 of these cities – including Auckland (New Zealand), Dar es Salaam (Tanzania), Nairobi (Kenya) and Seattle (US) – sourced 70% or more of their electricity from renewable sources; this was more than double the number of cities (42) in 2015.¹²

More than 40 self-reporting cities were powered entirely by renewables in 2017.¹³ Three-quarters of these, or 30 cities, were in Latin American countries that had high renewable energy shares in national generation, facilitated by large hydropower resources.¹⁴ Other cities that achieved 100% renewable electricity in 2017 included Burlington (Vermont), Georgetown (Texas) and Rock Port (Missouri) in the United States, Reykjavik (Iceland)

and Shenzhen (China).¹⁵ In addition, many cities boasted renewable power shares that were well above the national or regional average, demonstrating their leadership in advancing renewables.¹⁶

Renewable energy also has provided consumers the opportunity to become decentralised electricity producers, primarily through the use of on-site solar PV systems. By supporting distributed renewable technologies for power generation, cities can reduce losses during transmission and distribution and minimise the need to build extensive energy infrastructure.

Although rooftop and building-integrated solar PV and wind power are the main renewable technologies used in cities, other options include concentrated solar PV, geothermal, hydropower, ocean power and bioenergy, depending on the resource availability and potentials.¹⁷ By developing waste-to-energy, cities can use local waste streams to produce renewable electricity as well as renewable heat for district heating in combined heat and power (CHP) plants. Cities can use biomass, biogas and landfill gas to produce bio-power and bio-heat, or use the heat from waste incineration to produce electricityⁱ.

In 2018, cumulative
distributed solar
PV installations
totalled 213 GW.

ⁱ In 2018, global renewable power capacity reached some 2,378 GW, from REN21 GSR 2019.

ⁱⁱ CDP, previously known as the Climate Disclosure Project, is a global environmental disclosure and reporting platform that allows cities, regions and companies to measure and manage their risks and opportunities related to climate change, water security and deforestation. In some cases, it is not clear whether reporting refers to renewable power consumption in municipal operations or city-wide. In addition, high renewable power shares are not necessarily a city's effort, as this is also dependent on state/provincial and national power mixes. In early 2019, ICLEI-Local Governments for Sustainability began collaborating with CDP to streamline the process of city reporting related to climate change, including reporting on renewables. See CDP, "What we do", <https://www.cdp.net/en/info/about-us/what-we-do>, and CDP, "Guidance for cities", <https://www.cdp.net/en/guidance/guidance-for-cities>, both viewed 6 May 2019.

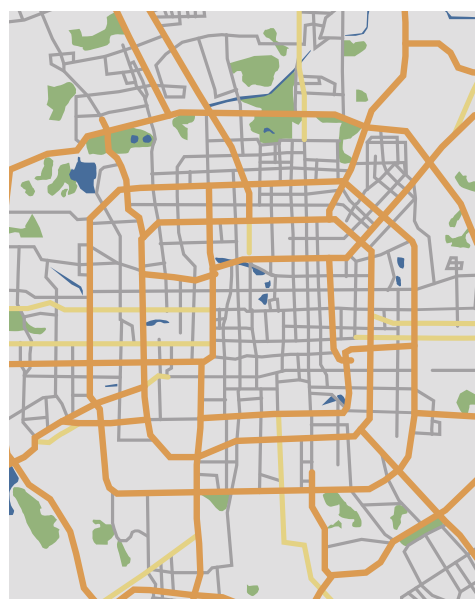
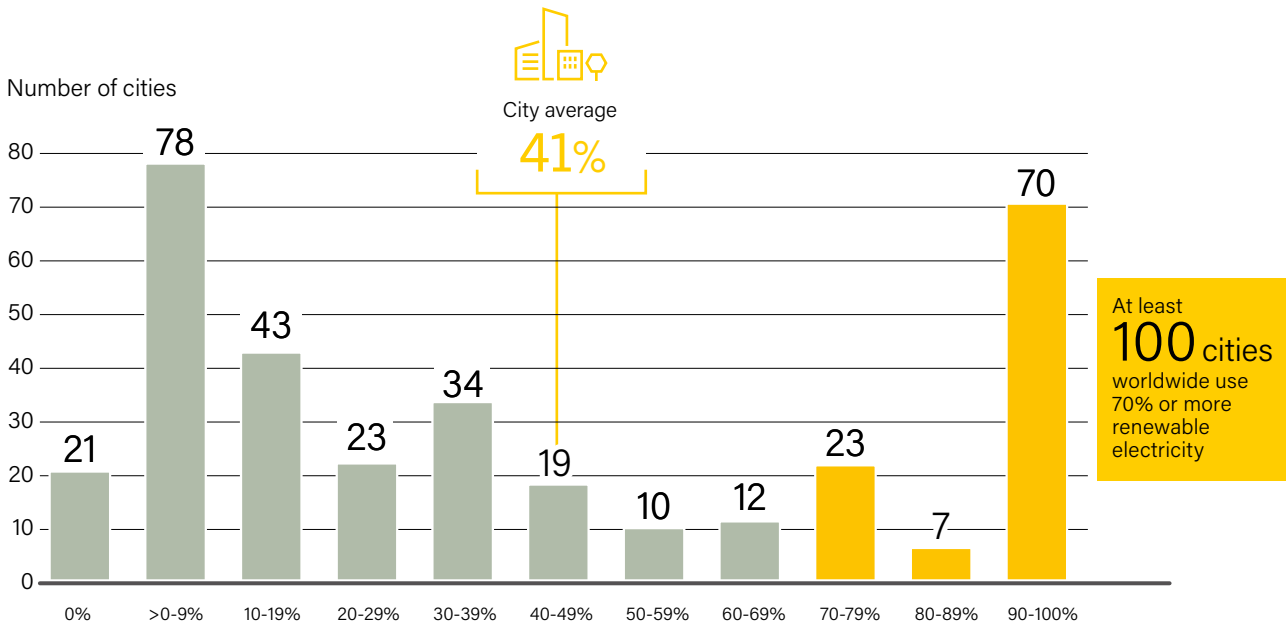


FIGURE 12. Renewable Power in Cities, by Number of Cities and Renewable Share, 2017



Note: The figure shows shares of renewables in the electricity consumption of 340 cities that self-reported to CDP.

City average is calculated based on the 340 cities shown.

Source: See endnote 11 for this chapter.

SOLAR PV MARKETS

Much of the renewable energy activity in cities has focused on distributed solar PVⁱ, in particular building-integrated solar PV, which can be installed on façades and rooftops, atop parking areas, on repurposed waste sites and in other urban spaces. Although distributed PV systems are reported on less frequently than utility-scale solar PV (which has made headlines for record-low bid prices and record-high project capacities), distributed installations continue to account for a large share of the global market.¹⁸ In 2018, cumulative distributed solar PV installations totalled 213 GWⁱⁱⁱ.¹⁹ Distributed solar PV additions of 41 GW that year accounted for 40% of total PV additions and for a quarter of renewable capacity growth.²⁰

Thanks to rapidly falling technology costs^{iv}, distributed solar PV generation now costs less per kilowatt-hour than the retail price of electricity from the grid in a growing number of countries, including in Australia and South Africa and across much of Europe and the United States.²¹ This enables municipal governments, residents, businesses and other urban actors to generate electricity on-site from local resources, often at lower cost.²² Distributed solar also has the potential to provide back-up for an unreliable grid supply and to facilitate electricity access among previously unelectrified populations both within and near cities.²³

Although global data on solar PV capacity (particularly utility-scale) are well tracked, obtaining comprehensive statistics on distributed solar PV generation is more difficult – even in cities

that have a municipal utility – because not all installations are disclosed to local or national utilities.²⁴ In the EU, for example, an estimated 200,000 “guerrilla” or “balcony” solar installations exist, with 40,000 in Germany alone.²⁵ While many cities require residents to report installations, enforcement remains challenging.²⁶

Municipal governments have shown leadership by installing rooftop solar PV systems (and sometimes also micro-grids) on public buildings such as schools, administrative buildings, and community and sports centres. In addition to reducing municipal costs, leading by example has played an important role in encouraging local residents and businesses to install their own PV systems.²⁷

In the United States, the largest grid-connected solar PV capacity is in Los Angeles (California), where citizens, businesses and public authorities had installed more than 440 MW as of 2019, supplying 11% of the city’s electricity mix.²⁸ High solar PV shares also exist in San Diego (351 MW in 2018) and San Jose (201 MW) in California, as well as in Phoenix (Arizona; 236 MW) and Honolulu (Hawaii; 227 MW).²⁹ Among smaller US cities, Tallahassee (Florida) had installed 30 MW of solar PV as of 2018 and Santa Fe (New Mexico) had installed 19 MW.³⁰

Belo Horizonte (Brazil) has deployed several hundred solar PV systems, including on the city’s football stadium (Mineirão) and on the main state government building.³¹ In Eilat (Israel), which aims to meet 100% of its power needs with solar by 2025, the grid

i Only the organic part of waste is considered renewable.

ii Including rooftop, commercial, industrial and micro-grid solar PV.

iii Led by commercial/industrial applications.

iv Global module prices declined an estimated 29% during 2018, following several years of reductions, due to competition, continued improvements in efficiency and manufacturing improvements that have reduced process costs and raw material needs. See GSR 2019.

has a limited capacity to capture all of the electricity generated by existing solar PV systems, so the city is developing pumped storage hydropower to store surplus solar power for use at night, reducing grid reliance and improving local energy security.³² In 2017, Mandurah (Australia) invested AUD 175,000 (USD 123,000) in a 200 kW solar PV system for its local recreation centre, which will meet around 20% of the facility's power demand and save the city an estimated AUD 75,000 (USD 50,600) in annual energy costs (a payback of under 2.5 years).³³

In addition, municipal governments have installed solar PV demonstration projects in visible areas, such as at city halls or in parks, to increase local awareness of solar energy. Many successful examples exist around the world. For example, Vulcan (in western Canada) has integrated solar PV into public art installations to raise interest in the technology.³⁴ In Dezhou (China), conventional street lights were replaced with solar lighting in highly visible areas, including traffic junctions and main roads.³⁵

Private solar PV installations also have increased in cities, facilitated by favourable building codes and other policies and by various financial or tax incentives at the municipal, state/provincial and national levels (→ see *Targets and Policies chapter*). This includes private installations at homes and businesses as well as broader community solar and wind energy initiatives (→ see *Citizen Participation chapter*).

Many large corporations, often with activities in or near cities, have scaled up their use of renewable electricity from solar PV, wind power and other sources, often facilitated by favourable policies and accelerated by falling costs¹ and the need for a disaster-resilient power supply (→ see *Box 2*).³⁶ Some companies use their large rooftop areas to source solar PV directly on-site. By mid-2019, the Swedish retailer IKEA had installed more than

900,000 solar panels on the roofs of its stores, distribution centres and other buildings worldwide; the company also invests in ground-mounted solar projects to advance its goal of becoming carbon negative by 2030.³⁷

The US tech company Apple announced in early 2018 that its global facilities across 43 countries were all operating on 100% renewable power.³⁸ The electricity is produced in part by 25 large solar PV plants totalling 626 MW; by rooftop solar systems at Apple's headquarters in Cupertino, California (17 MW); and by projects in Japan (where more than 300 systems are expected to generate some 18 GWh annually) and Singapore (with systems on 800 roofs).³⁹ The US retailer Target had installed 229 MW of rooftop solar PV on more than 470 stores by the end of 2018.⁴⁰

In Australia, retail asset manager Vicinity Centres announced plans in 2018 to install 11.2 MW of solar PV on five shopping centres and car parks across the country.⁴¹ In South Africa, a solar PV array of 10,900 panels was installed in 2017 atop a mall in Johannesburg, producing 1.2 megawatt-hours (MWh) and saving an estimated 2 GWh of electricity annually.⁴² The beverage multinational Coca-Cola installed an off-grid solar PV system on its manufacturing plant in Windhoek, Namibia, in 2019, and the company operates 11 off-grid solar PV plants in the country, totalling 10.5 MW.⁴³

Rooftop solar PV also has been installed at many places of worship. In 2009, the Vatican invested USD 660 million in a 100 MW installation that made Vatican City the world's first fully solar-powered nation state.⁴⁴ In 2018, the 42 parishes of the Diocese of Maasin in Southern Leyte (the Philippines) became the first ecclesiastical territory in which all churches use solar energy.⁴⁵ In Amman (Jordan), policies to "green" mosques have resulted in numerous solar PV projects, supporting Amman's goal of becoming a carbon-neutral city by 2050.⁴⁶ As of 2019, around

¹ Solar PV module prices fell more than 90% between 2010 and 2018. See International Renewable Energy Agency, *Renewable Power Generation Costs in 2018* (Abu Dhabi: 2018), <https://www.irena.org/publications/2019/May/Renewable-power-generation-costs-in-2018>.

BOX 2. Corporate Sourcing of Renewables

Companies in or near cities have played an important role in scaling up the use of renewables, for example by investing directly in on-site renewable energy systems for self-consumption or by purchasing electricity through corporate PPAs or utility green procurement programmes. Since the mid-2000s, an increasing number of companies across different industries and economic sectors have committed to ambitious renewable energy targets and begun to source renewables to run their operations. As of 2019, more than 200 companies operating in over 140 countries had joined the RE100 initiative, committing to sourcing 100% renewable electricity as soon as possible (by 2050 at the latest). Together, these companies were creating a demand for some 188 TWh of renewable power annually in 2018, investing more than USD 90 billion in renewable power deployment to 2030.

Corporate commitments to renewables are driven by a range of factors, including favourable government policies, the increasing cost-competitiveness of renewable energy and internal environmental objectives established to meet the rising demand for social responsibility among consumers or investors. In Chicago (Illinois, US), the municipal government's Renewable Energy Challenge provides technical assistance and public recognition to businesses that establish and implement company-specific targets for 100% renewable electricity by 2035.

Although the US and European markets account for most corporate sourcing of renewables, the practice is spreading to other countries including Burkina Faso, Chile, China, Egypt, Ghana, India, Japan, Mexico, Namibia and Thailand.

Source: See endnote 36 for this chapter.

SIDEBAR 4: Urban Waste-to-Energy

Cities typically are responsible for managing the large volumes of waste produced by residents and from the diverse commercial and industrial activities within their boundaries. As cities grow, so too do the quantities of waste generated and the associated social, economic, environmental and health impacts.

Municipal solid waste (MSW) and urban wastewater, including sewage and industrial effluents, must be well managed – collected, sorted and treated – to avoid serious environmental impacts. If landfilled, the organic portion of MSW releases large amounts of methane, which, if not captured and flared or used, can contribute significantly to climate change. Uncontrolled landfilling also can produce large quantities of leachate, which like other urban wastewater can pollute waterways and groundwater if not managed carefully. The emissions from waste incineration can be highly toxic if plants are not equipped with extensive flue gas purification systems.

Worldwide, cities generated around 2 billion tonnes of solid waste in 2016, up more than 50% from the estimated 1.3 billion tonnes generated in 2012. The World Bank projects that this figure could reach 3.4 billion tonnes by 2050 if measures are not taken to stem the growth. In 2017, more than 80% of urban wastewater was being discharged directly into the world's waterways. Lagos (Nigeria) alone generated daily some 1.5 million cubic metres of wastewater, most of which flowed untreated into the city's lagoon.

Sustainable waste management and the transition to a “circular economy” marked by efficient management of resources can address the growing waste challenge by reducing, reusing and recycling the waste and recovering its significant energy content. A wide range of established technologies enable cities to minimise the negative impacts of urban waste (including associated greenhouse gas emissions) while producing local, renewable fuels that can be used for heat, electricity and transport.

The energy content of wastes varies greatly by city, depending on the cultural and socio-economic conditions. MSW typically has around one-third the energy content of coalⁱ. Sophisticated sustainable waste management processes can be costly, however, and the energy produced from waste can be expensive compared to that from fossil fuels and some other renewable sources. Thus, some cities support waste-to-energy deployment by issuing credits for each tonne of waste treated, or by adopting regulations that ban, tax or otherwise constrain less environmentally acceptable solutions.

Many technologies are available to convert waste into fuels for the generation of heat and/or electricity, as well as for use in transport. These include the capture of landfill gas (a mixture of methane and CO₂), anaerobic digestion of solid and liquid wastes (to produce biogas) and the direct combustion of solid wastes (to generate electricity and/or heat for district heating systems, for example). Landfill gas and biogas can either be burned directly to produce heat and/or electricity or upgraded to biomethane, a renewable natural gas that can be pressurised and injected into gas pipelines or used as a transport fuel.

The recovery of landfill gas is widely deployed in cities around the world. In 2017, Sabará (Brazil) completed a gas recovery plant at its local landfill with the capacity to produce 5.7 MW of electricity. To the north-east, the city of Jabotão dos Guararapes was completing a 12.8 MW landfill gas system, large enough to meet the electricity needs of an estimated 52,000 people.

Anaerobic digestion, a biological approach to treating sewage and other liquid effluents (as well as agricultural and industrial wastes), results in the production of biogas, which can be used to heat and/or power the wastewater treatment plant or exported for other uses. In 2017, Europe was home to some 17,783 anaerobic digestion facilities, around 16% of which were sewage and wastewater treatment plants.

The biogas produced by digestion also can be upgraded to pipeline-quality gas in the form of biomethane. In 2018, more than 500 biomethane installations were operating in Europe, many of them in cities. In Sweden, more than 60% of municipalities collect food waste for energy purposes, producing an estimated 5.2 petajoules (PJ) of biomethane annually that can be injected into the local gas grid or used as a transport fuel.

In Asia, India's Sustainable Alternative Towards Affordable Transport initiative is expected to support the opening of 5,000 biomethane plants by 2023; the plants would use agricultural waste, MSW and cattle manure as feedstock to produce up to 15 million tonnes of biomethane annually, displacing up to half of the country's natural gas imports. Karachi (Pakistan) aims to fuel 200 buses with biomethane produced from 3,200 tonnes of cow manure.

Solid wastes can be burned directly in large-scale combustors designed to cope with the very heterogeneous fuel supply. The heat from combustion can be used to generate electricity, and the co-produced heat is often fed to municipal district heating systems. Nearly 500 such plants were operating in cities across Europe as of mid-2019.

China also has greatly expanded its energy production from MSW and uses more than 100 million tonnes of solid waste annually for this purpose. In the Middle East, Dubai (UAE) is building an AED 2.5 billion (USD 681 million) waste-to-energy plant that will convert an estimated 1.8 million tonnes of waste annually into refined fuel to feed a 185 MW power plant, which is scheduled to begin operations in 2020.

In addition to generating heat and power, refuse-derived fuel can be used as a feedstock to produce other fuels and chemicals through gasification or pyrolysis or via biological treatment. In Edmonton (Canada), the company Enerkem uses a gasification process to transform sorted MSW to methanol and ethanol. Similar plants are being built in Rotterdam (Netherlands) and elsewhere.

ⁱ Because MSW is usually a mixture of organic material as well as plastics and other products derived from fossil fuels, not all energy produced from this waste can be classified as renewable; it is standard practice to classify 50% of the energy derived from MSW combustion as renewable energy. In contrast, the energy produced by anaerobic digestion is considered to be 100% renewable because it is derived from the organic parts of the waste.

Source: See endnote 7 for this chapter.

500 mosques country-wide were powered with rooftop solar, and systems were planned on a further 35 mosques.⁴⁷ Rooftop solar PV also has been mounted on some of the most well-known mosques in Marrakech (Morocco) as well as on US synagogues in Boston (Massachusetts), Boulder (Colorado), Pasadena (California) and Stamford (Connecticut), among others.⁴⁸

STREET LIGHTING MARKETS

Worldwide, lighting accounts for 15% of annual electricity consumption, and public lighting – primarily street lighting – represents around 4%, equivalent to the annual electricity consumption of Germany.⁴⁹ Most public lighting is concentrated in cities, where it can account for up to 40% of the municipal electricity budget.⁵⁰ To reduce costs, municipal governments have implemented energy-efficient lighting programmes, and many also are embracing solar-powered street lights as a cost effective and reliable solution.⁵¹ Globally, nearly 5,800 (or more than 90%) of the more than 6,300 action plans submitted to the Covenant of Mayors for Climate & Energy as of November 2019 included the use of energy efficiency and renewable energy in public lighting to reduce greenhouse gas emissions.⁵²

Cities around the world have adopted efficient lighting programmes and policies to save energy and reduce electricity costs. Developing and emerging economies, particularly in Asia and sub-Saharan Africa, have large potential for future savings because many of these countries are expected to experience significant economic growth in the coming decades, and many currently have no efficient lighting policies in place.⁵³ Through the use of energy-efficient lighting, these countries could save more than 83 TWh of electricity annually by 2030 (equivalent to almost 69 million tonnes of CO₂ and USD 7.2 billion) and 1,280 TWh cumulatively by 2040 (equivalent to 1 billion tonnes of CO₂ and USD 110 billion).⁵⁴

Global sales of solar street lighting reached a cumulative 3.8 million units in 2017, up more than 70% from 2013 and generating around USD 3 billion in revenue.⁵⁵ Most of the lighting was sold as stand-alone systems, and less than a quarter was grid connected.⁵⁶ Sales of LED lights dominated the market segment, and a much smaller share of systems used compact fluorescent lamps (CFLs).⁵⁷ Almost half of solar street lighting sales were in Asia and the Pacific, while the Middle East and Africa accounted for around a third.⁵⁸

Numerous cities have implemented solar street lighting projects, including Amsterdam (Netherlands), Barcelona (Spain), Beijing (China) and Las Vegas (Nevada, US).⁵⁹ In many parts of Africa, city governments are installing solar PV systems to improve infrastructure and reduce municipal energy costs. The total potential of solar-powered street lights in sub-Saharan Africa is estimated at 96-160 GW, or double the region's installed electric generating capacity.⁶⁰ In Jinja and Kampala (Uganda), solar street lighting has greatly reduced both upfront installation costs and operation and maintenance costs relative to conventional grid-based lighting.⁶¹ Bujumbura (Burundi) has deployed solar street lighting since 2017, and similar initiatives have occurred or are under way in Dakar (Senegal), Dar es Salaam (Tanzania), Lomé (Togo), Ouagadougou (Burkina Faso) and all 47 counties in Kenya.⁶²

HEATING AND COOLING

In cities, modern renewables can provide thermal energy for space and water heating, process heat and cooling, either through the use of stand-alone systems for individual buildings or via district networks that connect a large number of buildings. Energy efficiency and renewable energy also have been key to the development of “net zero” buildings and districts with greatly reduced energy use and/or carbon emissions (→ see *Sidebar 5*).⁶³ Stand-alone renewable energy systems typically include solar thermal systems on building façades and rooftops, as well as modern biomass stoves and boilers. Renewable heat also can be produced from biomass, geothermal and solar thermal sources for injection into district heating networks.

In addition, renewable electricity can provide heat via electrically driven appliances – such as electric heat pumps – for individual buildings and district networks. Heat pumps are considered an important enabling technology for the increased use of renewables. The pumps can reduce curtailment of variable renewable energy such as wind and solar power by using the (surplus) electricity generated from these sources to meet heating and cooling demand. When used with appropriate control measures and thermal storage (for example, thermal mass, hot water tanks and chilled water), heat pumps can help balance the electrical system by shifting load away from peak periods. Heat pumps that are connected to district heating systems can increase flexibility by using thermal storage capacities. When used for heating, some of the output of heat pumps (or all of the output, if operated with 100% renewable electricity) can be renewable energy. (→ See *Systems Integration chapter in GSR 2018*.)



Public lighting can account up to 40% of municipal electricity budget

SIDEBAR 5: Net Zero Buildings and Districts

Buildings account for more than half of a city's emissions on average and are a significant source of air pollution, both from the construction process and from lifetime energy use. An estimated half a million people die each year due to outdoor air pollution caused by energy use in buildings. Net zero carbon buildings and net zero energy districts have played a critical role in combating climate change and air pollution in cities, by reducing energy use and associated greenhouse gas emissions, as well as by providing renewable energy.

A net zero building is defined as a highly energy-efficient building that is fully powered from renewable energy sources (on-site and/or off-site). "Net zero" is achieved by reducing energy use through efficiency measures and by either replacing fossil fuel-based energy use with on-site generation from renewables or procuring locally produced off-site renewable energy.

Various initiatives aim to increase the number of net zero buildings in cities. Some are based solely on local government commitments, while others involve industry and national actors at a global scale. Further, some focus on new buildings, while others aim to decarbonise both new and existing buildings. Under the C40 Net Zero Carbon Buildings Declaration, mayors of 25 citiesⁱⁱ worldwide (mainly in Europe and North America, plus 4 cities in South Africa), representing more than 130 million people, have pledged that all new buildings will be net zero starting in 2030, and that all new and existing buildings will meet this standard by 2050.

A different initiative, the World Green Building Council's Net Zero Carbon Buildings Commitment, goes beyond city governments to include 23 companies, 6 states and regions,



and 23 cities around the globe to promote and support the target of 100% net zero carbon buildings by 2050. Under the complementary Zero Carbon Buildings for All Initiative, launched in September 2019, participating financial and industrial actors commit to providing expertise and more than USD 1 trillion in investment by 2030, and national and local leaders commit to decarbonising all new buildings by 2030 and all new and existing buildings by 2050.

At a broader scale, the concept of net zero energy districts has gained popularity in cities. Such districts are built to maximise energy efficiency and to use renewable energy at a district level, as opposed to an individual building level, offering economies of scale to increase cost effectiveness. District-level net zero energy projects present opportunities to optimise the collective energy use of buildings through energy balancing, bulk procurement, district heating and cooling systems, and mobility-oriented development.

Numerous examples of net zero energy districts exist worldwide. In Palava (India), a rapidly developing city located 40 kilometres from Mumbai that is being built to zero energy standards, key city policies have helped to reduce the carbon footprint of transport to nearly zero. The co-location of business and residential areas has shortened travel distances, and the provision of pedestrian, bicycle and e-charging infrastructure has minimised the need for motorised transit. Palava also aims to achieve net zero energy standards by adopting rooftop solar PV and other renewable technologies, by ensuring high levels of energy efficiency, and by treating and re-using all greywater and blackwater.

In Pittsburgh (Pennsylvania, US), the district of Hazelwood Green, a 620,000 m² mixed-use development at the site of a former steel mill, aims to achieve net zero energy standards by adopting renewable energy solutions while taking advantage of its diverse energy use profile. The district is composed of residential, industrial, retail and office buildings, each with different energy use patterns and varying load profiles throughout the day. With almost all buildings integrating solar PV generation capacity, this diverse use profile ensures the cost-effective balancing of supply and demand, while allowing Hazelwood Green to achieve net zero energy.

i Net-zero carbon objectives (carbon neutrality) aim to achieve net zero CO₂ emissions either by balancing carbon emissions with carbon removal or by completely eliminating CO₂ emissions from a system. Net zero energy objectives aim to achieve net zero energy use by maximising energy efficiency and producing as much energy as is used. See Cameron Brown, "What's the difference between carbon neutral, zero carbon, and negative emissions?" Cleantech Rising, 4 October 2018, <https://cleantechrising.com/whats-the-difference-between-carbon-neutral-zero-carbon-and-negative-emissions/>, and Better Buildings Initiative, "Zero energy districts", <https://betterbuildingsinitiative.energy.gov/accelerators/zero-energy-district>, viewed 24 June 2019.

ii The 25 cities are Los Angeles, New York City, Newburyport, Portland (Oregon), San Francisco, San Jose, Santa Monica, Seattle and Washington, D.C. (all US); Cape Town, Durban, Johannesburg and Tshwane (all South Africa); Montreal, Toronto and Vancouver (all Canada); as well as Copenhagen (Denmark), Heidelberg (Germany), London (UK), Medellin (Colombia), Oslo (Norway), Paris (France), Stockholm (Sweden), Sydney (Australia) and Tokyo (Japan).

Source: See endnote 63 for this chapter.

STAND-ALONE SYSTEMS

Biomass (in solid, liquid and/or gaseous form) can be used in modern appliances such as wood or pellet stoves and biomass boilers to provide water and space heating for individual buildings.⁶⁴ Many cities, including Krakow (Poland), New York City (New York, US) and Prague (Czech Republic), have banned or plan to ban the burning of coal, briquettes and/or some oils for heating, due in part to air pollution concerns.⁶⁵ Such steps have led to the emergence of markets for alternatives.⁶⁶

Solar thermal technologies can provide low-temperature heat for water and space heating, for drying and for cooling (although this remains a niche market), and systems that use concentrating collector technologies can provide high-temperature heat or steam.⁶⁷ Municipal building codes, such as mandates requiring the installation of solar thermal in buildings, facilitate the use of such systems in urban areas. In 2000, Barcelona (Spain), through its Solar Thermal Ordinance, became the first city to require the use of solar thermal energy in all new buildings, renovated buildings and buildings changing their use (private and public) (→ see *Targets and Policies chapter*).⁶⁸

Although global data on urban renewable heat capacity and generation are lacking, numerous examples exist of solar thermal-related projects undertaken by city governments and local private investors. In Kyiv (Ukraine), the government installed solar water heaters at 28 preschools and nurseries between 2015 and 2018.⁶⁹ In Belo Horizonte (Brazil) private investors installed more than 3,500 solar water heating systems in blocks of flats between 1998 and 2017 and continued to add capacity in 2018, establishing Belo Horizonte as Brazil's solar city.⁷⁰

As part of Mexico's Energy Sustainability Strategyⁱ, roughly 81,000 homes (3.2% of the total) in Mexico City were equipped with solar water heaters by 2018, a number that is expected to reach 135,000 by 2024.⁷¹ Mexico City also is investing MXN 14.7 million (USD 770,000) during 2012-2020 to provide solar water heating to 10 public hospitals.⁷² As of 2019, Panama City (Panama) had installed at least one solar thermal system and had another 40 systems in the pipeline.⁷³ In Karnataka state (India), the public utility in Bengaluru has implemented a bylaw to encourage the use of solar thermal, and as of 2018 more than 1,200 million m² of collector area had been installed in the city.⁷⁴

Solar thermal collectors also can drive thermally driven chillers to provide cooling. A key advantage of solar cooling is the timing match between the supply (solar radiation) and the demand for cooling.⁷⁵ By the end of 2018, an estimated 1,800 solar cooling systems had been installed worldwide.⁷⁶ Such systems were operating in 2019 at a school in Phoenix (Arizona, US), at Qassim University in Buraydah (Saudi Arabia), at IKEA stores in Singapore, at an office building in Gandhinagar (India) and atop a shopping centre in Victoria (Australia), among other places.⁷⁷

DISTRICT HEATING AND COOLING NETWORKS

District heating and coolingⁱⁱ networks provide thermal energy in the form of heating or cooling to residential, commercial, institutional and industrial buildings, and are being developed in cities around the world.⁷⁸ Such systems enable the use of renewables in the thermal energy sector and can be effective and efficient mechanisms for providing affordable heating and cooling while also reducing a city's reliance on fossil fuels.⁷⁹ Most of the existing district heating and cooling systems rely on little to no renewable energy, so renewables account for only a minor part of the thermal energy used in district systems globally.⁸⁰ However, interest in the use of renewable energy in such systems is increasing in many countries.⁸¹

Most of the district heating networks in operation are in Europe, China and North America.⁸² In Europe, where the networks are widespread, an estimated 6,000 district heating systems supplied around 12% of EU heat demand as of 2019.⁸³ The largest European markets are in Germany, followed by Poland and Sweden.⁸⁴ Across the region, district heating networks are shifting increasingly to renewable energy sources, as in Berlin (Germany), Copenhagen (Denmark), Lodi (Italy), London (UK), Tartu (Estonia), Vilnius (Lithuania) and Zurich (Switzerland).⁸⁵

On a national level, several European countries boast high average shares of renewables in district heating networks. In 2019, all of Iceland's district heating needs were met by renewables (including recycled heat).⁸⁶ Other leading countries included Switzerland (85.6% renewable energy and recycled heat), Lithuania (68.7% renewables), Denmark (58.9% renewables) and France (56% renewables and recovered heat).⁸⁷ The Russian Federation is home to the world's largest installed district heating capacity, although little of it is renewably powered.⁸⁸

China's numerous district heating networks, with an overall capacity exceeding 462 gigawatts-thermal (GW_{th}), are concentrated mainly in the country's north, where they provide around 55% of total space heating.⁸⁹ Most of these systems rely primarily on coal, and renewables contribute only about 1% of thermal energy.⁹⁰ However, regulations and incentives aimed at reducing air pollution are encouraging increased use of renewable energy sources in a number of networks.⁹¹

Biomass sources account for an estimated **95%** of renewable energy in district heating.

District heating networks are present in all 50 US states and are becoming widespread across North America.⁹² Although the majority of US networks (more than 70%) use natural gas, some rely at least in part on

i The high penetration of solar water heaters in Mexico City also has been facilitated by a national, long-term green credit scheme. See Bärbel Epp, "Green credits in Mexico: Push for the market", Solarthermalworld.org, 2 October 2008, <https://www.solarthermalworld.org/news/green-credits-mexico-push-market>.

ii Because district heating and cooling needs a sufficiently high density of thermal loads to justify the cost and effort of installing the necessary infrastructure, including the distribution grid, such networks predominately operate or are under development in cities and towns (and some villages). See C40 Cities and United Nations Environment Programme, *Good Practice Guide: District Energy* (Paris: 2016), <http://www.districtenergyinitiative.org/sites/default/files/publications/1c40pggdeoriginal-21092017534.pdf>.

renewable sources.⁹³ Boise (Idaho) heats more than 90 buildings (0.5 million m²) in its city centre with geothermal energy.⁹⁴ In Latin America, district energy networks remain relatively rare, although systems are starting to emerge, particularly in Chile: by the end of 2018, 10 cities in the country – including Coyhaique, Renca, Temuco and the capital Santiago – were developing district systems.⁹⁵

Where renewables are being used to supply district energy networks, the technologies selected and their share of the energy produced differ from system to system. **Bioenergy** is the most widely used renewable energy source in district heating networks, but geothermal direct use and large-scale solar thermal systems also are increasing in popularity.⁹⁶

Globally, biomass sources such as wood and wood pellets account for an estimated 95% of the renewable energy in district heating.⁹⁷ Several countries, including Austria, Denmark and Sweden, rely heavily on biomass for district heating systems in their cities and towns. In Austria, more than 2,100 municipal district heating systems use biomass purchased from local farmers as their primary fuel source.⁹⁸ In Denmark, biomass supplies 60% of the thermal energy for district heating (which supplies 65% of homes), and the rest is derived from fossil fuels.⁹⁹ In Sweden, where district heating accounts for 60% of overall heat consumption, biomass supplies two-thirds of network heat.¹⁰⁰ In Lithuania, where 57% of residents are served by district heating, 61% of heat was produced with local biomass in 2015.¹⁰¹

Other cities in Europe as well as the United States have advanced bio-heat for district energy systems. Pécs (Hungary) has invested extensively in its district heating network, providing 31,000 homes and 450 public buildings with 100% renewable heat from straw and agricultural wastes collected in the region.¹⁰² The local farmers and agricultural operators who provide the feedstock are directly compensated for the system's annual fuel expenses of roughly HUF 4 billion (USD 14.2 million).¹⁰³ In the Russian Federation, some of the country's 17,000 or so district heating systems are being refurbished to increase the use of local biomass sources such as wood.¹⁰⁴ Similarly, St. Paul (Minnesota, US) phased out the use of coal for district heating and cooling in 2019, completing a transition begun in 2003 to rely entirely on municipal wood waste for heat (with 65 MW_{th} of thermal capacity, combined with 25 MW of power capacity).¹⁰⁵

The direct use of **geothermal** energy – direct geothermal extraction for heating and cooling – in district heating is increasing, representing one of geothermal's largest and fastest growing applications.¹⁰⁶ Europe is one of the most active markets for geothermal district heat, although this market is highly localised.

Reykjavik (Iceland) uses geothermal energy to provide 100% of

its district heat, and most of the heating in the country is from geothermal sources.¹⁰⁷ In 2018, Gyor (Hungary) completed a new well for a district heating system that serves 24,000 dwellings.¹⁰⁸ The use of geothermal energy in district heating networks in France continued to expand in and around Paris and in Strasbourg, where a geothermal project is expected to provide electricity plus enough heat via district heating systems to supply 26,000 residents.¹⁰⁹

Germany had 37 relatively small (40 MW_{th} or less) geothermal district heat plants as of the end of 2018 (totalling 336 MW_{th} of thermal capacity), which were used mainlyⁱⁱ for district heat production; construction also was under way on new facilities.¹¹⁰ Munich (Germany) was building a new 50 MW_{th} plant that is expected to provide heat for 80,000 residents and to help the city achieve its goals to generate all district heating from renewables by 2040 and to become carbon neutral by 2050.¹¹¹

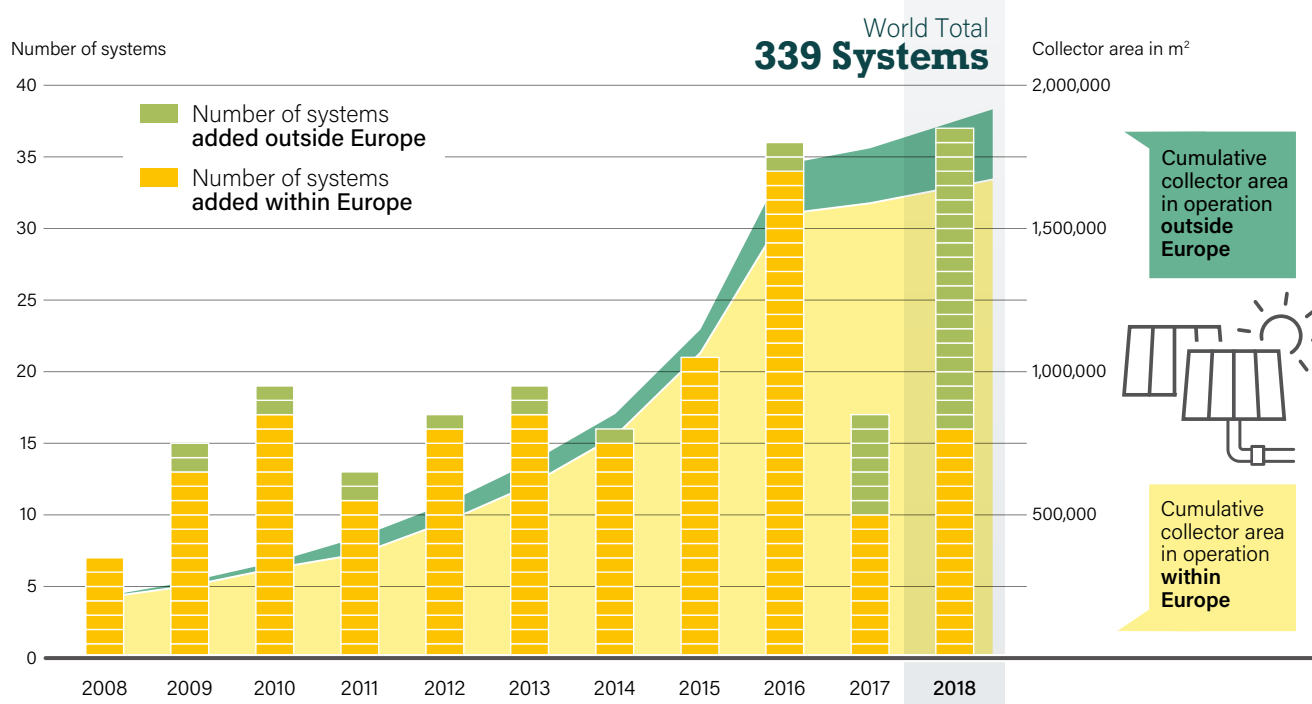
In some cases, private and municipal utilities, as well as commercial and industrial entities, have deployed **solar thermal** systems to provide space heating for large residential, commercial and public buildings and communities.¹¹² Globally, at least 339 large-scale (greater than 350 kilowatts-thermal or 500 m²) solar thermal systems, including those feeding district networks, were in operation by the end of 2018, for a total capacity of 1.35 GW_{th} (→ see Figure 15).¹¹³ Most were in Europe, although interest is picking up elsewhere.¹¹⁴



i District heating, swimming pools and other public baths together account for around 80% of global direct geothermal energy consumption and capacity, which totalled an estimated 26 GW_{th} by the end of 2018. Pools and baths are about equal in scale to district heating but are growing less rapidly. See endnote 106.

ii Some of the geothermal district heating plants use binary technology to produce electricity as well.

FIGURE 13. Solar District Heating Systems, Global Annual Additions and Total Area in Operation, 2008-2018



Note: Includes large-scale solar thermal installations for residential, commercial and public buildings.

Data are for solar water collectors and concentrating collectors.

Source: See endnote 113 for this chapter.

In Denmark, the use of solar thermal energy has grown significantly in the district heating sector, where more than 1.3 million m² of solar collectors are connected to district heating.¹¹⁵ As of mid-2019, more than 120 Danish villages, towns and cities used solar collectors to produce heat, with a total capacity of 1 GW_{th}, covering 60% of national heat demand.¹¹⁶ In 2018, five German villages added solar fields to new or existing (mostly biomass-fired) district heating systems.¹¹⁷ In southern Europe, the municipal government of Alcalá de Henares (Spain) signed an agreement with Alcalá Ecoenergías for the construction of a district heating system that will rely on biomass and solar thermal; it is expected to be Spain's first large-scale renewable thermal plant, providing heat to 12,000 homes.¹¹⁸

Also in 2018, Jordan's first demonstration solar thermal plant began operating on a public hospital, and South Africa's first district heating network that incorporates solar thermal technologies began supplying heat to 14 student residence buildings at Wits University in Johannesburg.¹¹⁹ A 14 MW_{th} solar district heating network was completed in Langkazi (Tibet, China), meeting around 90% of heat demand.¹²⁰ In Bishkek (Kyrgyz Republic), a solar district heating plant that began operating in 2017 is to be joined by a second district heating installation.¹²¹

Activity continued in 2019. In Salaspils (Latvia), a 15 MW_{th} solar collector plant combined with a biomass boiler was commissioned to provide heat for nearly 15,000 inhabitants.¹²² Construction also began on what is expected to be Germany's largest solar district heating plant, which will heat the city of Ludwigsburg and the nearby town of Kornwestheim.¹²³ In Tibet, plans were under way for a third solar district heating project – with a 34,650 m² solar field and a 15,000 m³ tank for seasonal storage – following the 14 MW_{th} Langkazi project and the 12.6 MW_{th} Shenzha project.¹²⁴

Several large private companies have committed to greatly increasing the renewable share of energy used in the district heating networks that they operate. For example, Engie (France), one of the world's largest operators of district heating networks, announced in 2018 that it aims to increase the renewable share in its urban district thermal networks in Europe to at least 50%.¹²⁵ In 2019, Vattenfall (Sweden) partnered with Amsterdam (Netherlands) to invest EUR 400 million (USD 458 million) to advance the city's transition to a 100% renewable heating system by 2040.¹²⁶

The China Petrochemical Corporation (Sinopec) Green Action Plan, launched in 2018, emphasises the increased use of natural gas but also includes the expansion of geothermal heating capacity to serve 2.1 million urban residents.¹²⁷ Through a joint venture with Arctic Green Energy (Iceland), Sinopec plans to transition from coal to geothermal energy in 20 Chinese cities by 2023.¹²⁸

District cooling networks are in use in cities around the world, and not just in warmer climates. Such networks have operated for years in major cities such as Berlin and Hamburg (Germany), Dubai (UAE), Geneva (Switzerland) and Toronto (Canada).¹²⁹ Most district cooling systems deliver chilled water – often drawn from rivers, lakes or the ocean – to buildings and return thermal energy to water bodies through the use of heat exchangers or heat pumps (which can be operated using renewable electricity).

New district cooling systems are operating in Cyberjaya (Malaysia), Gujarat City (India) and Manila (Philippines), among others.¹³⁰ In India, Amaravati signed a concession in 2019 for the development of a district cooling system slated for operation in 2021, and Rajkot included district cooling in its smart city plan.¹³¹ A district cooling network in Singapore is being developed to serve the Punggol Digital District.¹³² Abu Dhabi (UAE) passed the first district cooling regulation in the Middle East and North Africa region in September 2019, setting up a uniform standard to ensure quality and competitiveness in the sector.¹³³ This is expected to enable the city to become a district cooling pioneer in the region.¹³⁴

Urban transport represented around **40%** of the energy used in the transport sector.



TRANSPORT

Globally, energy for the transport sector accounted for roughly one-third of total final energy consumption in 2018; most of this (95.9%) was met by oil and petroleum products (plus 0.8% non-renewable electricity), with small shares from biofuels (3.0%) and renewable electricity (0.3%).¹³⁵ Because transport remains heavily reliant on fossil fuels, it is a significant contributor to global CO₂ emissions, accounting for 23% of energy-related emissions globally in 2015.¹³⁶ Urban transport represented around 40% of the energy used in the transport sector that year and contributed an estimated 37% of transport CO₂ emissions (32% from urban passenger transport and 5% from urban freight).¹³⁷

Although no global systematic review has been conducted, the available data suggest that transport's contribution to urban air pollution is growing, especially in cities in Africa, Asia and the Middle East.¹³⁸ Road transport is responsible for up to an estimated 30% of fine particulate matter (PM_{2.5}) in European cities and between 12% and 69% in developing country cities.¹³⁹

Urban transport can be broken down into passenger transport – which includes both urban rail (light rail and metro) and urban road transport (buses, cars, two- and three-wheelers) – and freight transport (for example, waste collection trucks and delivery vehicles). Urban transport also can be categorised according to who owns or operates the fleets or services (whether public or private companies), which is particularly relevant in the context of municipal fleets.

Municipal governments often own and/or operate fixed infrastructure assets, putting these government actors in a better position to directly influence the provision of infrastructure rather than the provision of vehicles and services, which tend to be the domain of transport operating companies.¹⁴⁰ However, municipal governments are taking steps to decarbonise urban transport – especially passenger transport but also freight – through pledges and public procurement processes (→ see *Targets and Policies chapter*).¹⁴¹

City governments also have been embracing broader efforts towards sustainable transportⁱⁱ, driven by the need to reduce local air pollution and CO₂ emissions and to deal with other consequences of climate change and urbanisation (such as congestion, noise and energy security). These measures include applying integrated land-use and transport planning to reduce demand and increase efficiency, engaging in and supporting the production and consumption of renewable fuels, and developing infrastructure and backing technology that facilitates the integration of renewable energy (for example, natural gas vehicles and EV charging stations).¹⁴²

Citizens and businesses, too, are increasingly prominent actors in enabling sustainable modal and fuel shifts in urban transport as they transition to more-efficient transport modes and use renewable energy sources to decarbonise their private vehicles and services (such as the delivery of goods).¹⁴³

i In the UAE, urban district thermal networks supplied an estimated average 20% of total space cooling demand as of 2017. See endnote 129 for this chapter.

ii Sustainable transport is defined as “the provision of services and infrastructure for the mobility of people and goods – advancing economic and social development to benefit today’s and future generations – in a manner that is safe, affordable, accessible, efficient, and resilient, while minimizing carbon and other emissions and environmental impacts.” See United Nations, *Mobilizing Sustainable Transport for Development* (New York: 2016), <https://sustainabledevelopment.un.org/content/documents/12453HLAG-ST%20brochure%20web.pdf>.

RENEWABLE ENERGY IN URBAN TRANSPORT

Renewable energy development in urban transport requires a shift from fossil fuels to renewable fuels. The main entry points are the use of 100% liquid biofuels or of biofuels blended with conventional fuels, the use of biomethane in natural gas vehicles, and the electrification of transport, including through the use of battery-electric and plug-inⁱ hybrid vehicles and of hydrogen, synthetic fuels and electro-fuelsⁱⁱ, provided that the electricity is itself renewable (→ see Figure 16).¹⁴⁴

LIQUID BIOFUELS

Biofuels for transport, used principally for road transport, are part of important national strategies to improve fuel security, mitigate climate change and support economic development (→ see *Targets and Policies chapter*).¹⁴⁵ Although most biofuel blending mandates are adopted at the national level, cities have been experimenting with biofuels in transport as well.

Global production of transport biofuels increased nearly 7% in 2018.¹⁴⁶ The main biofuels produced are liquid biofuels, specifically ethanol (produced mostly from corn, sugar cane and other crops) and biodiesel (fatty acid methyl ester, or FAME, fuels produced from vegetable oils and fats, including waste oil). In 2018, global ethanol production increased nearly 7%, and biodiesel production rose about 5%, with the United States and Brazil occupying top positions in the production of both.¹⁴⁷

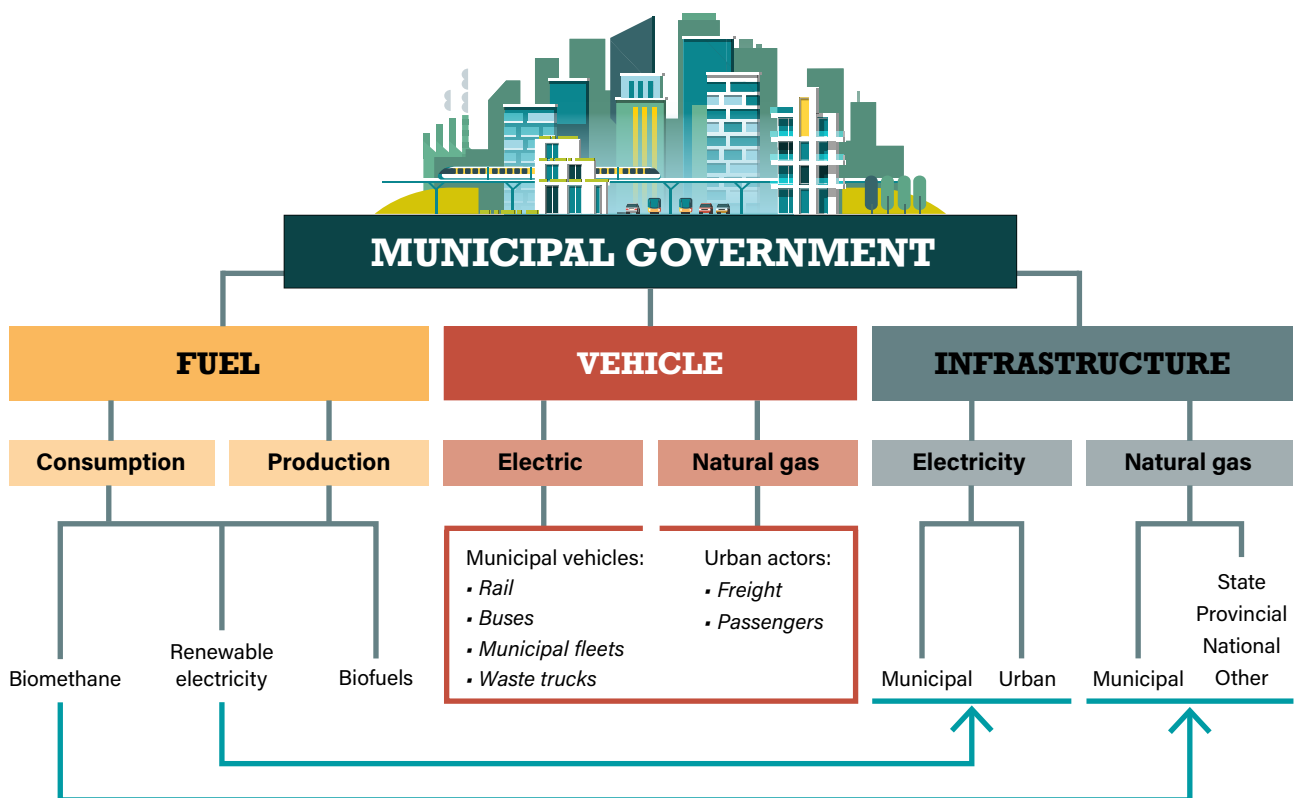
Overall, the share of biofuels in transport increased around 18% between 2013 and 2017, although starting from a small base.¹⁴⁸ Most liquid biofuels are consumed through the blending of ethanol or biodiesel at low percentages (typically less than 10% – E10 or B10 – by volume or energy) with fossil fuels. One reason for this is that low biofuel blends can be used in any combustion vehicle, whereas high biofuel blend levels or unblended biofuels require the use of flexible-fuel vehicles.¹⁴⁹

Some municipalities are converting their fleet vehicles from petrol to liquid biofuels. Dubai (UAE) is using biodiesel made from

i Plug-in hybrids differ from simple hybrid vehicles, as the latter use electric energy produced only by braking or through the vehicle's internal combustion engine. Therefore, only plug-in hybrid electric vehicles allow for the use of electricity from renewable sources. Although not an avenue for increased penetration of renewable electricity, hybrid vehicles contribute to reduced fuel demand and remain far more numerous than EVs.

ii Also known as e-fuels, electro-fuels are synthetic fuels that do not technically differ from conventional fuels such as diesel or petrol but are generated in procedures known as power-to-liquids and power-to-gas. Renewable electro-fuels are generated exclusively from electricity from renewable sources.

FIGURE 14. Entry Points for Renewable Energy in Urban Transport



100% local waste cooking oil as fuel for its municipal vehicles.¹⁵⁰ In Monroe County (New York, US), a Green Alternative Fuelling Station dispenses a variety of liquid biofuel blends (B20, E20 and E85) to power the 1,100 or so vehicles used in the county, including municipally owned car fleets.¹⁵¹

BIOMETHANE

The technology for converting waste into biogas, and then purifying and upgrading the gas to biomethaneⁱ for use in transport, is mature. Natural gas vehicles, which use compressed natural gas or liquefied natural gas as fuel, provide the only entry point for biomethane in transport.¹⁵² Therefore, the ongoing growth in natural gas vehicles and associated infrastructure around the world (for example, in China, Germany, India and Italy) is a pre-condition to increase the use of biomethane.¹⁵³

The contribution of biomethane is increasing rapidly, representing an opportunity to use municipal solid waste and wastewater to generate biofuels (→ see *Sidebar 4*).¹⁵⁴ The very nature of biomethane, as a renewable fuel created from organic waste, makes it possible for cities to combine the decarbonisation of transport with the creation of new models for a circular economy.¹⁵⁵

Biomethane use for transport is concentrated in the United States and in the EU. In the United States – the largest producer and user of biomethane for transport – domestic consumption of the fuel grew more than seven-fold between 2014 and 2017, then increased another 13% in 2018 to around 22 PJ.¹⁵⁶ In early 2019, more than 50 confirmed active plants nationwide were producing biomethane for use as a vehicle fuel, including plants in Billings (Montana), Fort Smith (Arkansas), Riverview (Missouri) and San Mateo (California).¹⁵⁷ Most of the plants were sourcing

waste from landfills (31 plants), with the rest obtaining it from livestock operations (9), wastewater treatment (7) and municipal food waste (5).¹⁵⁸

With more than 500 installations regionwide, Europe's biomethane consumption increased 13% in 2017 to 7.8 PJ (latest data available).¹⁵⁹ Biomethane is supplied in dedicated filling stations throughout the region in the form of compressed gas, mostly for urban public transport applications and other natural gas vehicles.¹⁶⁰ Production and use are concentrated in Sweden (5.2 PJ), where methane production from food waste is encouraged as part of a sustainable waste reduction policy, and where biomethane's use as a transport fuel is prioritised over its use for electricity production or for injection into gas grids.¹⁶¹ The next largest European users of transport biomethane in 2017 were Germany (1.6 PJ), Norway (0.42 PJ) and the Netherlands (0.23 PJ).¹⁶²

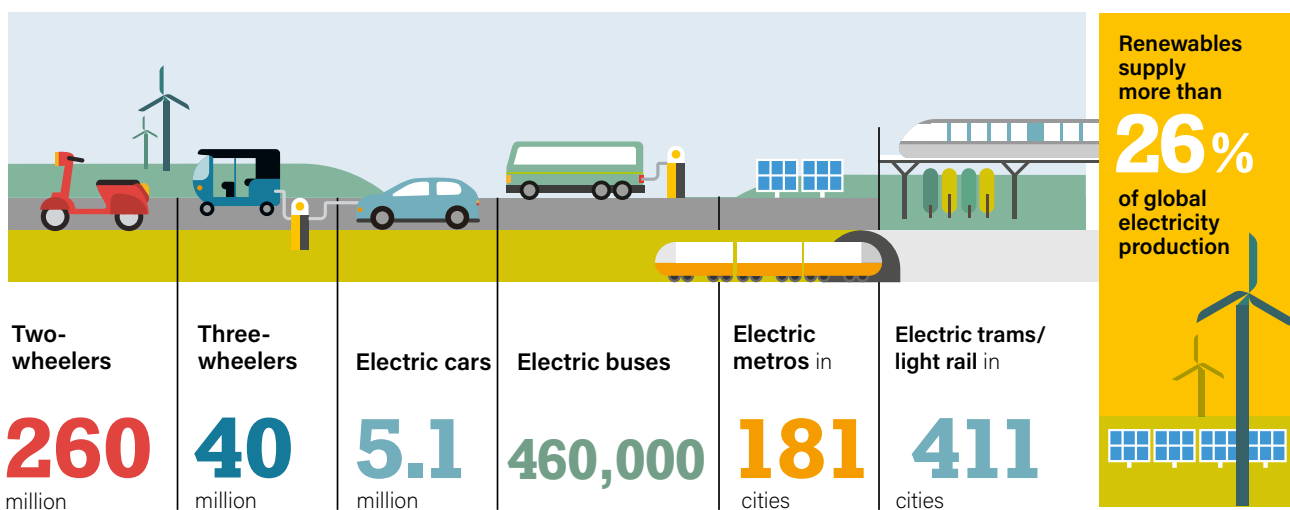
Several facilities to upgrade biogas to biomethane were opened in Europe in 2018, and three new countries (Belgium, Estonia and Ireland) connected biomethane facilities to national gas grids for the first time.¹⁶³ Biomethane plants also are developing rapidly in China.¹⁶⁴

RENEWABLE ELECTRICITY

Globally, the use of renewable electricity in transport increased 11% in 2018.¹⁶⁵ Until recently, electricity use in urban transport was limited mainly to light rail (trams), urban trains and metros; however, the sector has now opened entirely to electrification, as plug-in hybrids, fully electric passenger cars and other forms of e-mobility become more commonplace in many cities (→ see *Figure 17*).¹⁶⁶

ⁱ Biomethane is also known as renewable natural gas, renewable gas, green gas, upgraded biogas or renewable methane.

FIGURE 15. Global Electric Vehicle Markets, 2018



Source: See endnote 166 for this chapter.

SIDEBAR 6: Worldwide Expansion of E-mobility

Electric mobility, or e-mobility, represents a promising way to counteract the increasing negative impacts of urbanisation such as transport-related emissions as well as noise and air pollution. E-mobility also can provide energy security and facilitate the uptake of renewables in the transport sector.

The electrification of transport is expanding at a rapid pace. While EVs by themselves do not increase the renewable share of energy consumption, they enable the use of renewable electricity in the transport sector: as the share of renewables in the electricity mix increases, so does renewable energy's contribution to the sector. Further, EVs allow for the integration of higher shares of variable renewable electricity sources, such as solar and wind power, into the grid, as the EV batteries can act as a storage solution and facilitate demand-side management (for example, allowing for power transmission from vehicle to grid).

Municipal and/or national governments can enact different policy instruments to catalyse e-mobility (→ see *Targets and Policies chapter*). Through the implementation of building codes, urban planning and zoning regulation, cities such as Oslo (Norway) and Portland (Oregon, US) are actively encouraging more public infrastructure and local charging stations to facilitate electrification. Globally, as of 2018, the world's EV fleet was served by more than 5.2 million charging points for light-duty vehicles. Of these, 540,000 charging points (395,000 slow chargers and 145,000 fast chargers) were publicly accessible, and more than half of these were

in China. The charging infrastructure for light-duty vehicles is complemented by some 157,000 fast chargers for buses.

Many of the world's EV charging stations, including fast-charging facilities, are being installed in cities. Dubai (UAE) added another 100 EV charging points in October 2018, bringing the city's total to 200. Municipal charging stations also exist in cities ranging from Cairo (Egypt), Dunedin (New Zealand) and Johannesburg (South Africa) to Los Angeles (California, US) and Shanghai (China). The councils of Tweed Shire and Byron Shire in New South Wales (Australia) plan to establish a network of publicly available fast-charging stations along Australia's eastern coast to support the adoption of EVs.



Several cities are working to ensure that EVs are charged with renewable electricity.¹⁶⁷ As of 2018, Austin (Texas, US) had installed more than 650 public EV charging stations that rely entirely on renewable power.¹⁶⁸ In Rabat (Morocco), the Moroccan Institute for Research in Solar Energy and New Energies is installing a series of solar-powered car ports to recharge EVs.¹⁶⁹ Utrecht (Netherlands) launched its Smart Solar Charging system in early 2019, using locally produced solar electricity and linking it with EV charging.¹⁷⁰ Utrecht's system enables EVs to participate in "smart charging", or vehicle-to-grid (V2G) technology, which entails charging or drawing from EV batteries in response to the needs and capacities of the national electric grid.¹⁷¹

HYDROGEN

There is ongoing discussion about the generation of liquid or gaseous renewable electricity-based synthetic fuels or electro-fuels (also referred to as e-fuels or power-to-x), particularly through hydrogen pathwaysⁱ. Although less than 0.1% of global dedicated hydrogen production comes from water electrolysisⁱⁱ, interest in electrolytic hydrogen is growing as the costs of renewable electricity, especially from solar PV and wind, continue to decline.¹⁷² Efforts to upscale electrolyser capacity for hydrogen production were under way in several European countries as well as in China, Japan and the United States as of mid-2019.¹⁷³

Hydrogen produced with renewable electricity can support the decarbonisation of transport, particularly long-haul and heavy-duty transport.¹⁷⁴ In 2017, the Moreland Council and the Victorian State Government (Australia) built a commercial-scale renewable hydrogen refuelling station for waste collection (garbage) trucks

i Hydrogen can be converted to hydrogen-based fuels, including synthetic methane, methanol and ammonia, and synthetic liquid fuels, which have a range of potential transport uses.

ii Water can be converted into hydrogen and oxygen using an electrolyser and electricity. Electrolysis plays a central role in the deployment of renewable hydrogen.

As the share of EVs on the road grows, one of the chief concerns of local and regional utilities is how to encourage so-called smart charging, which refers to attempts to better optimise the charging of EVs in response to constraints in the grid. In most cases, this involves discouraging EV users from charging their vehicles during peak times and incentivising them to charge during off-peak hours.

By introducing a new, flexible source of electricity demand, smarter EV charging can play a key role in facilitating the integration of variable renewable energy sources such as solar PV and wind power into the grid. EV charging can be timed to better correspond with wind and solar power output, thereby easing the integration of these renewable sources and reducing the need for curtailment (purposeful reduction in renewable energy output due to grid-related challenges).

Some utilities are introducing new electricity rate structures specifically to adapt to the rapid growth in EVs. In Austin (Texas, US), the municipal utility has launched a pilot time-of-use programme that provides lower electricity rates for charging EVs outside the peak demand window. The utility also introduced a membership-based service for EV charging, in which drivers pay USD 4.17 per month to gain access to a network of more than 800 public charging stations powered by 100% renewable energy.

In Los Angeles (California, US), the municipal utility (Los Angeles Department of Water and Power) has focused its strategy on residential customers, offering ratepayers that have EVs special off-peak rates of USD 0.025 per kWh as well as a rebate of up to USD 4,000 for installing Level 2 (i.e., higher amperage and faster charging) EV charging stations.

Another innovation that has emerged in recent years is the use of deadline-differentiated pricing, which enables customers to choose the deadline (or overall time frame) by which they need their vehicle charged. By giving utilities more flexibility around the precise time frame during which EV charging can occur, such pricing structures provide a significant new source of flexibility in the power system while also supporting the integration of variable renewable energy sources.

In a recent example of deadline-differentiated pricing, the New York State Electric and Gas Corporation and Rochester Gas & Electric created an EV Smart Home Rate pilot project in three charging environments in Rochester (New York, US): a charger in a university parking garage, public EV chargers and at-home EV chargers. The size of the discount available to customers depends on the time frame selected by the customer, with more-flexible time constraints associated with larger discounts.

Source: See endnote 166 for this chapter.

aimed at tackling urban noise and air pollution.¹⁷⁵ In Europe, Akvo Energy and Ataway announced a plan in 2018 to deploy 33 renewable hydrogen refuelling stations to provide fuel for 400 hydrogen vehicles in urban and suburban areas of Paris and other French towns and cities, before expanding the project region-wide.¹⁷⁶

URBAN TRANSPORT MARKETS

The urban transport system comprises several different market segments. For passenger transport, options include rail transport systems (light rail and metro) and various road transport modes, such as buses, cars and two- and three-wheelers. Meanwhile, freight transport within cities includes waste collection trucks and delivery vehicles.

PASSENGER RAIL TRANSPORT

Urban rail infrastructure – ranging from commuter light rail systems to above- and below-ground metro systems – has scaled up rapidly over the past decade, laying the foundation for convenient, low-emissions transport within and between cities.¹⁷⁷ In 2018, the growth in urban rail slowed by 6%, compared to annual average growth of 36% during 2014-2018.¹⁷⁸ However, 121 individual urban rail projects were completed on six continents in 2018, totalling 1,270 kilometres (down from a record 1,348 kilometres in 2017).¹⁷⁹

Rail is the most highly electrified transport sub-sector, with virtually all urban rail networks being powered by electricity.¹⁸⁰ Although the share of renewable electricity consumed by urban rail is determined mainly by the national energy mix, some cities have started developing renewable energy projects to power their light rail and metro systems, mostly for energy security and sustainability reasons.¹⁸¹ As of 2015, an estimated 9% of the electricity used for rail transport was renewable.¹⁸²

Worldwide, more than
460,000
 electric buses
 were operating in more
 than 300 cities.

Light rail systems,

or trams, are present in more than 410 cities worldwide.¹⁸³ Most of these operate in Europe and Asia (Germany and the Russian Federation alone feature more than 120 of these systems), followed by North America; however,

developments are picking up in the Middle East as well.¹⁸⁴ Tram systems in sub-Saharan Africa and South America are developing at a slower pace but are present in Addis Ababa (Ethiopia), Mendoza (Argentina) and Santos (Brazil).¹⁸⁵ In 2018, new tram lines opened in Chengdu, Suzhou and Wuhan (China), Brussels (Belgium), Casablanca (Morocco), El Paso (Texas, US), Lisbon (Portugal), Milwaukee (Wisconsin, US), Nice (France), Oklahoma City (Oklahoma, US), Sétif (Algeria), Taipei (Chinese Taipei) and Ulm (Germany).¹⁸⁶

Powering trams with renewable energy remains rare, although examples exist. In 2019, Melbourne (Australia) connected a 128 MW solar PV system to its grid network specifically to power the city's tram system.¹⁸⁷ Similarly, Calgary (Canada) built 12 wind turbines to power its C-Train light rail system.¹⁸⁸ In 2018, Amsterdam Municipal Transport (GVB; Netherlands) announced that its entire urban rail fleet would be powered by wind energy starting in 2019.¹⁸⁹ Tokyo's Setagaya line is set to become Japan's first urban light train line to run entirely on renewables, namely geothermal and hydropower.¹⁹⁰ A hydrogen-powered tram has operated in Qiangdao (China) since 2016.¹⁹¹

In 2018, **metro systems**ⁱⁱ were running in 181 cities in 56 countries worldwide, particularly in Europe and the United States.¹⁹² Metro developments have increased in Asia and the Pacific in recent years, dominated heavily by China, and new systems opened in 2018 in Abuja (Nigeria; the first metro in sub-Saharan Africa), Amsterdam (Netherlands), Moscow (Russian Federation), New Delhi (India) and Palembang (Indonesia).¹⁹³

Some cities are coupling their metros to the scale-up of renewable power. In 2018, Santiago (Chile) commissioned a 100 MW solar PV park to supply more than half the electricity demand of its underground rapid transit system.¹⁹⁴ In New Delhi (India), the metro is powered in part by an off-site solar PV facility, while auxiliary services such as lighting and air conditioning rely on on-site rooftop solar PV systems.¹⁹⁵ As of mid-2019, metro services in several European cities – including Frankfurt and Nürnberg (Germany) and Málaga and Seville (Spain) – were supplied by renewable sources.¹⁹⁶ In a more holistic approach, an estimated 56% of the public transit system in Oslo (Norway), mainly its trams, train and metro systems, is powered by renewables, thanks to the high share of hydropower in the country's electricity mix.¹⁹⁷

PASSENGER ROAD TRANSPORT

In response to increasing urbanisation and other factors, the number of roads in cities has increased significantly in recent decades. The expansion of road transport has led to high levels of urban congestion with varying negative impacts.¹⁹⁸ Due to its heavy reliance on diesel, petrol and other fossil fuels, road transport is often the largest source of local air pollutants in urban centres around the world.¹⁹⁹ In total, road transport accounted for around 75% of global transport energy use in 2016, with passenger vehicles representing more than two-thirds of this.²⁰⁰

Liquid biofuels – primarily ethanol and biodiesel – provided around 4% of global road transport energy in 2016 and comprised nearly all (91%) of the renewable share of road transport's energy use.²⁰¹ However, the rapid increase in EV deployment in recent years represents an opportunity to further increase the share of renewables in transport.²⁰² In 2016, an estimated 26% of the electricity consumed by EVs was renewable.²⁰³ Electricity (through the use of EVs) is growing in popularity for shorter travel distances, suiting the needs of urban users while increasing fuel efficiency and helping to reduce air pollution.²⁰⁴

A recent survey of 156 US cities suggests that alternative fuel vehicles such as EVs, hybrid-electric vehicles, and vehicles that run on biodiesel are an increasingly attractive option for local government fleets.²⁰⁵ After a six-month pilot to test heavy-duty and off-road vehicles on a 99% renewable diesel blend, New York City announced its intention to exclusively use the cleaner alternative for its 13,000 diesel-powered vehicles.²⁰⁶

Buses

Urban buses account for around 8% of the greenhouse gas emissions (per passenger-kilometre travelled) associated with transport.²⁰⁷ Diesel was the most popular bus fuel in 2019, used in half of the world's bus fleets, while another 17.4% of buses consumed diesel with additives, and 4.1% consumed biodiesel.²⁰⁸ A further 18% of buses were electric, while compressed natural gas buses accounted for 10.5%.²⁰⁹

In the United States, around 6.4% of bus fleets use **biodiesel**, and in the EU 9.9% of buses use biodiesel and 0.6% use **biogas**.²¹⁰ Trondheim (Norway) introduced 189 new public buses running on either biogas or biodiesel in August 2019, and the initiative is extending to other Scandinavian cities.²¹¹ Public buses in Sweden have run completely on biofuels (dominated by biodiesel) since September 2019, including buses in Gothenburg, Kristianstad, Linköping and Malmö.²¹² Three buses in Mangaluru (India) started running on biodiesel made from cooking oil (and diesel) in 2019.²¹³

i Light rail is defined as "a tracked, electrically driven local means of transport, which can be developed step by step from a modern tramway to a means of transport running in tunnels or above ground level. Every development stage can be a final stage in itself. It should however permit further development to the next higher stage." See European Rail Research Advisory Council (ERRAC) and International Association of Public Transport (UITP), *Metro, Light Rail and Tram Systems in Europe* (Brussels: 2012), https://www.uitp.org/sites/default/files/ckc-focus-papers-files/errac_metrolr_tramsystemsineurope.pdf.

ii Metro is understood as "a tracked, electrically driven local means of transport, which has an integral, continuous track bed of its own (large underground or elevated sections)". See ERRAC and UITP, *Ibid.*

Karachi (Pakistan) is developing a bus rapid transit system with more than 200 public buses fuelled by **biomethane** produced from 3,200 tonnes of cow manure; it was scheduled to begin operations in 2020.²¹⁴ In Bristol (UK), 77 state-of-the-art biomethane buses were expected to start operation in 2019 to improve the air quality.²¹⁵ The public transport authority in Lille (France) has relied almost exclusively on natural gas technology to power its surface vehicles during the last 25 years, and more than 420 active units were using biomethane (from household waste) as fuel in 2019.²¹⁶

The global stock of **electric** buses (battery electric vehicles and plug-in hybrid electric vehicles) has grown rapidly in recent years. Of the 3 million public transport buses in operation worldwide in 2018, more than 460,000 were electric buses, operating in more than 300 cities.²¹⁷ City governments are driving this trend through electrification mandates, subsidies and bus procurement strategies (→ see *Targets and Policies chapter*).²¹⁸

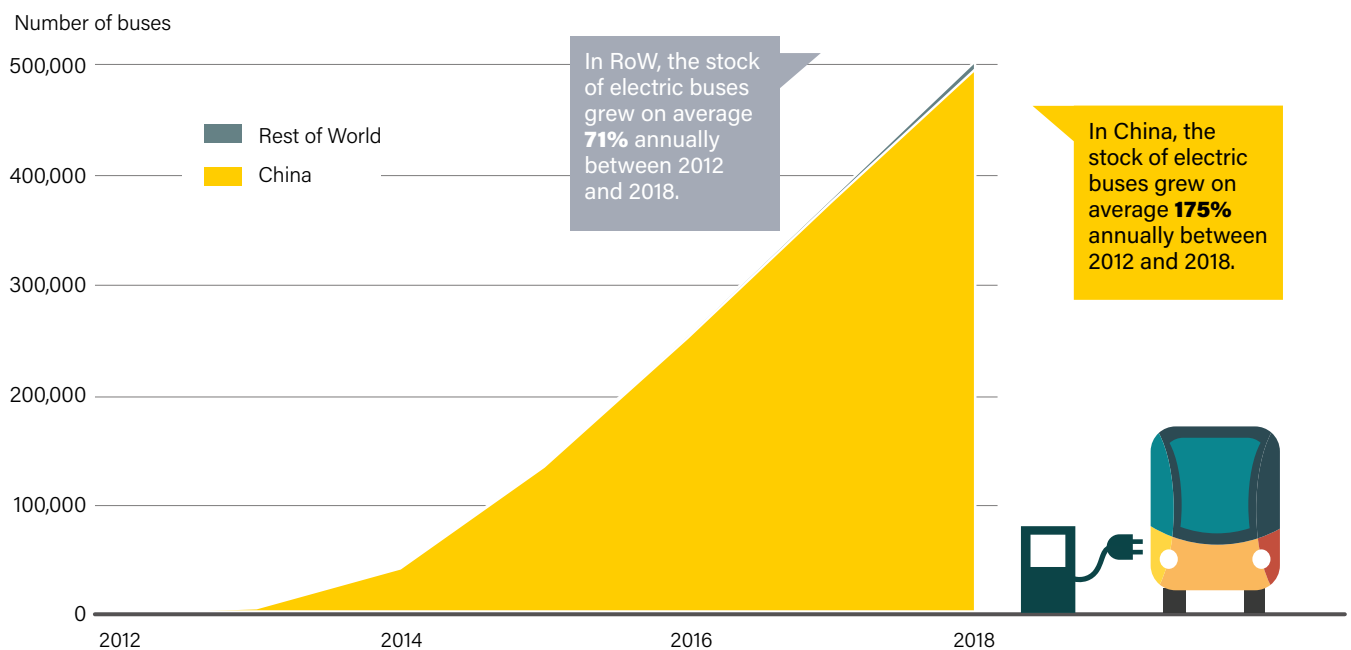
Almost all of the world's electric buses (more than 98%) in 2018 were deployed in China (→ see *Figure 18*); by one estimate, around 18% of China's total bus fleet was electrified as of year's end.²¹⁹ Shenzhen, for example, has more than 16,000 electric buses in operation, driven by the need to reduce local air pollution.²²⁰ More than 2,100 electric buses were in use in European cities such as Berlin (Germany), London (UK), Rotterdam (Netherlands) and Moscow (Russian Federation), and e-buses also were present in Japan and the United States.²²¹ Other cities pursuing efforts to electrify their bus fleets include Abu Dhabi (UAE), Tshwane (South Africa) and Wellington (New Zealand).²²²

In Latin America, the demand for electric buses is surging. To tackle local air pollution, Santiago (Chile) has deployed 200 e-buses, the largest fleet in the region, and is expected to add another 500 in 2020, supporting its plan to make 80% of the city's buses electric by 2022.²²³ Medellin and Cali (Colombia) operated 64 and 26 e-buses respectively in 2019, followed by Guayaquil (Ecuador), with 20 e-buses and São Paulo (Brazil) with 15.²²⁴ Buenos Aires (Argentina) introduced eight electric buses on four major bus lines in a trial phase as part of its Clean Mobility Plan 2035.²²⁵

Most municipal e-bus fleets are not specifically linked to commitments to scale up renewable energy; however, some exceptions exist.²²⁶ In early 2019, Portland (Oregon, US) announced that its entire electric bus fleet would be powered by wind energy, making it the first US public transport company to make this commitment.²²⁷ The electric bus fleet of Bergen (Norway), consisting of 136 buses, was expected to start running on 100% renewable energy in 2020.²²⁸

Hydrogen buses are scaling up rapidly, with several hundred already on the roads in certain Chinese cities.²²⁹ A new H2Bus consortium in Europe, announced in 2019, aims to deploy 1,000 commercially competitive buses fuelled with hydrogen from renewable power, the first 600 of which are due by 2023 in cities across Denmark, Latvia and the UK.²³⁰ In Japan, the Tokyo Metropolitan Government has set up a USD 330 million fund to promote the use of renewable hydrogen buses for the 2020 Olympics.²³¹

FIGURE 16. Electric Bus Global Stock, China and Rest of World, 2012-2018



Note: Data are from BloombergNEF. Sales add up to 425,000 electric buses, which presents a discrepancy from the 460,000 reported by the International Energy Agency.

RoW = Rest of World

Source: See endnote 219 for this chapter.

Cars and two- and three-wheelers

Private cars, two- and three-wheelers and taxis were used for an estimated 67% of urban passenger transport in 2015, while 1.5% of passengers used shared mobility.²³² Although private cars account for less than a third of trips in cities worldwide, they are responsible for 73% of urban air pollutants.²³³ To boost air quality levels, cities have implemented measures to restrict the use of certain vehicle types (diesel or gas-powered, older than a certain year, etc.) in urban areas (→ see *Targets and Policies chapter*).²³⁴ Stimulated in part by these measures in cities such as Athens (Greece), London (UK), Milan (Italy) and Paris (France), alternatively powered cars accounted for 3.6% of the EU car fleet in 2017 (2.8% natural gas, 0.6% hybrid and 0.2% electric) and represented 7.4% of new EU passenger car registrations in 2018.²³⁵

As of 2017, around 99% of the passenger cars produced worldwide were equipped with internal combustion engines, with the majority of these being gasoline or diesel (95%) followed by hybrid EVs (3.4%) and plug-in hybrid EVs (0.7%).²³⁶ While different **biofuel** blends are commonly used in cars, the use of **natural gas** vehicles also has increased rapidly in countries like China, Iran, India and Pakistan.²³⁷ As of 2016, only 0.4% of the cars registered in Europe were fuelled by natural gas.²³⁸

The global stock of **electric** passenger cars (battery electric and plug-in hybrids) reached 5.1 million units in 2018, a 63% increase from the previous year (→ see *Figure 19*).²³⁹ This is similar to the year-on-year growth of 57% in 2017 and 60% in 2016.²⁴⁰ Around 45% of the world's electric car fleet was located in China, where the stock nearly doubled between 2017 and 2018.²⁴¹ Europe accounted for 24% of the global EV stock, and the United States represented 22%.²⁴²

Global electric car sales neared 2 million in 2018, up 68% from the previous year.²⁴³ Sales of plug-in electric passenger cars grew as a share of the total market for new vehicles, from 1.3% in 2017

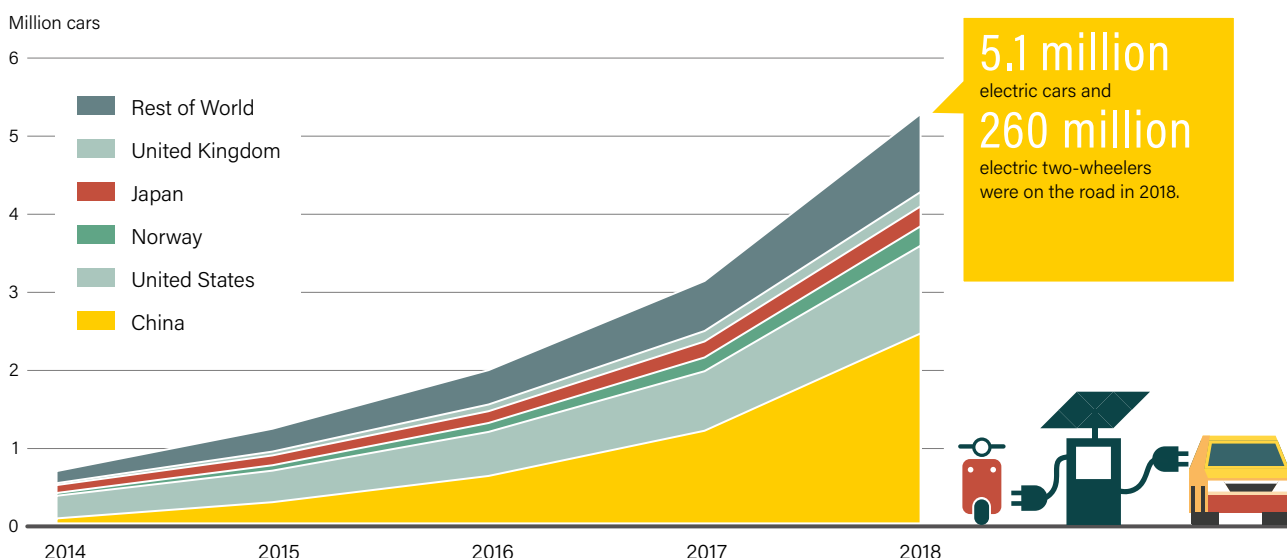
to 2.1% in 2018.²⁴⁴ While these numbers reflect all markets, not only urban ones, cities play an important role: as of late 2018, 40% of all EVs in use were clustered in 20 cities that jointly accounted for 3% of the global population.²⁴⁵ Still, only 0.3% of the electricity used in transport is renewable.²⁴⁶

At the city level, car sharing companies are shifting increasingly to EVs, often coupling this with commitments to power the vehicles with renewables (→ see *Mobilising Finance chapter*). Electric taxi fleets are operating in cities such as Bogotá (Colombia), Brussels (Belgium), Curitiba (Brazil), London (UK), Mexico City (Mexico), Montevideo (Uruguay), Nairobi (Kenya), Rotterdam (Netherlands), Santiago (Chile), São Paulo (Brazil), Shenzhen (China), and Chicago, New York, San Diego and San Francisco (US).²⁴⁷ Although less widespread, renewably powered taxis exist in, for example, Graz (Austria) and London (UK).²⁴⁸ Taxis powered by hydrogen fuel cells were emerging in 2019 in Copenhagen (Denmark) and Seoul (Republic of Korea).²⁴⁹

Light-duty fuel cell electric vehicles (FCEVs) receive the most public attention when it comes to the direct use of **hydrogen** in mobility applications.²⁵⁰ By the end of 2018, around 11,200 hydrogen-powered cars were on the road globally.²⁵¹ More than half of the global FCEV passenger car fleet was in the United States, mainly in California, and Japan and the Republic of Korea also showed notable deployment.²⁵² Hydrogen refuelling stations for road transport vehicles have picked up momentum in recent years, particularly in Japan, Germany and the United States, for a worldwide total of 381 in 2018.²⁵³

Over the past two decades, two- and three-wheeler fleets have expanded at an annual average rate above 7% in many middle- and low-income countries including Bangladesh, India, Indonesia, the Maldives, Myanmar, Nepal, the Philippines and Sri Lanka.²⁵⁴ In recent years, **electric two- and three wheelers**, including electric bikes, bicycles, scooters and motorbikes, have

FIGURE 17. Electric Car Global Stock, Top 5 Countries and Rest of World, 2014-2018



Source: See endnote 239 for this chapter.

evolved as a convenient, rapid means of traversing cities. The global stock of electric two-wheelers reached around 800 million in 2018, one-quarter of which are in China.²⁵⁵

Electric two-wheelers in European cities are distributed mostly through shared rental schemes: the two largest operators, Coup and Cityscoot, have deployed 8,400 electric two-wheelers in Berlin (Germany), Madrid (Spain) and Paris (France).²⁵⁶ More than 50 electric scooter companies are active in cities worldwide, some of which have started to link their scooters to renewable electricity.²⁵⁷ For example, Lime – active in more than 100 cities across Europe, North America, Latin America, the Middle East and Asia – charges its entire fleet of 120,000 scooters with 100% renewable energy.²⁵⁸

The stock of electric three-wheelers exceeds 50 million in China and is around 2.4 million in India.²⁵⁹ Hydrogen-fuelled three-wheelers also have been used in India, mainly in New Delhi.²⁶⁰

URBAN FREIGHT TRANSPORT

Globally, road freight consumes around half of all diesel fuel and is responsible for 80% of the global net increase in diesel use since 2000.²⁶¹ Energy use for road freight transport grew more than 50% between 2015 and 2017 and accounted for 32% of the total transport-related energy demand in 2017.²⁶² Urban road freight accounts for 18% of CO₂ emissions from all surface freight.²⁶³

Although heavy-duty vehicles represent less than a quarter of total freight activity, they are responsible for three-quarters of the energy demand and CO₂ emissions from freight.²⁶⁴ In cities, freight trucks and other heavy-duty road vehicles are used, for example, to deliver mail and packages and to bring building materials to construction sites, and they also include garbage trucks and firefighting trucks.²⁶⁵ Historically, **biodiesel** has been the most commercialised clean fuel option for trucks (supplying 1.6% of final energy to road freight transport), but other fuels are gaining momentum, including natural gas (1.2%), biomethane (less than 0.01%), electricity and hydrogen.²⁶⁶

Trucks fuelled by either compressed or liquefied **natural gas** accounted for around 1% of the total stock in 2015, with around half a million heavy-freight trucks on the road, mostly in India and China.²⁶⁷ More recently, developments have favoured the penetration of methane for trucking in three regions: China, the EU and the United States.²⁶⁸ In 2018, nearly 850 new compressed natural vehicles were put into circulation in the Ile-de-France region (France), two-thirds of which were heavy trucks.²⁶⁹ To improve local air quality, municipal and provincial governments continue to promote the use of compressed natural gas and liquefied natural gas in the heavy-duty sector, including trucks.²⁷⁰

The market for **electric** medium- and heavy-duty freight trucks remains small compared with other types of EVs. An estimated 1,000-2,000 medium- and heavy-duty electric trucks were sold in 2018 in China, where the stock likely exceeds 5,000 units.²⁷¹ In Europe, a group of original equipment manufacturers delivered electric medium-freight trucks to selected fleet operators (such as logistics companies and waste collection services) for commercial testing; these included more than 50 electric trucks from DAF, MAN, Mercedes and Volvo.²⁷²

China led the global deployment of **hydrogen** fuel cell electric trucks in 2019, with more than 500 delivery vehicles operating in the city of Rugao alone and over 100 in operation in and around Shanghai.²⁷³

Waste collection trucks

In the early 2010s, around half of waste collection trucks were dual-fuel compressed **natural gas** vehicles.²⁷⁴ As of 2019, more than 17,000 natural gas waste and recycling trucks operated across the United States, and around 60% of the new collection trucks on order were powered by natural gas.²⁷⁵ Several European cities and regions – including Grenoble and Château Gontier (France) and Madrid (Spain) – have purchased natural gas vehicles to collect urban organic waste.²⁷⁶ The transition to natural gas vehicles leads to reduced noise and air pollution and facilitates the use of biomethane in transport.

In 2019, the City of Fresno (California, US) signed a two-year agreement with Clean Energy for liquefied **biomethane**, produced from solid waste, to power around 140 waste trucks.²⁷⁷ Seattle (Washington, US) had 100 waste trucks as of 2019 – most of them powered by biogas from waste and biodiesel from vegetable oil – and the city plans to double this fleet by 2020.²⁷⁸ Biomethane from dairy and landfill waste will power 86 waste trucks in Chicago (Illinois, US), 40 in Spokane (Washington, US) and 35 in Long Beach (California, US).²⁷⁹ In Surrey (Canada), a biomethane plant opened in 2018 to convert municipal waste and power the city's waste collection trucks.²⁸⁰

In Berlin (Germany), the local waste management company operates a biomethane plant that uses 60,000 tonnes of source-separated waste as feedstock.²⁸¹ On average, 95% of the biomethane produced by the plant is used internally to supply the 150 compressed natural gas trucks that collect the waste weekly.²⁸² Oslo (Norway) also expanded its use of biogas to waste disposal trucks in 2019.²⁸³

Although in its infancy, **electrification** is starting to be used for urban waste trucks in public and commercial fleets.²⁸⁴ In 2018, waste companies in Brazil and China placed large orders for electric refuse trucks (200 and 500 units, respectively), and in 2019 Rio de Janeiro (Brazil) introduced 9 electric waste trucks as part of its plan to expand its fleet to 20 vehicles by the end of 2020.²⁸⁵ Electric waste trucks also have been used in the US cities of Los Angeles and Sacramento (California) and Seattle (Washington), and in Melbourne (Australia) the first electric waste truck started operation in 2018.²⁸⁶ In 2017, two fully electrified waste collection trucks were added in Sarpsborg (Norway), taking advantage of the country's hydropower supply.²⁸⁷

Although coupling with renewable energy remains scarce, there are some examples of electric waste trucks powered by renewable sources. East Waste is developing a 30 kW solar PV system in Adelaide (Australia) to provide clean electricity to its fully electric waste collection truck.²⁸⁸

As of 2019, more than
17,000 natural
gas waste and recycling
trucks operated across the
United States.



Delivery vehicles

Delivery routes into inner-city centres are often referred to as “last mile”, which is what distinguishes the movement of urban goods from other categories of freight transport.²⁸⁹ Because most places of consumption are concentrated in urban areas, the delivery of goods generates a large amount of traffic congestion and related urban air pollution and noise.²⁹⁰ For these reasons, delivery companies and manufacturers have been seeking out alternative fuels for their vehicles (→ see Table 4).²⁹¹

In addition to delivery vans and trucks, the role of two- and three-wheelers in urban freight distribution has increased. In many cities, mostly as a solution to traffic congestion and high emissions levels.²⁹² For example, in Curitiba (Brazil) nearly 10% of registered motorcycles are used for urban freight distribution, and in Chennai (India) two- and three-wheelers carry out 44% of freight trips.²⁹³

TABLE 4. Electrification of Selected Delivery Companies and Renewable Energy Targets, As of Mid-2019

	Regions with Renewably Fuelled Vehicles in Operation	Status as of Early 2019	Target
Amazon	Global, but majority in US	100,000 electric vans ordered (10,000 on the road by 2021; 10,000 by 2030); electric three-wheelers and rickshaws; compressed natural gas vehicles	80% renewable energy across all operations by 2024, and 100% by 2030; 50% of all shipments net zero carbon by 2030, and 100% by 2040
Carrefour	France	200 biomethane trucks	By 2025, reduce greenhouse gas emissions per delivery 30% compared to 2010
DHL	Global, but majority in Europe	7,000 e-drivetrains, 3,200 e-bikes and 9,000 other e-bikes and e-trikes; drivetrains charged with 100% renewable electricity; company-wide renewable electricity use of 63%	Zero emissions by 2050
La Poste	France	35,000 EVs	Reduce CO ₂ emissions by 20% per household served between 2008 and 2020; achieve 100% renewable power by 2020
Post CH	Switzerland	6,000 e-trikes	By 2030, achieve carbon neutrality and 100% renewable energy; switch to 100% electrification for more than 4,600 delivery vans and 180 service vehicles
PostNord	Sweden	5,000 electric bicycles, mopeds and cars (around 28% of the fleet)	By 2020, reduce carbon emissions 40% relative to 2009
Waitrose	UK	10 biomethane trucks	Transport fleet to be zero-carbon by 2045; net zero carbon emissions in all operations by 2050

Source: See endnote 291 for this chapter.

Due to the increasingly restrictive nature of policy and regulation underlying transport in urban centres (for example, low-emission zones, diesel bans) (→ see *and Policies chapter*), more and more delivery companies are exploring the opportunity of integrating biomethane

More than
30 companies

have committed to purchasing over 200,000 EVs by 2030.

into compressed natural gas fleets. Among the most ambitious projects is the commitment by Carrefour (France) to purchase 200 biomethane trucks to make deliveries in Bordeaux, Lille, Lyon, Marseille and Paris.²⁹⁴ Waitrose, a UK-based supermarket chain, also has rolled out a small fleet of delivery trucks powered by biomethane.²⁹⁵

UPS, FedEx, Ryder Systems and Dillion Transport recently began purchasing growing shares of **natural gas** trucks to renew their fleets; UPS in particular plans to buy biomethane converted from waste sources to power its fleet of natural gas vehicles.²⁹⁶ UPS also launched the world's first **hydrogen fuel cell** electric delivery truck.²⁹⁷ Manufacturing companies including Nikola, Scania and Toyota were working on several truck prototypes based on hydrogen fuel cell systems.²⁹⁸

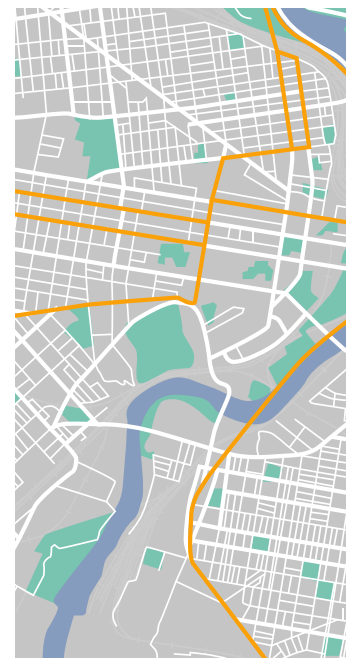
Cities are particularly suited for **electric** vehicle delivery systems because urban areas comprise dense and predictable routes, intense usage and start-and-stop driving.²⁹⁹ To reduce greenhouse gas emissions and increase reputational benefits, more than 30 companies, including ASKUL Corporation (Japan), Ingka Group (Netherlands), the State Bank of India (India) and Unilever (UK), committed jointly in early 2019 to purchasing over 200,000 EVs across their operations by 2030.³⁰⁰ These

companies had deployed or purchased more than 10,000 EVs as of 2018, most of which were using renewable energy for some portion of their charging.³⁰¹

As of 2018, DHL deployed close to 20,000 e-scooters, electric bikes and e-trikes, mostly in Europe but also in growing markets such as Vietnam.³⁰² As of 2018, around one-fifth of DHL's delivery fleet was zero emission vehicles, and the company aims to be zero emissions by 2050.³⁰³ In late 2018, IKEA announced that it would use zero emission trucks for home deliveries in five cities: Amsterdam (Netherlands), Los Angeles and New York (US), Paris (France) and Shanghai (China).³⁰⁴

Postal services have also embraced renewable delivery options. The Swiss postal carrier has pledged to go 100% electric by 2030, and as of 2018 all of the company's electricity needs were met by renewables.³⁰⁵ In France, La Poste committed to powering its fleet of more than 35,000 EVs with 100% renewable energy by 2020.³⁰⁶

To meet carbon reduction targets, many more urban delivery companies are transitioning to EVs, but without making a specific link to renewables. As of late 2018, FedEx had expanded its fleet to include more than 1,100 electric medium-duty vans in California (US).³⁰⁷ Amazon announced in 2019 that it was buying 100,000 electric trucks to make deliveries from 2021 onwards.³⁰⁸ PostNord in Sweden operates around 5,000 electric bicycles, mopeds and cars, and in Austria the national postal carrier has pledged to go 100% electric by 2030.³⁰⁹ In Hamburg (Germany), the delivery company DPD had electrified its entire fleet as of mid-2019, including cars, trucks, cargo bikes and scooters.³¹⁰





MOBILISING FINANCE AND ENABLING BUSINESS MODELS

5

- Eagle Nest, New York
- East Hampton, New York
- Eau Claire, WI
- Encinitas, CA
- Eureka, CA
- Goleta, California
- Hanover, New Hampshire
- Hillsborough, North Carolina
- Kennett Township, PA
- Kennett Township, PA
- La Mesa, CA
- Lafayette, CO
- Large, FL
- Longmont, CO
- Lund Municipality
- Årteå Municipality
- Södertälje Municipality
- Sollentuna Municipality
- Täby Municipality
- Upplands Väsby Municipality
- Uppsala Municipality
- Madison, WI
- Menlo Park
- Middleton, WI
- Minneapolis, MN
- Moab, Utah
- Monterey City, CA
- Nederland, Colorado
- Nevada City, California
- New Brunswick, NJ
- City of Norman, OK
- Northampton, MA



MOBILISING FINANCE AND ENABLING BUSINESS MODELS

Global investment in renewable power and fuels (not including hydropower projects larger than 50 MW) totalled USD 288.9 billion in 2018.¹ Some of this represents investment in cities, although the exact amount is unknown.² Cities self-reporting to CDP in 2017 had a combined 150 renewable energy projects in the pipeline, with total project costs of USD 2.3 billion.³ These projects are part of a wider portfolio of more than 1,100 clean infrastructure projects – which also comprise electric transport and energy efficiency – in over 360 cities, for a total investment value of more than USD 57 billion.⁴

Investment in renewable energy and clean infrastructure projects in cities is expected to keep growing. In 2018, the International Finance Corporation estimated that opportunities for climate-related investments in cities could reach USD 29.4 trillion globally by 2030.⁵ Most of these investment opportunities are expected in green buildings (USD 24.7 trillion), with EVs (USD 1.6 trillion) and public transport (USD 1 trillion) also expected to garner substantial investments.⁶ Direct investment opportunities in renewable energy in urban areas are projected to reach USD 842 billion in 2030.⁷

Cities have an opportunity to realign global investment patterns and to shift the flow of capital towards more sustainable infrastructure, including renewable energy projects. A critical factor in accelerating the energy transition in urban areas is mobilising investment in building-integrated renewable energy infrastructure – such as rooftop solar PV and solar thermal – as well as investing in key enabling technologies such as district heating networks, EVs, storage technologies and sector coupling.

Improving the ability of municipal governments to access finance is a top priority for cities around the world.⁸ Municipal governments can increase the flow of capital to both renewables and key

enabling technologies in two ways: 1) by allocating their own municipal funds and/or borrowing funds for related projects (→ see *Financing Mechanisms section below*) and 2) by creating the conditions for the spread of innovative business models that

support investments by residents, local businesses and other actors such as universities and civil society groups. Important business models include power purchase agreements, leasing and peer-to-peer energy sharing (→ see *Business Models section below*).

The challenge is not only increasing the amount of money available for urban renewable energy projects, but also creating an enabling framework that facilitates existing and new financing from a variety of sources.⁹ Municipal governments are responsible for only a small share of the total financing that occurs within a city's boundaries. Many of the investments that occur – whether in the energy, buildings, commercial or industrial sectors – are made by private individuals and companies, who have their own priorities, planning horizons and funding constraints. This underscores the importance of understanding the various roles that city governments can play not simply in levying taxes and spending the proceeds, but also in taking critical action as conveners, policy makers, trendsetters and promoters of low-carbon investment.

Global investment in renewable power and fuels totalled

USD 288.9 billion
in 2018.



■ FINANCING MECHANISMS FOR RENEWABLES IN CITIES

A municipal government's ability to invest in renewable energy projects often depends on its capacity to reallocate existing budgets and/or broaden its revenue sources.¹⁰ The ability to collect revenues (from taxes, fees and other levies) at the municipal level varies widely. For example, Freiburg (Germany) has an annual budget of USD 3,638 per resident to invest in local infrastructure and other priorities, whereas African cities such as Iwo (Nigeria), Ouagadougou (Burkina Faso) and Addis Ababa (Ethiopia) have much smaller per resident budgets of USD 14, USD 22.5 and USD 91, respectively.¹¹ When comparing cities around the world, the cities with the largest infrastructure deficits also often are the most financially constrained and face the greatest hurdles to mobilising financing, as is the case in sub-Saharan Africa.¹²

Municipal governments encounter challenges in financing both renewable energy projects as well as a wide range of enabling technologies and infrastructure. These challenges include a lack of upfront public capital and limited institutional capacity to impose taxes or fines, institutional inertia, investor perceptions of risk and low returns, the inability to borrow from national governments or to issue municipal bonds, and information gaps.¹³ Municipal governments often have limited budgetary flexibility and face multiple competing claims on their resources, including public safety, water supply, pension liabilities, roads, bridges and waste management.¹⁴ Rapid urbanisation is making many of these pressures more acute.

In addition, many cities (especially in developing countries) are not perceived as creditworthy, making it more difficult to take out bonds and loans and to attract private investment.¹⁵ This challenge is inversely proportional to the cost of capital: cities with lower credit ratings are usually charged higher interest rates to finance projects. Recent estimates show that less than 20% of the 500 largest cities in the developing world are deemed creditworthy in

their local context, and less than 4% are considered creditworthy in international capital markets.¹⁶ Only 25 of South Africa's 280 municipalities are deemed bankable or creditworthy.¹⁷

The lack of bankability is often linked to a perceived lack of financial sustainability (including a low revenue base), limited control over budgets, poor transparency, political instability, and missing regulatory frameworks at both the city and national levels.¹⁸ Limited capacity to develop infrastructure projects can be another significant barrier: the World Bank estimates that only 20% of the world's 150 largest cities have the analytical capacity needed for low-carbon planning.¹⁹

Furthermore, municipal governments often face constraints in how much they can invest in any given year. As a result, city governments frequently have to rely on co-funding arrangements with other levels of government. In some cases, however, this co-funding is inadequate, unpredictable or declining in real terms over time. In Canada, the share of municipalities' funding that comes from the federal and provincial governments has decreased from nearly 50% in the 1970s to 12.3% in 2018.²⁰ Canadian cities' high reliance on local sources of income, as in many cities around the world, makes it difficult for municipalities to invest in major infrastructure projects such as district heating networks and metro systems without partnering with other levels of government or private investors.

To overcome these challenges and narrow the financing gap, municipal governments use a range of financing sources (in addition to their own revenues) and models based on stakeholder collaboration and partnerships.²¹ When funds for renewables in cities are not supplied directly by municipal budgets, they can come from bonds (including municipal and green bonds), public-private partnerships, land value capture and dedicated funds (including from development finance institutions and green banks).

More recently, innovative financing instruments such as crowdfunding have become popular. Crowdfunding applications are less a tool for municipal governments than for individual or commercial interests to finance projects within city limits.

BONDS

Municipal governments can use bonds to finance renewable energy projects. Bonds have the potential to drive investment by allowing cities to access long-term financing at stable prices.²² The USD 100 trillion global bond market is increasingly being leveraged for climate-related investments, including renewable energy projects, through tools such as municipal bonds and green bonds.²³

The
United States
is the world's largest market for municipal bonds, with a total of USD 320.2 billion issued in 2018.

Municipal bonds are one of the most widely used instruments for municipal finance, having helped finance trillions of dollars of urban infrastructure projects since the bonds were first applied in the early 19th century.²⁴ Although municipal bonds traditionally have been used to fund major infrastructure or other projects, a number of programmes specifically link municipal bonds to renewable energy projects (especially solar PV), for example in the California cities of Berkeley, Palm Desert, San Diego, San Francisco, Santa Monica and Solana Beach, and in the state's Sonoma County.²⁵ The United States is the world's largest market for municipal bonds, with a total of USD 320.2 billion issued in 2018.²⁶

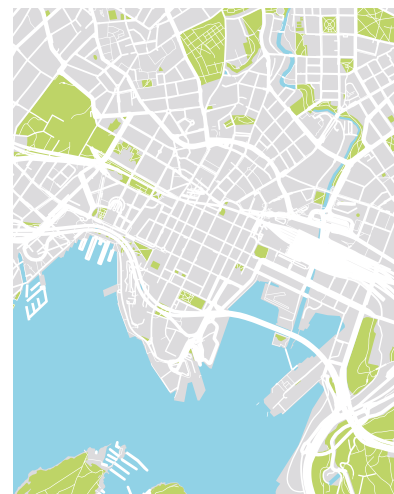
Bonds tend to provide more attractive conditions than traditional bank loans when financing long-term infrastructure projects, and many municipalities (particularly larger cities) consider municipal bonds to be the best tool to meet their financing needs.²⁷ The two main types of municipal bonds are general obligation bonds and revenue bonds. General obligation bonds are loans that can be repaid through a variety of tax and income sources available to the municipality; they rely first and foremost on the creditworthiness of the issuing municipality, not on the financial return or attractiveness of the project.²⁸ In the case of revenue bonds, the loan repayment is backed by a specific revenue stream, such as the electricity sales generated by a renewable energy project or the power rates collected by the municipal utility.

The next-largest markets for municipal bonds (after the United States) are Germany, Japan, Canada, China and Spain.²⁹ Creating bond markets at the sub-national level has become an emerging priority for developing countries and emerging economies: China has been at the forefront of introducing reforms and supporting sub-national capital markets to allow cities and local governments to borrow independently.³⁰ In recent years, local and regional governments in Colombia, India, Poland and South Africa also have gained the ability to issue bonds.³¹ However, only a small number of cities in Africa and Latin America have issued municipal bonds, including Belize City (Belize), Bogota (Colombia) and Rio de Janeiro (Brazil).³²

Despite its attractiveness, issuing bonds to finance city infrastructure carries a host of fixed costs, including legal costs, underwriter fees and the costs of obtaining an independent credit rating, which can make the total cost of bond financing prohibitive even within a well-developed capital market.³³ For small municipalities, a lack of financial expertise, limited access to financial markets and the desire to borrow comparatively small amounts of capital may impede their ability to issue bonds for infrastructure, renewables or other projects.³⁴

In some cases, to tap into the bond market smaller municipalities have joined together to establish municipal pooled financing mechanisms, which typically are established as government-backed entities through co-operation among different local authorities. These pooled mechanisms enable municipal governments to collectively access loans on the capital markets (from national or even international investors) rather than doing so individually or through local banks.³⁵ Pooled financing can help improve access to finance for small and medium-sized cities that have difficulties tapping into capital markets directly.³⁶

In Scandinavia, pooled financing mechanisms have emerged as an important intermediary to help cities and local governments access financing. Such mechanisms account for 98% of public sector borrowing in Denmark, 60% in Finland and 45-50% each in Norway and Sweden.³⁷ Although most pooled financing mechanisms are used mostly in developed countries, this approach has mobilised close to USD 3 billion in municipal bond finance in developing country cities over the last 15 years (for example, in India and Mexico), including to finance projects in the energy and transport sectors.³⁸



In recent years, **green bonds or climate bonds** have emerged as an alternative financial instrument to enable national and municipal governments, as well as companies, to tap into financing. Green bonds are identical to normal bonds, except the proceeds are earmarked for qualifying investments in green technologies or in various forms of climate adaptation and mitigation.³⁹ Investors obtain a certain interest rate over a stipulated period of time, and the funds must be used for the specific purpose for which the bond was issued. This provides investors with greater visibility over the actual use of the funds than is the case for traditional bonds.

In 2018, more than half of green bond proceeds (52%) – at all levels of investment – were earmarked for renewable energy, with differences among countries.⁴⁰ At a global level, around USD 51 billion in renewable energy projects were supported by green bonds in the first half of 2019.⁴¹

City and local governments account for less than a quarter of the global green bond market (around 23% in the first half of 2019).⁴² Authorities in 14 countries issued local green bonds in 2018, with most of them in the United States, Canada, Australia and Sweden.⁴³ Since 2013, more local green bonds have been issued in the United States than in any other country; however, the volume of all US bonds, including green bonds, decreased in 2018 as a result of tax changes and rising interest rates.⁴⁴ In developing countries and emerging economies, local green bonds have been issued in Argentina, Mexico, South Africa and Vietnam.⁴⁵

As of September 2019, city governments worldwide had issued more than USD 670 million in green bonds specifically to finance renewable energy investments.⁴⁶ This includes investments in Honolulu (Hawaii, US), Johannesburg (South Africa), Paris (France) and the cities of Gothenburg, Lund, Malmö, Norrköping and Vasteras (all in Sweden).⁴⁷ Gothenburg has used green bonds to finance Sweden's largest solar project, the expansion of the city's district heating system and the electrification of the vehicle fleet, helping to increase the share of renewables in the city's transport sector.⁴⁸ Johannesburg and Cape Town (South Africa) have used green bonds to fund several low-carbon transport developments, including the conversion of buses to biogas and the purchase of electric buses.⁴⁹

In a more innovative application, green bonds are being used to finance Property Assessed Clean Energy (PACE) loans, which local governments provide to private or commercial property owners seeking to invest in energy efficiency improvements or renewables.⁵⁰ Around 23% of commercial PACE investments and 21% of residential PACE investments are for renewable energy projects.⁵¹ The owners gradually pay back their loans through slightly higher property taxes. The loans are linked to the property rather than to the owners, and repayment can be transferred with property sales. The PACE model is especially popular in the United States (→ see: *Targets and Policies chapter*).



PUBLIC-PRIVATE PARTNERSHIPS

Public-private partnerships provide an alternative means of financing for municipal governments that lack the funds to develop renewable energy or infrastructure projects when there is no guarantee that the private sector will invest.⁵² These arrangements vary across countries, sectors and projects and may take the form of build-operate-transfer, design-build-operate or lease-develop-operate.⁵³

Private participation in infrastructure (PPI) projects, which include public-private partnerships as well as other private financing, were strong in East Asia and in Latin America in early 2017, the most recent year for which data are available.⁵⁴ In developing and emerging economies, private sources financed 48% of PPI projects, public sources financed 23% and development finance institutions financed 29%.⁵⁵ In the first half of 2017, the energy sector dominated PPI projects, accounting for nearly three-quarters of global investments.⁵⁶ Of that share, renewable energy projects accounted for 83%.⁵⁷ As one example, in Yokohama and Kawasaki (Japan), a public-private partnership in 2016 implemented a low-carbon hydrogen supply chain that uses hydrogen produced from wind energy to power forklifts.⁵⁸

LAND VALUE CAPTURE

Land value capture (LVC) is an approach used to help finance new infrastructure projects by harvesting a portion of the increase in value of nearby property caused by this investment. LVC tools include tax increment financing, development charges, development rights and joint development. By unlocking a new source of revenue, LVC can help finance more sustainable and renewably powered urban infrastructure.⁵⁹ Transport is a major catalyst of urban land value increase, and LVC often is used to help fund major transport infrastructure projects by capturing the future value that those developments are expected to create, ahead of their implementation.⁶⁰

To date, no known projects have used LVC to finance renewable energy projects in cities, but some have used it to finance electric transport, enabling the integration of renewable power in the transport sector.⁶¹ LVC has made it possible to secure financing for new metro and rail investments in Copenhagen (Denmark), Gold Coast City (Australia), London (UK) and Portland (Oregon, US).⁶²

LVC mechanisms also are an integral feature of active land management systems, particularly in Europe. In Germany, the cost of the infrastructure for developing Hamburg's municipally owned HafenCity project – one of the largest renewables-based urban regeneration initiatives in the region – was financed in part by the sale of sites.⁶³ The use of LVC also has been central to sustainable urban development in Freiburg, as the city moves towards its goal of using 100% renewable energy by 2035.⁶⁴

DEDICATED FUNDS

In many cases cities are enabling investment in renewable energy projects with the support of dedicated funds from multilateral development banks or green banks. Such funds often require close co-operation across a range of stakeholders and a long-term commitment to renewable energy.⁶⁵

Development finance institutions (also known as development banks), often in partnership with local banks, can provide the kind of catalytic finance required to unlock investments in renewable energy assets, including in capital-intensive projects such as district heating networks. Such institutions can step in with long-term financing that local commercial banks may be unwilling or unable to provide. Around 75% of urban climate finance from development finance institutions comes at commercial rates, but concessional finance (at below-market rates) is also an option.⁶⁶ By de-risking projects and providing support through local capacity building, multilateral agencies are helping to crowd-inⁱ more private financing, greatly increasing the volume of capital available to support low-carbon investment worldwide.

Analysis of nine development banks found that overall climate financeⁱⁱ flows in 2014 totalled some USD 54 billion, representing 26% of the banks' investments, with an average of 31% of climate finance being spent in urban areas.⁶⁷ Separate analysis of eight development banks in 2013 revealed that most finance was in the form of commercial-rate and sub-commercial-rate loans, with 20% of financing going to projects in the energy sector, including renewable energy and energy efficiency projects.⁶⁸

Development finance institutions have supported numerous renewable energy projects in cities. In Africa, with support from the UK Department for International Development and partner banks, municipal and private financing has funded projects including a mini-hydropower plant in Gaseke (Rwanda).⁶⁹ In Asia, Germany's KfW bank invested EUR 500 million (USD 569 million) in 2016 to finance two metro lines in Nagpur (India), where rooftop solar panels installed on stations and depots supply 65% of the metro's energy needs.⁷⁰ In Europe, Banja Luka (Bosnia and Herzegovina) partnered with the European Bank for Reconstruction and Development in 2018 to create a new district heating company that uses a 49 MW biomass boiler plant to heat surrounding districts, reducing reliance on heavy fuel oil.⁷¹ In the Pacific Islands, the World Bank and the Asian Development Bank (ADB) collaborated with the Australian government and others to fund solar PV systems on Kiribati and in Nuku'alofa (Tonga).⁷²

Green banks typically are set up as a public financing authority that leverages private capital to accelerate the growth of renewables and other related technologies. Just like a traditional bank, green banks conduct their own financial assessments and lend funds to qualifying projects. The initial capital often comes from direct government funding, enabling green banks to leverage

i Crowding-in is when an initial investor (for example, a public investor, impact fund or foundation) puts in the first tranche of money and thereby helps to encourage other private sector players to join. Sometimes this involves assuming a lower seniority in the repayment structure, so that public funds are used to absorb the first losses should anything go awry.

ii In this case climate finance is defined as investments in infrastructure and broader climate-related initiatives that contribute to low-carbon urban development or urban resilience.

public resources and combine them with private financing to expand the pool of financing available. They can stimulate further investment and help address a gap in the market by introducing more competition and by improving the terms on which many cities and local governments can borrow for renewable energy and related investments.

The initial cash infusion can be raised in a range of ways, including through the issuance of bonds, surcharges on local utility bills (particularly in cities with their own municipal utility) and direct government allocation of funds, as well as from revenues from dedicated taxes, such as on carbon. The initial funds also can be obtained from foundations and community development institutions.

As of mid-2019, green banks were operating at the national level in Australia, Japan, Malaysia, Switzerland and the United Kingdom, at the state level in the United States (California, Connecticut, Hawaii, New Jersey, New York and Rhode Island), at the county level in Montgomery County, Maryland (US) and at the city level in Masdar (UAE) and Washington, D.C. (US).⁷³ The green bank model also has been deployed across several countries in southern Africa.⁷⁴

The Green Bank Network, a group compiling information across nine green banks worldwide, estimates that 59% of investments are in renewable energy projects.⁷⁵ This represents around USD 8.8 billion of the total USD 14.9 billion invested or committed by green banks by mid-2019.⁷⁶

Efforts also are under way at the international level to establish a global green cities development bank that would bring together multilateral lenders to help overcome the funding challenges that many cities face (particularly in the developing world) by lending directly to support cities' climate action efforts.⁷⁷

CROWDFUNDING

Crowdfunding, or raising money from a relatively large number of people in small, individual amounts – generally via the Internet and social media – has unleashed a new way for city governments to engage residents in financing local infrastructure assets. Crowdfunding models are diverse and include patronage donations, reward-based donations, pre-sales, traditional lending, social lending (without interest), peer-to-peer lending (often at a low interest rate), peer-to-business lending and equity crowdfunding.⁷⁸ These models have been used to finance parks, gardens, transport infrastructure, waste management and more.

Crowdfunding for renewable energy projects is less common, although the approach has been used in Asia, Africa (especially for small, off-grid projects), Europe and North America. In Asia, Indiegogo has been used to fund biogas and solar power projects, and in Africa the Trine platform has financed solar power projects in Kenya (37 loans), Zambia (11), Nigeria (8), Tanzania (6) and Uganda (3), among others.⁷⁹ In Europe, local crowdfunding has been mobilised to finance community solar projects in Geneva (Switzerland), Somerset (UK) and cities throughout the Netherlands, as well as to finance EV smart charging stations in London (UK).⁸⁰

Throughout the EU, crowdfunding frameworks have been developed specifically to finance district energy projects in cities, demonstrating how such approaches can be deployed in different parts of the renewables sector.⁸¹ In North America, numerous examples exist of crowdfunded solar PV projects, including in the US states of Connecticut, Florida and Massachusetts.⁸² A tidal energy turbine project in Nova Scotia (Canada) was supported through crowdfunding of a large publicly listed company.⁸³

By mid-2019,
green banks had
invested or committed

**USD 8.8
billion** in
renewable energy projects.



BUSINESS MODELS DRIVING RENEWABLES IN CITIES

A variety of business models are enabling city governments, local businesses, citizens and large corporations to scale up the use of renewables.⁸⁴ These innovative models have emerged in response to a mix of factors – including price reductions in renewable energy, supportive tax policies and new digital technologies – and have been spurred by changes in consumer awareness and behaviour. While such innovation has been limited mainly to the power sector, new opportunities also are becoming available in heating, cooling and transport. Some key business models facilitating investment in renewable energy projects in cities are described as follows.

- **Renewable energy purchase agreements** are long-term contracts between a renewable energy project and a power buyer (for example, a utility), in which the buyer agrees to purchase the energy generated by the project for a fixed price during the contract's tenure.⁸⁵ These are most common in the electricity sector, where they are called power purchase agreements (PPA).
- **Energy service companies (ESCOs)** provide a range of services including solutions for energy efficiency improvements as well as renewable energy supply. They design improvements/ systems, install necessary elements and offer maintenance.
- **Leasing** enables customers to pay a recurring fee to use the electricity generated by an on-site or nearby rooftop solar PV system for a given time period (solar leasing), or to use a low-emission or electric bus (bus sharing) or electric vehicle (EV sharing). In these cases, the company owns and maintains the system/vehicle.
- **Pay-as-you-go (PAYG)** approaches enable consumers to purchase renewable energy systems (often solar PV) through a small down payment followed by regular instalments until they own the entire system.
- **Peer-to-peer energy sharing** consists of a direct contract between an individual energy generator and a local energy user (or users).

As these models spread to cities around the world, households, businesses and local governments are gaining access to a growing range of choices to participate in and invest in the energy transition.



RENEWABLE ENERGY PURCHASE AGREEMENTS

Renewable energy purchase agreements are used most commonly by corporations as well as cities.⁸⁶ At the city level, they are used predominantly in the United States but also have been applied in Australia and South Africa.

In the United States, tax incentives for renewable electricity have helped make PPAs an attractive model. Because private entities have the requisite tax liability, renewable generation is financed mainly by private, rather than public, entities. Many US cities have partnered with private companies or developers to sign municipal PPAs.⁸⁷ For example, in 2015 the Department of General Services of Washington, D.C. signed a PPA with a wind power project to supply 30-35% of the city government's electricity needs.⁸⁸

In some cases, cities whose electricity demand is too small to make a bilateral PPA possible have grouped with other city governments to sign larger, collective PPAs. Collective PPAs for renewables have been initiated in 20 US cities – including Boston (Massachusetts), Chicago (Illinois), Houston (Texas) and Portland (Oregon) – as well as in Australia (in Melbourne and surrounding municipalities).⁸⁹

ENERGY SERVICE COMPANIES

ESCOs, or businesses that provide energy services ranging from efficiency projects to power supply, represented a USD 28.6 billion market in 2017, up 8% from the previous year.⁹⁰ Although ESCOs are active worldwide, more than half are based in China, roughly a quarter are in the United States, and 10% are in the EU.⁹¹ China alone has more than 2,300 registered ESCOs, of which some 72% were established in the five years up to 2017.⁹² In the United States, state and local government buildings as well as schools accounted for 75% of the ESCO market in 2017, up from 40% in 1990.⁹³ Other countries with ESCO revenues of USD 300 million or more per year include Brazil, Canada and India.⁹⁴

Although ESCOs traditionally have focused on energy efficiency and energy performance improvements, some include renewable energy in their portfolios.⁹⁵ Notable differences exist in ESCO markets across countries and regions. For example, energy supply contracts account for the majority of ESCO business in Germany and Japan, but for very little in Canada, China and the United States. Where energy services are offered, the ESCO model has commonly been used in the solar thermal industry, such as in Dordogne (France) and Austria.⁹⁶ Examples also exist for solar PV installations.⁹⁷

In some cases, municipal governments have entered into agreements with ESCOs for energy efficiency and renewable energy measures in city-owned buildings. For example, in Halsnaes (Denmark), solar PV was installed as part of an ESCO agreement with the target of supplying a fixed percentage of future energy with "green" energy.⁹⁸

LEASING

Leasing schemes enable consumers to rent a specific renewable energy or energy efficiency system, paying a fixed amount over a set period to use that system.⁹⁹ At the city level, the leasing of solar panels to generate renewable power has increased in popularity, but the model also is being used in other sectors, such as through leasing of electric buses or cars.¹⁰⁰ Cities and other consumers typically use leasing schemes to avoid paying the high upfront costs associated with, for example, buying, installing and maintaining solar panels or e-buses.¹⁰¹

A number of companies have begun using **solar leasing** models that enable customers to install solar power directly on their rooftops or on adjacent land at little-to-no upfront cost. These contracts can help customers save money by providing a discount on their electricity price. As an indication of the global range, companies are offering solar leasing in Cape Town (South Africa), Manila (Philippines), cities across India, Malaysia and the Middle East (Dubai, UAE), many European cities including Heidelberg (Germany), and cities across Australia, Canada and the United States.¹⁰² Under this model, individuals as well as municipal governments are able to lease solar panels: in 2013, Kansas City (Missouri, US) installed and leased 25 kW of solar PV systems on municipal buildings across the city.¹⁰³

The importance of this business model is growing. For example, Sunrun operates one of the largest fleets of leased residential solar energy systems in the United States, with some 233,000 customers spread across 22 states, the District of Columbia and Puerto Rico. As of the end of 2018, the company had deployed 1,575 MW of solar PV systems, with a contracted revenue of more than USD 5.3 billion.¹⁰⁴ In Africa, the micro-solar leasing business Zola Electric has brought rooftop solar power to more than 1 million people across Côte d'Ivoire, Ghana, Nigeria, Rwanda and Tanzania.¹⁰⁵

The **leasing of low-emission or electric buses** also is gaining popularity worldwide.¹⁰⁶ Bus leasing allows operators to overcome the financing challenges of acquiring low-emission or electric buses by reducing or eliminating the upfront cost, which is often much higher than for traditional diesel buses.¹⁰⁷ In Asia, bus

leasing schemes exist in Bangalore (India) and Baoding (China), among other cities.¹⁰⁸ The ADB runs a USD 275 million clean bus leasing programme, and in 2017 the bank signed a USD 75 million loan to finance the leasing of low-emission buses in several Chinese cities together with private sector partners.¹⁰⁹ In Europe, the cities of Ängelholm (Sweden), Eindhoven (Netherlands), Prague (Czech Republic) and Warsaw (Poland) all have used e-bus leasing schemes to modernise their fleets.¹¹⁰

By leasing e-buses for their fleets, cities are able to support the integration of renewable energy into their transport systems. For example, in Santiago (Chile), the city's bus operator has leased 100 e-buses that are refuelled using electric charging terminals that draw power primarily from the country's solar PV plants.¹¹¹ Plans are in place to expand bus leasing in other South American cities such as Lima (Peru).¹¹²

Some companies offer bus operators the opportunity to pay upfront for the e-bus itself – which is comparable in price to a diesel bus – but then to lease the costly e-bus battery.¹¹³ Several US cities, such as Moline (Illinois) and Park City (Utah), are using or have agreed to use e-bus battery leasing schemes.¹¹⁴

ELECTRIC VEHICLE SHARING

Cities also can encourage car sharing for electric vehicles. Car sharing platforms, which enable customers to lease or rent cars on a short-term basis, have skyrocketed since 2010, reflecting changing consumer demand as well as growing public and political pressure to reduce air pollution and carbon emissions.¹¹⁵ As of mid-2019, around 236 car sharing operators were active in 59 countries, spanning some 3,128 cities worldwide.¹¹⁶

As part of their portfolios, some car sharing companies offer EVs powered by 100% renewable electricity. For example, Volkswagen's WeShare platform in Berlin (Germany) has offered EVs powered by 100% renewables since late 2018.¹¹⁷ In the United States, multiple car sharing companies have partnered with EVgo, the largest public EV charging company, which has powered its entire network of EV charging stations with 100% renewables since mid-2019.¹¹⁸



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PAY AS YOU GO

Pay-as-you-go (PAYG) companies offer customers the ability to access a stand-alone solar system equipped with a battery bank and a range of appliances to meet household needs. They have become increasingly popular in Africa – where most sales are concentrated in Kenya, Uganda and Tanzania – and in Asia (for example, in India, Indonesia and Pakistan).¹¹⁹

Although the off-grid leasing market traditionally has focused on providing electricity access in rural and remote regions, a growing number of companies are servicing customers in urban and peri-urban areas where the grid supply can be unreliable, including in Goma and Kinshasa (Democratic Republic of the Congo).¹²⁰ Similar developments are driving the adoption of solar home systems in cities across Côte d'Ivoire, India, Myanmar and Nigeria.¹²¹ Examples also exist of software-enabled PAYG interfaces being used in solar home power systems in developed country cities such as San Jose (California, US).¹²²

PEER-TO-PEER ENERGY SHARING

In some cities, customers that generate their own energy supply are using peer-to-peer energy trading platforms to trade with their neighbours, making it possible to monitor and exchange energy in real time. The peer-to-peer model was initiated in New York City (US) in 2016 and has since expanded to many other cities, although it remains somewhat novel.¹²³ Energy trading systems are now active in cities around the world including in the London boroughs of Brixton and Hackney (UK), Fremantle (Australia), Wyomissing (Pennsylvania, US) and more than 11 cities in Germany.¹²⁴ In 2018, a peer-to-peer trading platform based on solar PV was launched in Bangkok (Thailand).¹²⁵

Most peer-to-peer energy trading platforms make use of blockchain technologies. Blockchain provides a way for micro-payments to be made to individual prosumers with low transaction costs and to compensate prosumers for their electricity generation within very short time intervals (for example, 15 minutes).¹²⁶ Hull (UK) created its own encrypted currency (the HullCoin) to enable such transactions to be monetised, and the municipality reinvests all of the profits in efforts to reduce poverty in its jurisdiction.¹²⁷

Peer-to-peer energy sharing networks are facilitating the adoption of renewables in urban areas by creating more decentralised and customer-focused energy networks that help to improve the economics of investing in distributed technologies (for example, by minimising transaction costs). Businesses are able to forge partnerships among consumers and among different companies, linking consumers and enabling them to share, for example, excess renewable electricity and battery storage capacity. Participants often receive better financial return for the small amounts of electricity generated by their system than what is available through traditional net metering or feed-in tariff policies that compensate producers for feeding their excess energy to the grid.





6

CITIZEN

PARTICIPATION



CITIZEN PARTICIPATION

Citizens play a key role in advancing the urban energy transition. The energy systems present in cities affect the lives of urban residents in direct ways, influencing how their energy is produced, transmitted and used as well as factors such as local air quality and the reliability of electricity access (→ see *Drivers chapter*).¹ Specific and sustained citizen participation in energy is critical. Residents can actively shape the renewable energy infrastructure of their cities by, for example, investing directly in renewables (→ see *Mobilising Finance chapter*), choosing among diverse energy suppliers and opting for renewable energy tariffs (whether for electricity or heating). Residents also can have an impact by partnering with others to create community-based energy projects. Meanwhile, citizen opposition to fossil fuel projects can be a driver for renewables, while opposition to renewable projects can be a barrier.²

For a variety of reasons, it is essential that city residents are on board with any transition to renewables. Because the space available for urban renewable energy installations tends to be limited, new infrastructure such as solar panels nearly always affects the direct living space of people. Moreover, because cities are cultural, administrative and economic centres, broad political support in urban areas is essential for efforts to successfully scale up renewables outside city boundaries as well.³

A lack of available data makes it difficult to present a full picture of how citizens participate in urban energy transitions worldwide. Although substantial data are available for certain regions – such as Europe, North America and Australia – data for other regions (such as sub-Saharan Africa) are sparse. Moreover, in cases where national data are available, they often are not broken down at the city level, making it difficult to consolidate information for cities. In addition, different regions and countries use terms related to citizen involvement differently: for example, “community energy” is more strictly defined

in the European context compared to the US (→ see *Community Renewable Energy section below*). All of this makes it challenging to make direct comparisons among countries and regions.

■ ENABLING CONSUMER CHOICE

Enabling consumers to choose their electricity or heat supplier provides new possibilities for renewables in cities. Consumer choice is prevalent mainly in the power sector, but it also exists in the heating and cooling sector. Since the 1970s, when countries began opening up their electricity markets, reforms have enabled customers in many places to choose from different suppliers.⁴ This has allowed residents to play a more active role in shaping the electricity mix of their city or region, for example by choosing suppliers that are investing the most in renewables. In areas where multi-family housing units are common, or for customers with shared roof space, with limited disposable income or who rent rather than own their dwellings, consumer choice is one of the most readily available ways to participate actively in the renewables transition and gain a sense of energy “ownership”.⁵

In many electricity markets worldwide – including in Australia, the Philippines, most of Europe and a growing number of US states – industrial, commercial and even residential customers have access to consumer choice in their electricity supply, rather than having to buy from the incumbent.⁶ Power sector reforms have made it possible for utilities to offer renewable energy purchase options, and have given rise to providers that supply exclusively renewable electricity.⁷ This in turn has pushed many established energy companies to expand their portfolios and include more renewables or even make plans to switch to 100% renewables. For example, E.ON in the UK switched to supply all of its 3.3 million customer households with 100% renewable energy in mid-2019.⁸

In the United States, around 850 utilities – including private, municipal and co-operatively owned utilities – offer renewable energy options and products to their customers.⁹ By the end of 2017, an estimated 5.5 million retail electricity customers procured some

112 TWh of electricity from such programmes, representing around 3% of US retail electricity sales.¹⁰ The largest and most successful US programmes are led by municipally owned utilities, including in River Falls (Wisconsin), Sacramento (California) and Wellesley (Massachusetts), demonstrating the importance of local leadership at the municipal level.¹¹

In the EU, liberalisation of the electricity market helped open the doors for consumer choice, and customers in many countries can now freely select their suppliers.¹² For example, customers in Berlin (Germany) can choose among 60 different suppliers of renewable energy, 5 of which are regional companies.¹³ Customers in Stockholm (Sweden) can choose among more than 100 certified green tariffs from more than a dozen suppliers.¹⁴

In countries without a reliable central grid, urban residents often rely on decentralised pay-as-you-go (PAYG) electricity suppliers that use solar PV. The most prolific off-grid solar PV applications are solar home systems that provide power for lighting and mobile phone charging with the help of battery storage. In Africa, such systems are most common in Kenya, Tanzania, Uganda, Burundi and Rwanda.¹⁵ Several privately owned start-up companies and social entrepreneurs have configured solar home systems and payment models using mobile phones to enable hundreds of thousands of households and small businesses to benefit from solar energy. The business models illustrate the convergence of information technology and renewable technologies. In addition to providing clean and affordable energy, these innovations have led to several thousand skilled jobs across the continent.¹⁶

In certain instances, consumer choice may not be the optimal solution – and instead has to be limited – to provide the greatest community benefit and for environmental and economic efficiency.¹⁷ In the case of district heating, the key to efficient systems is a high share of connected residences; if large numbers of citizens choose to opt out because of consumer choice or other reasons, the efficiency of this approach could decline considerably. For example, Swedish municipalities held a de facto heat supply monopoly, essentially preventing other options for consumers; in Denmark, similar legislation was in place until January 2019, when further liberalisation of the energy sector took place.¹⁸ It remains to be seen what this change means for Danish district heating systems.

Consumer choice is prevalent mainly in the power sector, but it also exists in the heating and cooling sector.

■ THE EMERGENCE OF PROSUMERS

Individual households and businesses are increasingly able to generate renewable energy for their own use because of advances in information and communication technologies (ICT), falling prices for renewable energy appliances, and supportive policies and regulations for renewables. This has led to a new player in the energy system: the prosumerⁱⁱⁱ.¹⁹ Due to the more limited urban space for renewables, the prosumer model is more widespread in rural areas; however, increasing numbers of urban prosumers, supported by city policies, are finding innovative ways to produce their own energy.

Although many categories of prosumers exist, including at the residential, commercial and industrial scales, the most common type are homeowners who install solar panels on their roofs to produce a share of household electricity needs, while exporting the surplus to the grid or using battery technology to store it for later use (→ see *Urban Renewable Energy Markets* chapter).²⁰ This development has great potential to further the energy transition in cities worldwide. Small-scale solar PV solutions are particularly suitable for cities, as roof space is often readily available.

National and state-level policies play an important role in shaping the prosumer pathway. The main policy and regulatory instruments to support the rise of prosumers in cities have been net metering and feed-in tariff (FIT) policies, often combined with supportive tax incentives and rebate programmes (→ see *chapter*).²¹

In Australia, cities are rapidly scaling up rooftop solar, driven by state-level policies and increasingly attractive economics. By the end of 2018, 21.6% of houses (excluding apartments) in the country had installed solar PV systems, with even higher shares in Queensland and South Australia (more than 30% of houses) and in some individual postal codes (more than 75%).²² In Africa, less than 1% of households in Lagos (Nigeria) have rooftop solar, but numbers are rising because distributed solar is generally seen as a good solution for small and medium-sized companies that suffer from irregular power supply from the centralised grid.²³

In cities across the United States, as well as in places like Manila (Philippines) and Cape Town (South Africa), the emergence of new business models such as solar leasing have reduced the upfront costs and complexity of going solar, boosting the prosumer sector (→ see *Mobilising Finance* section). However, in many cities this model is less common due to regulatory barriers, a lack of supportive policies, the characteristics of the built environment and the prevalence of tall multi-unit buildings, which makes it more difficult to install customer-sited solar.²⁴ For these kinds of housing arrangements, residents must collectively make decisions on how to use the roof space and how to finance solar PV systems, as well as grapple with legal questions about ownership and grid access. City administrations can provide support, for example through local energy agencies and by simplifying building codes and other local regulations. Alternatively, balcony-mounted plug-in solar PV modules are a viable option for tenants that lack access to roof space.

i No breakdown is available of PAYG between urban and rural areas.

ii In Copenhagen (Denmark), the local district heating system supplies 97% of the city's heat demand, while across Sweden district heating systems provide more than half of the heating needs of residential and service sector buildings. Source: See endnote 18.

iii By definition, prosumers are both producers and consumers of energy, using their own energy supply to meet part or all of their energy needs. See endnote 19.

Many municipal governments have actively supported prosumers through specific policies and programmes (→ see *Targets and Policies chapter*). For example, 40 municipalities in South Africa have allowed small-scale embedded generation of electricity, and as of July 2017 an estimated 138,000 small-scale solar PV systems totalling 144 MW of installed capacity were in use in the country.²⁵ Durban is one of 25 municipalities that have introduced net metering schemes to encourage local residents and businesses to invest in distributed renewable energy projects.²⁶ Two cities in South Africa actively encourage citizen participation by offering financial support. Under Cape Town's Property Assessed Clean Energy (PACE) programme, the city plays an intermediary role between the prosumer and the financier by facilitating payments.²⁷ In Nelson Mandela Bay Metropolitan Municipality, a programme aims to develop up to 250 MW of rooftop solar PV capacity by facilitating the sale of surplus electricity generated by local prosumers to other consumers in the area.²⁸

Evidence shows that to achieve high numbers of prosumers in a city, it is beneficial to mix different policies and have a coherent policy package in place. Seoul (Republic of Korea) has an ambitious target to reach 1 GW of installed solar PV capacity by 2022, and a bundle of policies has set the city on course to reach this goal, including a citywide FIT, direct subsidies, leasing schemes and loans for solar PV panels at preferential rates.²⁹ In addition, the city has offered to rent out roof space on public buildings and other open spaces to co-operatives and private companies that want to set up larger-scale solar PV. Finally, Seoul has made it obligatory for public institutions to install solar PV systems in case of renovation or modification of public buildings. Between 2015 and 2018, 13,125 households in Seoul become prosumers, generating a combined 252,989 MWh of electricity in 2018.³⁰

In a slightly different approach, Newstead (Australia) empowered local prosumers by negotiating with its electricity distributor in 2018 to reduce network charges for power generated from small-scale solar PV systems.³¹ In Kalmar (Sweden), households that do not have an independent roof and little financial capital can become prosumers by buying shares in two solar PV parks developed by the local public energy company Kalmar Energi, which together produce some 2.9 million kWh annually.³² Customers can buy shares corresponding to a maximum of 80% of their average annual electricity consumption, with the amount produced deducted from their electricity bill.³³

Other viable technologies for urban residents include combined heat and power (CHP) generators that use biomass-based fuels (for example, wood chips), solar hot water systems, and systems that can be powered with electricity from renewable sources, such as air-to-air heat exchangers and ground-source heat pumps. Germany alone has 2.4 million solar thermal installations for water and space heating, most of them on single-family homes.³⁴

COMMUNITY RENEWABLE ENERGY IN CITIES

The number of community energy projectsⁱ using renewable sources has surged in recent years.³⁵ Through this approach, a community collectively initiates, develops, owns or invests in projects that deliver direct benefits to the local population.³⁶ Assessing the full scope of community energy initiatives in cities is difficult, however, because of a lack of data and varying definitions of the term. For example, in Germany community energy refers more narrowly to citizen associations, whereas in the United States it includes projects for which electric utilities (not necessarily municipal utilities) or third-party providers sell "shares" to local consumers. Nevertheless, the trends show that renewable energy initiatives involving citizens are increasingly present in cities worldwide.

Although community energy frequently is associated with northern European countries such as Denmark and Germany, such projects are emerging elsewhere including Australia, Canada, Japan, Thailand and the United States.³⁷ Historically, community energy has been more prevalent in rural areas, but the number of urban projects is increasing, driven by environmental awareness, by the emergence of new business models that make community-level financing easier and by a desire for greater ownership of local energy infrastructure (→ see *Drivers chapter*).³⁸ Movements such as Transition Towns are encouraging renewable energy pioneers to bring community energy concepts to cities worldwide (→ see *Box 5*).³⁹

In community projects, sometimes hundreds or even thousands of households come together to finance projects that are larger than what individual residents could finance alone. These efforts often are enabled by national, state/provincial or local policies. Around the world, community energy projects are helping customers – including local businesses and low-income residents – save money on their energy bills by producing energy on-site, while often enabling participants to earn a decent return on their investment.⁴⁰



ⁱ Community energy projects vary in size and organisational structure and can include housing associations, co-operatives, non-profit customer-owned enterprises and partnerships initiated by local governments. Projects also vary in technology, governance, funding and motivation. They often come in the form of co-operatives made up of citizens, sometimes in combination with public entities or companies. Most community energy projects focus on producing electricity, but many cases also exist of collectively owned heating systems, as in Feldheim, Germany. See endnote 35.

BOX 5. Transition Towns

The Transition Towns movement, or Transition Network, was founded in 2006 as a grassroots movement with the aim of making local communities more resilient and independent from fossil fuels. The movement seeks to transform communities by focusing on increasing social capital, building up resilient local economies and phasing out fossil fuels. It started in 2006 in the English town of Totnes and has since spread to more than 1,000 projects in over 50 countries as of 2019. In many instances, local Transition Town initiatives co-operate with city administrations.

The umbrella of the Transition Towns movement connects hundreds of communities and local initiatives worldwide and has contributed to bringing renewable energy technology into cities. In Japan, the Transition Town initiative Minami Aso was founded in direct response to the Fukushima nuclear accident in 2011, and a central aspect of the group is the integration of renewables into the built environment. The Átalakuló Wekerle Transition Town in Hungary's capital Budapest is advancing local energy efficiency and renewable energy projects. In Nottingham (UK), the V3 Power project

is a worker-owned co-operative that offers education and service around renewable energy technology, empowering residents to become prosumers and to increase their energy independence by generating their own energy with renewable sources.

Source: See endnote 39 for this chapter.



Thanks to progress in Denmark, Germany and the UK, Europe is at the forefront of community energy development. The European Federation of Renewable Energy Cooperatives (REScoop) represents 1,500 co-operatives encompassing 1 million citizens that have jointly invested EUR 2 billion (USD 2.3 billion) in renewable energy projects.⁴¹ Collectively, their annual turnover is EUR 750 million (USD 858 million), and they have created roughly 1,100 direct jobs regionwide, demonstrating the potential scale of local and co-operative initiatives to mobilise investment and drive job creation.⁴²

In 2017, Germany was home to some 1,024 registered energy co-operatives, of which 547 used solar PV, 158 bioenergy, 112 wind and 27 hydropower.⁴³ These accounted for around 100 GW of installed electricity capacity, and an additional 195 co-operatives managed local heat grids.⁴⁴ In Denmark, at least 1,109 community energy projects existed during the period 1980-2018; the number peaked at 931 in 1999 and has since declined to around 650 in 2014.⁴⁵ Many of these initiatives are wind power associations (a more rural phenomenon) and district heating systems, which often are located in densely populated areas such as cities.⁴⁶

In 2018, the UK had 275 community energy organisations, accounting for 168 MW of installed electricity capacity and for 1.96 MW of heat generation; of these groups, 231 were located in England (including 10 in London) and 43 were in Wales.⁴⁷ A special funding programme for urban community energy initiatives has awarded 75 grants to projects using a variety of technologies, and the country has added 33 energy storage projects and 29 low-carbon transport projects.⁴⁸ However, recent policy changes such as decreases in subsidies and FITs have made it difficult for communities to establish new projects.⁴⁹

In Sweden, municipalities have considerable power to engage in local energy planning, and district heating systems were present in nearly all of the country's municipalities (283 out of 290) as of mid-2019. Many municipalities own all or part of local energy companies, making it easier for city governments to support renewable energy systems and establish community-based projects. For example, the local energy providers Kalmar Energi, Öresundskraft, Sala-Heby, and Telge Energi all have started local community energy projects using wind and solar PV. However, it is difficult for citizens in Sweden to establish community energy projects that are independent of local authorities, because of the country's centralised system for electricity production, its already carbon-efficient electricity sector and its low energy prices. As of 2018, some 140 citizen-led initiatives in Sweden were producing around 160 MW of renewable electricity.⁵⁰

Housing associations have great potential to support community energy projects. In Sweden, national subsidies have supported efforts by housing associations to use their shared roofs for solar PV; as of 2018, at least 10 housing associations had set up renewable energy systems.⁵¹ In Tallinn (Estonia), the Vilde 70 association, consisting of 120 residents in 54 apartments, installed new heat pumps for heating and a 150 kW solar PV system during a major renovation of its housing stock in 2015.⁵²

In Denmark, many wind farms are at least partly community owned, including the Middelgrunden project off the coast of Copenhagen, which is owned 50% by a municipal utility and 50% by around 10,000 investors who bought shares.⁵³ In Geneva (Switzerland), residents can invest in and own shares of the solar PV system installed on the roof of the Stade de Genève. Each share corresponds to 100 kWh of electricity per year for 20 years, and the electricity produced by the share is deducted from the

resident's home electricity bill.⁵⁴ In 2016, Eelko (Belgium) issued a concession contract to develop a district heating grid in which citizens own at least 30% of the lots; the goal is to transition the grid to 100% renewable energy supply by 2036 at the latest.⁵⁵

In the United States, the term community energy is defined more broadly and includes projects developed by electric utilities and third-party providers that sell shares to local customers. As of August 2019, some 5,379 community energy projects had been registered, of which at least 226 were located in urban areas.⁵⁶ Many are solar PV projects, and by the end of 2018 thousands of communities across 43 states had successfully developed a combined 1,387 MW of community solar and "shared" solar projects.⁵⁷ The biggest is the Rosemount Community Solar Garden development in Minneapolis (Minnesota), with a capacity of 32 MW.⁵⁸ To address energy poverty, the state of Colorado has initiated a number of Low-Income Community Solar Projects, which together provide affordable electricity to 380 households state-wide.⁵⁹ Similar programmes include the Illinois Solar for All scheme and the Denver Housing Authority Solar programme.⁶⁰

Several Asian countries have a long-standing history of community energy. Micro-hydropower is widespread in India and Nepal and has helped provide energy access to rural municipalities.⁶¹ Japan is home to some 200 community energy projects.⁶² By 2017, the country's total community energy capacity for solar PV reached 86 MW and 37 MW of wind, reflecting the growing popularity of such projects in the wake of the 2011 Fukushima nuclear disaster.⁶³

Japanese urban community projects exist in Aizu, Odawara, Shizuoka, Takarazuka, Tokushima and Yamaguchi (all Japan), with a combined installed capacity of 17 MW of wind and solar PV.⁶⁴ Iida made plans as early as 2004 to install solar PV systems on 38 roofs of public buildings; local residents raised the required JPY 201.5 million (USD 1.85 million) in investment and became owners of the plants, which are expected to generate revenues until 2024.⁶⁵ Since 2016, in the Tokyo suburb of Tama City, the community solar start-up Tama Empower, established in response to the Fukushima disaster, provides "DiO (Do it Ourselves)" solutions to local communities, involving citizens in learning about solar PV systems, managing the installation and providing support on operation and maintenance.⁶⁶

More than 100 community energy projects are active in Australia.⁶⁷ In Sydney, a group of citizens called Inner West Community Energy has supplied information and technical support for a variety of projects, including a 50 kW solar PV system installed on a parking facility that connects to three EV charging stations.⁶⁸ The Pingala group, also based in Sydney, sets up collectively owned solar gardens to help reduce the electricity bills of residents who own shares in the project.⁶⁹ At the initiative of students, a solar PV and smart metering system was installed at the Stucco housing co-operative in Newtown, a municipal-owned collective housing space for students at the University of Sydney; the system compares tenants' electricity consumption with the output of the solar PV system, helping students reduce their bills.⁷⁰ Elsewhere in Australia, the Lismore Community Solar Project, financed jointly by community members and the city council, consists of two 99 kW solar PV farms, the first of which began operating in 2018.⁷¹ In New Zealand, at least 70 community energy projects are active

(24 in urban areas) with a combined capacity of 606 MW.⁷²

In Latin America, community energy projects are less prevalent. Still, community energy structures played an important role in electrifying large parts of

Costa Rica, although their importance in pushing a renewable energy system based on co-operatives has since declined due to centralised energy governance.⁷³ In Brazil, the Faxinal Housing Project in Curitiba incorporated renewable energy components in the planning phase, and 26 new low-income housing units have gained access to solar energy produced on-site.⁷⁴

Community energy projects in many countries, including across entire regions of Africa, often lack political support. In West Africa, support mechanisms such as FITs are largely absent, and in most African countries, small-scale renewable energy producers do not have permission to feed into the grid.⁷⁵ Even in places in sub-Saharan Africa where targets and supporting policies are in place, cities often lack the resources to facilitate a roll-out of community energy projects.⁷⁶

Nevertheless, in many parts of Africa community energy projects have played an important role in providing energy to rural communities that remain unconnected to central grids. Communities in South Africa increasingly are choosing renewable micro-grid solutions in part because the national grid is unreliable, but also because of the declining costs of solar PV panels and the tripling (in real terms) of domestic electricity tariffs in the last decade.⁷⁷ In the City of Tshwane, a co-operative of 25 small-scale farms uses a combination of solar PV and biogas from livestock waste to power the local community.⁷⁸ Elsewhere in Africa, recent tax exemptions for renewables in Mali have opened the door to an increase in community energy projects.⁷⁹

City administrations can support community energy projects in different ways, for example by allocating a specific quota for local ownership of new renewable energy projects. This approach is widespread in Denmark, where local residents as a collective have the preferential right to buy up to 20% of shares in wind farms before shares are sold to external investors.⁸⁰ In the case of the Buurzame Stroom project in Ghent (Belgium), the city administration played the role of intermediary, initiating community energy co-operation among residents, companies and universities in 2018 with the aim of combining different modes of energy production and use.⁸¹ Diverse housing ownership structures are included to give low-income neighbourhoods the opportunity to benefit from the project's renewable energy developments, including local grid management, the use of electric cars, battery technology at the household level and 5,000 m² of solar PV panels.⁸²

City administrations support community energy projects, for example by allocating a specific quota for local ownership of new renewable energy projects.

Progress in information and communications technology has enabled people to establish new forms of energy co-operatives that connect consumers directly through apps and interactive databases with a network of small-scale producers. ICT also introduces into the energy sector alternative economic concepts such as crowdfunding and the sharing economyⁱ (in the form of collective-self consumption). In Europe, for example, the Catalan (Spain) organisation Som Energia uses its online platform to connect electricity producers and consumers; with more than 58,000 members, the co-operative produces 13.5 GWh per year and supplied energy to 300 member municipalities in 2017.⁸³ The Portuguese co-operative Coopérnico, with 1,345 members, has invested more than EUR 1 million (USD 1.4 million) in local renewable energy projects via its online platform and project database, whereby members can inform themselves about and invest in projects.⁸⁴

Through its EnerCit'IF project, Paris (France) is providing renewable energy co-operatives access to roof space on publicly owned buildings. Information on available and suitable roof space can be found via an online database. In the first half of 2019, city residents raised EUR 100,000 (USD 110,000) used in combination with subsidies from the city, to set up solar PV systems on nine schools in Paris.⁸⁵ Lisbon (Portugal) launched a similar project – the SOLIS platform – in May 2019 to bring together public authorities, citizens and companies to use the city's available rooftop space for solar PV production, aiming for 103 MW of cumulative installed capacity by 2030.⁸⁶ In Croatia, crowdfunding of renewable energy projects has proven promising, as demonstrated by the 30 kW solar plant on the city-owned Development Centre and Technology Park in Križevci.⁸⁷ A dedicated crowdfunding platform also exists for renewable energy projects in the country.⁸⁸

■ PARTICIPATORY GOVERNANCE TO MINIMISE OPPOSITION

Participation strengthens local democratic processes and produces solutions that are better tailored to the needs of local residents.⁸⁹ This way, cities can achieve fairer configurations of the local energy system, making sure that benefits stay in the communities. Participatory planning processes help to avoid local opposition to energy projects, such as NIMBY or “Not in My Backyard” perspectives (→ see Box 6).⁹⁰ Many cities have experienced resistance to fossil fuel projects (often coal power plants or natural gas infrastructure), including Hamburg (Germany), where citizens objected to a coal-powered district heating system.⁹¹ In South Africa, civil society organisations have taken the Department of Energy to court over irregular processes on nuclear energy procurement, stalling the process indefinitely and creating a key milestone and turning point for renewables in the country.⁹²

Opposition also can arise towards renewable energy projects, due to concerns about aesthetics, noise or nature protection issues. In some cases, opposition is entangled with existing conflicts around land and the failure to recognise indigenous rights and practices. In several cities in Oaxaca (Mexico), inadequate local participation led to violent conflict related to the construction of wind farms.⁹³ Conflict also has arisen around the Fosen wind park near Trondheim (Norway), which is sited on land traditionally used as reindeer pasture by indigenous Sami herders.⁹⁴

Participatory planning and governance are tools to cater to the needs and preferences of local communities in renewable energy development. This approach aims at including all citizens in strategic and managerial decision making at the local level. This way, conflicts and opposition are addressed early on and citizens take an active role in shaping their energy systems, which in turn strengthens local energy democracy.⁹⁵

BOX 6. NIMBY

NIMBY, or “Not In My Back Yard”, describes a negative attitude towards projects sited close to one's place of residence. These projects can be any kind of infrastructure or building, including social housing, hospitals or transmission lines. In the energy sector, NIMBY does not necessarily involve the rejection of a specific technology, but rather may reflect discontent with how a particular project was planned, or with how certain decisions around the project were made. Similarly, NIMBYism may be higher when local residents are not given the opportunity to invest in the project.

In most cases, NIMBY in response to energy projects is a rural phenomenon, as most large energy projects – such as the construction of wind farms or transmission lines – occur in the countryside. However, NIMBYism also has slowed the deployment of renewables in or near cities. In Copenhagen (Denmark), an onshore wind energy project was scaled down from eight to only three turbines after local citizens objected to the construction of a larger wind park. NIMBY, especially to energy projects, often can be addressed effectively by including inhabitants in decision-making processes and guaranteeing the financial participation of local communities.

Source: See endnote 90 for this chapter.

i Broadly defined, the sharing economy is a concept in which people use ICT to share underutilised services and assets. In theory, the sharing economy can help with increasing efficiency and reducing material throughput. An example is tool libraries, in which citizens can borrow power tools that they no longer need to own themselves. With regard to renewables, concepts from the sharing economy can help link producers and consumers and buffer intermittencies of energy production.

ii The core idea of energy democracy is to establish local and democratic control over energy production and distribution through a transformation of our energy systems, including the phase-out of fossil fuels, the (re-)municipalisation of critical energy infrastructure and the inclusion of decentralised producers. This transition towards energy democracy entails reducing emissions and minimising energy poverty. Citizens are the driving actor for energy democracy and take an active role in decision-making processes and in the production of renewable energy. This way, the prosumer becomes a key stakeholder in an energy democracy.

Participatory governance is a growing trend, mainly in Europe but also in other places around the world.⁹⁶ In Gaildorf (Germany), residents participated actively in the planning and construction of a combined wind and pumped storage hydro-power plant; the municipality made acceptance

Participatory governance

is a growing trend, mainly in Europe but also in other places around the world.

by citizens a precondition for issuing a building permit and held a referendum before giving permission to the project developer.⁹⁷ The Dutch city of Enschede started the project *Enschede wekt op* (Enschede wakes up) as a platform to involve residents in the city's plan to transition to 100% sustainable energy by 2050.⁹⁸ In France, the city of Grenoble has initiated a citizen participation process to meet its goal of 100% renewable electricity by 2022; residents were invited to contribute to the city's climate roadmap, and existing initiatives were incorporated into the general plans.⁹⁹

Cities also are starting to use **participatory budgeting**ⁱ to let residents participate in decisions around local investments, including renewable energy projects. For example, Paris has earmarked 5% of its investment budget, or around EUR 500 million (USD 553 million), for participatory budgeting, of which 20% (EUR 100 million, or USD 110 million) is reserved for climate-related investments.¹⁰⁰

In sub-Saharan Africa, involvement of citizens and civil society organisations in energy projects is generally lacking.¹⁰¹ There are notable exceptions, however. In South Africa, the National Planning Commission is undertaking extensive public participation in the roll-out of the Just Transitionⁱⁱ, the country's attempt to chart a pathway towards a socially just phase-out of coal from the energy mix.¹⁰² At the same time, there are calls for community-owned renewable energy projects, especially from low-income communities, both to enable poor households to benefit from receiving affordable and clean energy and as a means of income generation.¹⁰³

In response to these calls, South Africa's CHOICES (Community and Household Options In Choosing Energy Services) project includes citizens in energy planning, with the aim of reducing energy poverty by empowering communities to make energy choices that reflect their specific needs.¹⁰⁴ The City of Cape Town provides two platforms for discussion: the Energy, Water and Waste Forum (previously called the Energy Efficiency Forum) convenes regular meetings with community groups, civil society organisations and businesses to share solutions and discuss concerns and project updates, while the Sustainable Energy Markets directorate convenes a forum to discuss solutions to energy poverty.¹⁰⁵

RE-MUNICIPALISATION AND PUBLIC OWNERSHIP

In recent years, a wave of cities worldwide have taken previously privatised infrastructure back into their own hands. Between 2005 and 2017, 835 cases of so-called re-municipalisation were recorded globally, of which 311 were related to the energy sector, the majority of them since 2010.¹⁰⁶ Roughly 90%, or 284, of these energy-related (re-)municipalisations took place in Germany, but cases also exist in the United States (6), the UK (5) and Japan (4), among other countries.¹⁰⁷

Citizen initiatives are often the starting point for the re-municipalisation of city electricity and district heating grids or energy companies.¹⁰⁸ Notable examples of re-municipalisation are Berlin and Hamburg (Germany), where residents pushed the cities to buy local electricity grids back from private investors partly with the aim of providing more renewable energy for local residents.¹⁰⁹

Having direct control over energy infrastructure can make it easier for city and local government officials to integrate a higher share of renewables into the local energy system.¹¹⁰ In Barcelona (Spain), the city-owned Barcelona Energia supplies electricity to public buildings and facilities, public companies and around 20,000 homes.¹¹¹ The electricity comes from certified renewable sources and favours local producers, which reflects Barcelona's attempts to strengthen local democratic decision making.¹¹² In Cádiz (Spain), the city-owned Eléctrica de Cádiz meets all the power needs of public buildings and facilities and supplies 80% of households with electricity from renewable sources.¹¹³ In addition, EUR 500,000 (USD 572,368) of company profits are used to support projects addressing energy poverty in the city.¹¹⁴

Vienna (Austria) owns Wien Energie, the local utility company that supplies around 2 million residents with electricity, heating and cooling.¹¹⁵ The company has integrated 32 citizen-owned plants (including 13 in the city of Vienna), which use a variety of renewable energy technologies and are financed through crowdfunding organised by the company.¹¹⁶ The company also helps residents become prosumers by providing "turnkey" solar PV systems, which are ready to use and do not require residents to have technical expertise.¹¹⁷

In 2015, the city of Nottingham (UK) founded the non-profit Robin Hood Energy company, which aims to reduce energy poverty by providing affordable energy to local citizens. The company's "green energy" stream enables customers to choose 100% electricity from certified renewable sources.¹¹⁸ A year later, Bristol (UK) took a similar step and founded Bristol Energy, which aims to increase the share of renewables while also fighting energy poverty.¹¹⁹

i "Participatory budgeting is a democratic process in which community members decide how to spend part of a public budget", from Participatory Budgeting Project, "What is PB?" <https://www.participatorybudgeting.org/what-is-pb/>, viewed 15 October 2019.

ii Just Transition is a framework developed by the trade union movement to encompass a range of social interventions needed to secure workers' jobs and livelihoods when economies are shifting to sustainable production, including avoiding climate change, protecting biodiversity and ending war, among other challenges. It has been broadened beyond a focus on protecting workers only to also encompass wider society, especially the most vulnerable poor and working class communities. See endnote 102.

■ TABLE R1. Renewable Energy Targets, Municipal Operations and City-wide in Selected Cities, As of Mid-2019

Country	Municipal Operations Targets	City-wide Targets
Australia	Cockburn (20% by 2020), Sydney (30% by 2030)	Canberra (100% by 2020), Sydney (30% by 2030), Uralla (100% by 2020-2025)
Austria		Amstetten (100% by 2030); Bruck an der Leitha (100%, no date), Kötschach-Mauthen (100% by 2020), Salzburg (32% by 2050)
Belgium	Ghent (50% by 2020)	Antwerp (13% by 2020), Brussels (27% by 2030), Ghent (20% by 2020)
Brazil	Fortaleza (30% by 2030)	Belo Horizonte (79.3% by 2030)
Bulgaria		Burgas (26% by 2020)
Canada	Calgary (100% by 2025), Nelson (100% by 2050), Saanich (100% by 2050), Slokan (100% by 2050), Victoria (100% by 2050)	Calgary (30% by 2030), Edmonton (10% by 2035), Nelson (100% by 2050), Saanich (100% by 2050), Slokan (100% by 2050), Vancouver (100% by 2050), Victoria (100% by 2050)
Chile		Independencia (30% by 2030)
China		Beijing (8% by 2020, 15%, no date), Shenzhen (15% by 2020)
Chinese Taipei		Kaohsiung (8% by 2025, 11% by 2030)
Colombia	Bucaramanga (30% by 2025)	Bucaramanga (30% by 2025)
Croatia		Kaposvar (100% by 2050)
Denmark		Copenhagen (100% by 2050), Egedal (8% by 2020), Frederikshavn (100% by 2030), Gladsaxe (100% by 2035), Samsø (100% by 2030), Sønderborg (100% by 2029)
Ecuador	Quito (2% by 2045)	
Estonia		Tartu (45% by 2020)
Finland		Helsinki (20% by 2020)
France	Besancon (23% by 2020), Paris (100% by 2050)	Grenoble (100% by 2050), Le Mené (100% by 2030), Loos (100% by 2050), Nancy (20% by 2020), Paris (25% by 2020, 100% by 2050), Toulouse (4.25% by 2025), Val d'Ille (100% by 2030)
Germany		Bad Hersfeld (100% by 2050), Bamberg (100% by 2035), Berlin (17.8% by 2020), Cologne (20% by 2020), Ebersberg (100% by 2030), Felsberg (100% by 2020), Frankfurt (100% by 2050), Freiburg im Breisgau (100% by 2050), Fürstfeldbruck (100% by 2030), Giessen (100% by 2030), Hamburg (100% by 2050), Morbach (100% by 2020), Münster (100% by 2050), Steinfurt (100% by 2050), St. Michaelisdonn (100% by 2038), Trier (100% by 2050)
Hungary		Kaposvár (100% by 2050)
India	Jaipur (15% by 2020)	Kochi (5% by 2020)
Indonesia	Jakarta (30% by 2030)	
Italy	Ancona (20% by 2020)	Ancona (20% by 2020), Firenze (5% by 2020, 10% by 2050)
Japan		Tokyo (20% by 2024), Yokohama (100% by 2050)
Jordan		Amman (10% by 2020)
Kenya	Kisumu (30% by 2022)	
Korea, Republic of		Incheon (11.8% by 2025), Sejong (15% by 2020)
Liberia		Monrovia (20% by 2030)
Malaysia	Alor Gajah (40% by 2020)	Kota Kinabalu (11% by 2020), Melaka (11% by 2020), Shah Alam (11% by 2020)
Mexico	Puebla da Zaragoza (15% by 2030)	
Monaco		Monaco (20% by 2020)

■ TABLE R1. Renewable Energy Targets, Municipal Operations and City-wide in Selected Cities, As of Mid-2019 (continued)

Country	Municipal Operations Targets	City-wide Targets
Netherlands		Amsterdam (20% by 2020), Enschede (100% by 2050), Flevoland (100% by 2020), Rotterdam (40% by 2020), The Hague (100% by 2040)
Norway		Oslo (100% by 2020)
Palestine, State of		Abasan Al-Kabira (60% by 2030)
Peru		Magdalena del Mar (10% by 2025), San Isidro (3% by 2021)
Poland		Warsaw (20% by 2020), Wroclaw (15% by 2020)
Romania		Bistrita (50%, no date)
Russian Federation		Moscow (4% by 2020)
Senegal		Dakar (15% by 2035)
South Africa	Durban (10% by 2020), eThekweni (40% by 2030), Msunduzi (30% by 2030)	Cape Town (10% by 2020), Ekurhuleni (10% by 2025), Msunduzi (30% by 2030), Pietermaritzburg (30% by 2030)
Spain	Balmaseda (29% by 2020), Tolosa (5% by 2020), Vitoria Gasteiz (14.8% by 2020)	A Coruna (20% by 2020), Amurrio (20% by 2020), Areatza (20% by 2020), Balmaseda (29% by 2020), Barcelona (10% by 2024, 100% by 2050), Durango (20% by 2020), Errenteria (2.8% by 2020), Granada (4% by 2020), Madrid (10% by 2020), Palma (20% by 2020), San Sebastian (25% by 2030), Vitoria Gasteiz (2.6% by 2020), Zaragoza (34% by 2020)
Sweden	Gävle (100% by 2020), Kristianstad (100% by 2020), Lund (100% by 2020), Malmö (100% by 2020), Södertälje (100% by 2020), Trollhättan (84% by 2020), Vårgårda (100% by 2020)	Malmö (100% by 2030), Skane (100% by 2020), Stockholm (100% by 2040), Trollhättan (60% by 2020), Uppsala (100% by 2030), Vårgårda (100% by 2030), Växjö (100% by 2030)
Switzerland	Geneva (100% by 2050), Zurich (35% by 2020, 60% by 2035, 90% by 2050)	Lausanne (20% by 2020), Zurich (25% by 2020, 50% by 2035, 80% by 2080)
Ukraine		Chortkiv (100% by 2050), Kamianets-Podilskyi (100% by 2050), Lviv (100% by 2050), Zhytomyr (100% by 2050)
United Arab Emirates		Dubai (7% by 2020, 25% by 2030, 75% by 2050)
United Kingdom		Manchester (100% by 2050)
United States	Boulder, Colorado (60% by 2050), Breckenridge, Colorado (100% by 2025), Brisbane, California (100% by 2020), Chicago, Illinois (100% by 2025), Fayetteville, Arkansas (100% by 2030), Lakewood, Colorado (45% by 2025), Minneapolis, Minnesota (100% by 2020), Orlando, Florida (100% by 2030), Phoenix, Arizona (15% by 2025), Portland, Oregon (100% by 2030), Portland, Maine (100% by 2040)	Arlington, Virginia (15% by 2050); Austin, Texas (65% by 2027); Baltimore, Maryland (15% by 2020); Berkeley, California (100% by 2030); Boulder, Colorado (100% by 2030); Chicago, Illinois (25% by 2025, 100% by 2040); Cleveland, Ohio (100% by 2050); Columbia, South Carolina (100% by 2050); Concord, New Hampshire (100% by 2050); Cornish, New Hampshire (100% by 2050); Downingtown, Pennsylvania (100% by 2035); Flagstaff, Arizona (50% by 2050); Hillsborough, North Carolina (100% by 2050); Keene, New Hampshire (100% by 2050); Lakewood, Colorado (45% by 2025); Las Vegas, Nevada (25% by 2025, 100% by 2035); Los Angeles, California (65% by 2036, 100% by 2050); Milwaukee, Wisconsin (25% by 2025); Minneapolis, Minnesota (100% by 2030); Nevada City, California (100% by 2050); Palo Alto, California (33% by 2020); Rochester, Minnesota (100% by 2031); Salt Lake City, Utah (100% by 2032); Tacoma, Washington (15% by 2020)
Vietnam		Da Nang (6% by 2030)
Zimbabwe		Harare (25% by 2025)

Note: No date means that a target date was unavailable at the time of publication.

Source: See endnote 1 for this section.

■ TABLE R2. Renewable Power Targets, Municipal Operations and City-wide in Selected Cities, As of Mid-2019

Country	Municipal Operations Targets	City-wide Targets
Australia	Adelaide (100% by 2020), Canberra (100% by 2020), Sydney (100% by 2019)	Adelaide (50% by 2025), Canberra (100% by 2020), Coffs Harbour (100% by 2030), Lismore (100% by 2023), Sydney (100% by 2020), Yackandandah (100% by 2022)
Bahamas		Nassau (100% by 2020)
Brazil	Belo Horizonte (30% by 2030)	Brasilia (5% by 2020)
Canada		Edmonton (100% by 2030), Toronto (20% by 2050)
Chile		Antofagasta (20% by 2025)
Chinese Taipei		Kaohsiung (11% by 2030), Pingtung (20% by 2025), Taipei (12% by 2020, 15% by 2026)
Denmark		Copenhagen (100% by 2025)
Finland	Lahti (10% by 2020)	Turku (50% by 2020)
France		Loos (100% by 2020), Nancy (20% by 2020), Paris (100% by 2050)
Georgia		Kutaisi (100% by 2050)
Germany	Hanover (100% by 2050), Landshut (100% by 2037)	Alheim (100% by 2030), Berlin (25% by 2050), Bonn (50% by 2020, 100% by 2050), Coelbe (100% by 2040), Frankfurt (100% by 2050), Furth bei Landshut (100%, no date), Gräfenhainichen (100% by 2020), Hegau Bodensee (100% by 2030), Lauf (100% by 2030), Lübow-Krassow (100% by 2030), Marburg-Biedenkopf (100% by 2040), Minden-Lübbecke (100% by 2030), Moosburg a.d. Isar (100% by 2035), Morbach (100% by 2020), Münchweiler (100% by 2020), Munich (100% by 2025), Nalbach (100%, no date), Osnabrück (100% by 2030), Prenzlau (100% by 2020), Rietberg (100% by 2030), Saerbeck (100% by 2030), Solms (100%, no date), Speyer (100% by 2030/2040), Starnberg (100% by 2035), Ulm (100% by 2020), Wangen im Allgäu (100% by 2020), Westlausitz (100% by 2050), Wilhelmsburg (100% by 2025)
Gibraltar		Gibraltar (15% by 2020)
India	Patna (6.6% by 2022)	
Indonesia		Malang (20% by 2020)
Israel		Eilat (100% by 2025)
Italy		Dobbiaco (100%, no date), Firenze (45% by 2030)
Japan		Fukushima (100% by 2040), Hiroshima (50% by 2030), Nagano (10% by 2020, 20% by 2030, 30% by 2050), Takarazuka (100% by 2050), Tokyo (30% by 2030), Toyama (20% by 2030)
Kenya		Kisumu (100% by 2020)
Korea, Republic of		Incheon (11% by 2035), Seoul (20% by 2020)
Liberia		Monrovia (10% by 2030)
Malaysia	Alor Gajah (40% by 2020)	Melaka (11% by 2020), Shah Alam (11% by 2020)
Mexico	Puebla de Zaragoza (15% by 2030)	
Netherlands		Amsterdam (25% by 2025, 50% by 2040), Groningen (100% by 2035), Nijmegen (100% by 2045), The Hague (100% by 2040)
New Zealand		Auckland (90% by 2025, 100% by 2040), Napier (90% by 2020), Wellington (78-90% by 2030)
Pakistan		Karachi (5% by 2020)
Palestine, State of		Abasan Al-Kabira (40% by 2030)
Philippines	Pasig (10% by 2020)	Mindanao (100%, no date)
Portugal		Lisbon (17% by 2020), Ovar (99% by 2030)

■ TABLE R2. Renewable Power Targets, Municipal Operations and City-wide in Selected Cities, As of Mid-2019 (continued)

Country	Municipal Operations Targets	City-wide Targets
Romania		Alba-Iulia (4% by 2020)
Russian Federation		Moscow (1% by 2020)
Slovenia		Šentrupert (100% by 2020)
South Africa	eThekweni (40% by 2030), Msunduzi (100% by 2030)	Cape Town (20% by 2020), Durban (40% by 2030, 100% by 2050), Ekurhuleni (10% by 2020), Johannesburg (50% by 2040), Nelson Mandela Bay (10% by 2020)
Spain		Granada (4% by 2020), Madrid (100% by 2050), Murcia (5% by 2020), Palma (20% by 2020)
Sweden	Helsingborg (100% by 2020), Örebro (47% by 2020), Säfte (100% by 2030), Täby (100% by 2020)	Gothenburg (55% by 2030), Helsingborg (100% by 2035), Piteå (100% by 2020), Skellefteå (100% by 2020), Stockholm (100% by 2035)
Switzerland		Bern (80% by 2035), Nyon (98% by 2020)
Thailand	Hat Yai (10% by 2020)	Hat Yai (5% by 2030)
Uganda	Kasese (100% by 2020)	
United Arab Emirates		Abu Dhabi (7% by 2020), Dubai (7% by 2020, 25% by 2030, 75% by 2050)
United Kingdom		Manchester (100% by 2050)
United States	Alexandria, Virginia (50% by 2030); Asheville, North Carolina (100% by 2030); Atlanta, Georgia (100% by 2035); Avon, Ohio (100%, no date); Breckenridge, Colorado (100% by 2025); Chicago, Illinois (100% by 2025); Cincinnati, Ohio (100% by 2035); Columbus, Ohio (28% by 2019); Culver City, California (100% by 2019); Cupertino, California (100% by 2020); Easton, Pennsylvania (100% by 2020); Fayetteville, Arkansas (100% by 2030); Goleta, California (100% by 2030); Grand Rapids, Michigan (100% by 2025); Hillsboro, Oregon (100% by 2030); La Crosse, Wisconsin (25% by 2025); Largo, Florida (50% by 2030); Middleton, Wisconsin (100% by 2040); Minneapolis, Minnesota (100% by 2023); Orlando, Florida (100% by 2030); Park City, Utah (100% by 2022); Philadelphia, Pennsylvania (100% by 2030); St. Paul, Minnesota (100% by 2030); Salt Lake City, Utah (50% by 2020); San Francisco, California (100% by 2030); Santa Barbara, California (100% by 2030); Truckee, California (100% by 2020)	Abita Springs, Louisiana (100% by 2030); Albuquerque, New Mexico (25% by 2025); Amherst, Massachusetts (100%, no date); Angel Fire, New Mexico (100% by 2030); Arlington, Virginia (15% by 2050); Asheville, North Carolina (100% by 2042); Atlanta, Georgia (100% by 2050); Augusta, Georgia (100% by 2050); Austin, Texas (55% by 2025); Baltimore, Maryland (15% by 2020); Blacksburg, Virginia (90% by 2050); Boise, Idaho (100% by 2035); Boulder, Colorado (20% by 2020); Breckenridge, Colorado (100% by 2035); Brookeville, Maryland (50%, no date); Cambridge, Massachusetts (20% by 2020, 100% by 2035); Charleston, South Carolina (15% by 2020); Charlotte, North Carolina (100% by 2030); Chula Vista, California (100% by 2035); Cincinnati, Ohio (100% by 2035); Clarkston, Georgia (100% by 2050); Cleveland, Ohio (25% by 2030, 100% by 2050); Colorado Springs, Colorado (20% by 2020), Columbia, South Carolina (100% by 2036), Columbus, Ohio (10% by 2020, 40% by 2030), Concord, New Hampshire (100% by 2030); Culver City, California (100% by 2019); Davis, California (50% by 2020); Del Mar, California (100% by 2035); Denton, Texas (100% by 2020); Denver, Colorado (100% by 2030); Eagle Nest, New Mexico (100% by 2030); East Hampton, New York (100% by 2020); Eau Claire, Wisconsin (100% by 2050); El Paso, Texas (10% by 2020); Encinitas, California (100% by 2030); Eureka, California (100% by 2025); Evanston, Illinois (100% by 2035); Fayetteville, Arkansas (100% by 2050); Flagstaff, Arizona (50% by 2050); Fort Collins, Colorado (20% by 2020); Fort Lauderdale, Florida (20% by 2020); Goleta, California (100% by 2030); Grand Rapids, Michigan (100% by 2025); Hanover, New Hampshire (100% by 2030); Hillsboro, Oregon (75% by 2035); Hollywood, Florida (20% by 2025); Honolulu, Hawaii (100% by 2045); Huntsville, Alabama (20% by 2020); Jacksonville, Florida (30% by 2030); Keene, New Hampshire (100% by 2030); Kennett Township, Pennsylvania (100% by 2035); La Mesa, California (100% by 2035); Lafayette, Colorado (100% by 2030); Lakewood, Colorado (45% by 2025); Lancaster, California (100% by 2020); Largo, Florida (100% by 2040); Las Vegas, Nevada (25% by 2025); Longmont, Colorado (100% by 2030); Los Angeles, California (33% by 2020, 50% by 2030, 65% by 2036); Madison, Wisconsin (100% by 2050); Menlo Park, California (100% by 2030); Milwaukee, Wisconsin (25% by 2025); Minneapolis, Minnesota (100% by 2030); Moab, Utah (50% by 2024, 100% by 2032); Monterey, California (100% by 2040); Nederland, Colorado (100% by 2025); Nevada, California (100% by 2030); New Brunswick, New Jersey (100% by 2035); New York, New York (35% by 2025); Norman, Oklahoma (100% by 2025); Northampton, Massachusetts (100% by 2050); Oakland, California (3% by 2020); Ojai, California (100% by 2019); Orlando, Florida (100% by 2050); Oxnard, California (100% by 2019); Park City, Utah (100% by 2032); Pasadena, California (40% by 2020); Philadelphia, Pennsylvania (100% by 2030); Phoenixville, Pennsylvania (100% by 2035); Pittsburgh, Pennsylvania (100% by 2035); Planfield, New Hampshire (100% by 2030); Portland, Oregon (100% by 2035); Portola Valley, California (100% by 2019); Pueblo, Colorado (100% by 2035); Questa, New Mexico (100% by 2030); Raleigh, North Carolina (12.5% by 2020); Red River, Texas (100% by 2030); Richmond, California (87% by 2030); Rochester, Minnesota (25% by 2025, 100% by 2031); Rockville, Maryland (20% by 2022); Rolling Hills Estates, California (100% by 2019); Salem, Massachusetts (100%, no date); Salt Lake City, Utah (50% by 2020); San Antonio, Texas (50% by 2040); San Diego, California (100% by 2035); San Francisco, California (100% by 2030); San Jose, California (100% by 2022); Santa Barbara, California (100% by 2030); Santa Cruz County, California (100% by 2035); Santa Monica, California (100% by 2030); Sarasota, Florida (50% by 2024, 100% by 2045); Solana Beach, California (100% by 2035); South Lake Tahoe, California (100% by 2032); Southampton Town, New York (100% by 2025); Spokane, Washington (100% by 2030); Springfield, Massachusetts (50% by 2050); St Louis Park, Minnesota (100% by 2035); St. Paul, Minnesota (100% by 2030); St. Petersburg, Florida (100% by 2030); Summit County, Utah (100% by 2032); Tampa, Florida (25% by 2025); Taos, New Mexico (100% by 2030); Traverse City, Michigan (100% by 2040); Ventura, California (100% by 2019); Visalia, California (51% by 2030); Washington, D.C. (100% by 2032); West Chester Borough, Pennsylvania (100% by 2035); West Hollywood, California (100% by 2025); Whatcom County, Washington (100% by 2050); Winter Park, Florida (65%, no date)
Vietnam		Da Nang (6% by 2030)

Note: No date means that a target date was unavailable at the time of publication.

Source: See endnote 1 for this section.

■ TABLE R3. Renewable Heating and Cooling Targets, Municipal Operations and City-wide in Selected Cities, As of Mid-2019

Country	Municipal Operations Targets	City-wide Targets
Austria		Vienna (50% by 2050)
Brazil		São Paulo (40%, no date)
Canada		Toronto (5% by 2050)
Denmark		Copenhagen (100% by 2025)
Finland	Helsinki (100% by 2050)	
Georgia		Kutaisi (100% by 2050)
Germany	Landshut (100% by 2037)	Coelbe (100% by 2040), Gräfenhainichen (100% by 2020), Kassel (100% by 2030), Lübow-Krassow (100% by 2030), Minden-Lübbecke (100% by 2030), Moosburg a.d. Isar (100% by 2035), Munich (100% by 2040), Nalbach (100%, no date), Neuerkirch and Kuls (100%, no date), Osnabrück (100% by 2050), Prenzlau (100% by 2020), Speyer (100% by 2030/2040), Starnberg (100% by 2035), Ulm (100% by 2030), Wangen im Allgäu (100% by 2030), Westlausitz (100% by 2050), Wilhelmsburg (100% by 2050)
Italy		Dobbiaco (100%, no date)
Japan		Takarazuka (100% by 2050)
Malaysia		Melaka (11% by 2020), Shah Alam (11% by 2020)
Netherlands		Nijmegen (100% by 2045), The Hague (100% by 2040)
Norway		Bergen (100% by 2030), Oslo (100% by 2020), Stavenger (75%, no date)
Slovenia		Šentrupert (100% by 2020)
South Africa	eThekweni (40% by 2030)	
Spain		Granada (4% by 2020)
Sweden	Helsingborg (100% by 2020), Säffle (100% by 2030), Täby (100% by 2020), Uppsala (100% by 2020)	Helsingborg (100% by 2035), Piteå (100% by 2020), Skellefteå (100% by 2020)
Switzerland	Geneva (100% by 2050)	Bern (70% by 2035)
Ukraine		Chortkiv (100% by 2050), Kamianets-Polilskyi (100% by 2050), Zhytomyr (100% by 2050)
United Kingdom		Manchester (100% by 2050)
United States	St. Paul, Minnesota (100% by 2030)	Concord, New Hampshire (100% by 2050); East Hampton, New York (100% by 2030); Keene, New Hampshire (100% by 2050); Middleton, Wisconsin (100% by 2050); Nevada, California (100% by 2050); Norman, Oklahoma (100% by 2050); Phoenixville, Pennsylvania (100% by 2050); Plainfield, New Hampshire (100% by 2050); Portland, Oregon (100% by 2050); Truckee, California (100% by 2030)
Vietnam		Da Nang (6% by 2030)

Note: No date means that a target date was unavailable at the time of publication.

Source: See endnote 1 for this section.

■ TABLE R4. Renewable Transport Targets, Municipal Operations and City-wide in Selected Cities, As of Mid-2019

Country	Municipal Operations Targets	City-wide Targets
Brazil	Curitiba (100% by 2030)	
Denmark		Copenhagen (100% by 2025)
Germany	Münster (100% by 2050)	Ulm (100% by 2030)
Norway	Bergen (100% by 2020), Oslo (100% by 2020)	
Pakistan	Karachi (40% by 2020)	
Philippines	San Carlos (15% by 2025)	
Spain	San Sebastian (100% by 2030)	Palma (20% by 2020)
Sweden	Gothenburg (95% by 2025), Täby (50% by 2020)	Gävle (100% by 2030), Linköping (100%, no date), Säfte (100% by 2030), Täby (20% by 2020), Upplands Väsby (100% by 2020)
United Kingdom	Brighton (100% by 2030)	
United States	Pittsburgh, Pennsylvania (100% by 2030)	Concord, New Hampshire (100% by 2050); East Hampton, New York (100% by 2030); Honolulu, Hawaii (100% by 2045); Kauai, Hawaii (100% by 2045); Keene, New Hampshire (100% by 2050); Middleton, Wisconsin (100% by 2050); Nevada City, California (100% by 2050); Norman, Oklahoma (100% by 2050); Phoenixville, Pennsylvania (100% by 2050); Plainfield, New Hampshire (100% by 2050); Portland, Oregon (100% by 2050); San Francisco, California (50% by 2025, 100% by 2045); Summit County, Utah (100% by 2035); Truckee, California (100% by 2050)

Note: No date means that a target date was unavailable at the time of publication.

Source: See endnote 1 for this section.

■ TABLE R5. Renewable Energy Targets for Specific Amount of Installed Capacity or Generation, As of Mid-2019

Country	City	Coverage	Target
Argentina	Mar del Plata	City-wide	10 MW wind power
Australia	Adelaide	City-wide	2 MW solar PV on commercial and residential buildings by 2020
Canada	Toronto	City-wide	550 MW renewable energy by 2020; 1,000 MW by 2050
Canada	Toronto	Municipal	24 MW renewable electricity by 2020
Canada	Windsor	City-wide	90 MW renewable renewable electricity by 2041
China	Beijing	Municipal	1.16 GW solar power capacity; 650 MW wind power
China	Beijing	Municipal	Install a combined surface area of 9 million m ² of solar hot water collectors by 2020
China	Shenzhen	Municipal	150 MW rooftop solar PV capacity
China	Tianjin	Municipal	800 MW solar PV; 1,160 MW wind power; 155 MW biomass generating capacity by 2020
Chinese Taipei	New Taipei	City-wide	100 MW renewable electricity by 2025
Chinese Taipei	Pingtung	City-wide	800 MW renewable energy by 2020
Chinese Taipei	Taichung	City-wide	100 MW renewable energy by 2020
Chinese Taipei	Taipei	City-wide	14 MW renewable energy by 2025
Denmark	Gladsaxe	City-wide	500 MW renewable energy by 2035
Greece	Athens	City-wide	20 MW renewable electricity by 2030
Italy	Bologna	City-wide	10 MW solar PV by 2020
Italy	Torino	Municipal	100 MW renewable energy by 2020
Italy	Venice	Municipal	0.3 MW renewable electricity by 2020
Italy	Venice	City-wide	49.34 MW renewable electricity by 2020
Portugal	Lisbon	City-wide	103 MW renewable energy by 2030
Japan	Yokohama	City-wide	589 MW renewable energy by 2030
Japan	Yokohama	City-wide	429 MW renewable energy by 2020
Netherlands	Amsterdam	City-wide	75,000 MW renewable energy capacity by 2020
Netherlands	Rotterdam	City-wide	10 MW renewable energy by 2020
Norway	Oslo	City-wide	150 MW installed solar capacity by 2030
Republic of Korea	Seoul	City-wide	1 GW solar PV by 2022
Singapore	Singapore	City-wide	350 MW renewable energy by 2020
South Africa	Cape Town	City-wide	220 MW renewable electricity by 2022
South Africa	Durban	Municipal	720 MW renewable energy by 2030
South Africa	Ekurhuleni	City-wide	700 MW renewable electricity
Spain	Barcelona	City-wide	15.3 MW renewable electricity by 2020
Sweden	Esklistuna	City-wide	48 GWh wind power by 2020; 9.5 GWh solar PV by 2020
Sweden	Gothenburg	City-wide	500 GWh renewable electricity by 2030
United States	Arlington (VA)	City-wide	100 MW renewable energy by 2020
United States	Atlanta (GA)	City-wide	Triple the renewable energy capacity by 2020
United States	Boston (MA)	City-wide	25 MW renewable electricity by 2020
United States	Boulder (CO)	City-wide	175 MW renewable electricity by 2050
United States	Cincinnati (OH)	City-wide	38.7 MW renewable energy by 2020
United States	Long Beach (CA)	Municipal	2 MW renewable electricity by 2020

■ TABLE R5. Renewable Energy Targets for Specific Amount of Installed Capacity or Generation, As of Mid-2019 (continued)

Country	City	Coverage	Target
United States	Long Beach (CA)	City-wide	8 MW renewable electricity by 2020
United States	Los Angeles (CA)	City-wide	1.3 GW solar PV by 2020
United States	New Bedford (MA)	City-wide	40 MW renewable electricity by 2030
United States	New York (NY)	City-wide	250 MW solar PV by 2025
United States	New York (NY)	Municipal	100 MW renewable energy by 2025
United States	Rochester (NY)	City-wide	50 MW renewable energy by 2030
United States	Tempe (AZ)	Municipal	40 MW renewable energy by 2035

Source: See endnote 4 for this chapter.

■ TABLE R6. Cities with E-mobility Targets and Renewable Energy Targets, As of Mid-2019

Country	City	Coverage	Target	Is the city's e-mobility target linked to its renewable energy target(s)?*
Argentina	Buenos Aires	Municipal	8 new electric buses by 2035	No
Belgium	Brussels	Municipal	100% electric bus fleet by 2030	No
Brazil	Rio de Janeiro	Municipal	Procure only zero emission buses by 2025	N/A
Canada	Montreal	Municipal	Convert municipal fleet to electric by 2020	No
Canada	Montreal	Municipal	Electrify public transport by 2025	No
Canada	Toronto	Municipal	60 electric buses by 2020	No
Canada	Vancouver	Municipal	Procure only zero emission buses by 2025	No
Canada	Vancouver	City-wide	70% of light-duty vehicles to plug into external power source by 2050	No
Chile	Santiago	Municipal	500 more electric buses by 2020; procure only zero emission buses by 2025	N/A
China	Beijing	City-wide	Convert all newly added or replaced taxis from petrol to electricity (no target date)	No
China	Beijing	City-wide	Install 435,000 EV charging stations during 2016-2020	No
China	Foshan	Municipal	100% electric public transport by 2020	N/A
Colombia	Medellin	Municipal	Procure only zero emission buses by 2025	N/A
Denmark	Copenhagen	Municipal	Procure only zero emission buses by 2025; 100% of municipal cars to be zero emission by 2026	Yes
Denmark	Copenhagen	City-wide	Carbon-neutral transport by 2025	Yes
Ecuador	Quito	Municipal	Procure only zero emission buses by 2025	No
France	Paris	Municipal	Procure only zero emission buses and 100% clean bus fleet by 2025	Yes
France	Paris	City-wide	Ban diesel vehicles by 2024; ban petrol-fuelled cars by 2030	Yes
Germany	Berlin	Municipal	Procure only zero emission buses by 2025	N/A
Germany	Berlin	City-wide	1,100 EV charging points by mid-2020	N/A
Germany	Heidelberg	Municipal	Procure only zero emission buses by 2025	N/A
Greece	Athens	City-wide	Ban diesel cars and vans by 2025	N/A
Hong Kong	Hong Kong	City-wide	100% zero emission buses (no target date)	N/A
Iceland	Reykjavik	Municipal	100% of municipal vehicles powered by emissions-free energy by 2025	No
Iceland	Reykjavik	City-wide	Emissions-free vehicle traffic and public transport by 2040	No
India	Bangalore	City-wide	100% electric municipal buses by 2023; 100% electric auto rickshaws, cab aggregators, corporate fleets and school buses by 2030	N/A
India	New Delhi	City-wide	25% of new vehicle registrations to be EVs by 2023	N/A
India	New Delhi	Municipal	1,000 electric buses by 2019	N/A
Indonesia	Jakarta	Municipal	Procure only zero emission buses by 2025	N/A
Italy	Milan	Municipal	Procure only zero emission buses by 2025	N/A
Italy	Milan	City-wide	Zero emission city centre by 2030	N/A
Italy	Rome	City-wide	Ban all petrol cars by 2024; historical centre to be zero emission zone by 2030	N/A
Italy	Rome	Municipal	Procure only zero emission buses by 2025	N/A

■ TABLE R6. Cities with E-mobility Targets and Renewable Energy Targets, As of Mid-2019 (continued)

Country	City	Coverage	Target	Is the city's e-mobility target linked to its renewable energy target(s)?*
Japan	Tokyo	Municipal	Procure only zero emission buses by 2025	No
Japan	Tokyo	City-wide	50% of new cars sold to be zero emission vehicles by 2030	No
Mexico	Mexico City	Municipal	Procure only zero emission buses by 2025	N/A
Mexico	Mexico City	City-wide	Ban diesel cars and vans by 2025	N/A
Netherlands	Rotterdam	Municipal	Procure only zero emission buses by 2025; 100% zero emission buses by 2029	No
Netherlands	Utrecht	Municipal	Introduce e-buses (no target date)	N/A
New Zealand	Auckland	Municipal	Procure only zero emission buses by 2025	No
Norway	Oslo	Municipal	Procure 70 electric buses by 2019; procure only zero emission buses by 2025	No
Norway	Oslo	Municipal	Municipal fleet to be fossil fuel-free by 2020	No
Norway	Oslo	City-wide	100% of new cars and light freight vehicles to use renewable fuels or be plug-in hybrids by 2020	No
Poland	Warsaw	Municipal	Procure only zero emission buses by 2025	N/A
Poland	Warsaw	City-wide	1,000 EV charging points by 2020	N/A
Portugal	Porto	Municipal	86 new electric buses (41% of fleet) by 2020	N/A
Republic of Korea	Seoul	City-wide	120,000 EVs on streets by 2020; 100,000 motorcycles replaced by electric ones by 2025	No
Republic of Korea	Seoul	Municipal	Procure only zero emission buses by 2025; run all buses on clean natural gas, electricity or hydrogen by 2027	No
Republic of Korea	Seoul	Municipal	50% of bus fleet to be electric by 2020; 100% by 2025	No
Republic of Korea	Ulsan	Municipal	100% fuel cell bus fleet by 2035	N/A
Russia	Moscow	Municipal	Procure only zero emission buses by 2025	N/A
South Africa	Cape Town	Municipal	Procure only zero emission buses by 2025	No
Spain	Barcelona	Municipal	Procure only zero emission buses by 2025	No
Spain	Madrid	City-wide	Ban diesel cars and vans by 2025	No
Sweden	Stockholm	City-wide	Be a leading clean vehicle city by 2030	No
The Netherlands	Amsterdam	Municipal	Procure only zero emission buses by 2025	No
United Arab Emirates	Dubai	City-wide	2% electric or hybrid cars by 2020; 10% by 2030	No
United Kingdom	Birmingham	Municipal	Procure only zero emission buses by 2025	N/A
United Kingdom	London	Municipal	Procure only zero emission buses by 2025; 100% zero emission buses by 2037	No
United Kingdom	London	City-wide	100% zero emission taxis and private hire vehicles by 2033; all new road vehicles driven in the city to be zero emissions by 2040; entire transport system to be zero emissions by 2050	No
United Kingdom	Manchester	Municipal	Procure only zero emission buses by 2025	No
United Kingdom	Oxford	Municipal	Procure only zero emission buses by 2025	No
United Kingdom	Liverpool	Municipal	Procure only zero emission buses by 2025	N/A
United States	Austin	Municipal	Procure only zero emission buses by 2025	No
United States	Honolulu	Municipal	Procure only zero emission buses by 2025	Yes

■ TABLE R6. Cities with E-mobility Targets and Renewable Energy Targets, As of Mid-2019 (continued)

Country	City	Coverage	Target	Is the city's e-mobility target linked to its renewable energy target(s)?*
United States	Los Angeles	Municipal	Procure only zero emission buses by 2025; emission-free public transport by 2030	No
United States	Los Angeles	City-wide	10% electric and zero emission vehicles by 2025; 25% by 2035	No
United States	Santa Monica	Municipal	Procure only zero emission buses by 2025	No
United States	West Hollywood	Municipal	Procure only zero emission buses by 2025	N/A
United States	Portland (Oregon)	City-wide	EVs to displace 10% of kilometres driven by 2030 and a further 15% by 2050	No
United States	San Francisco	City-wide	Electrify all private forms of transport by 2040	No
United States	Seattle	Municipal	Procure only zero emission buses by 2025; procure only zero emission fleet vehicles by 2030	N/A
United States	Seattle	City-wide	30% of light-duty vehicles to be electric by 2030	N/A
United States	New York City	City-wide	20% of motor vehicles sold to be electric by 2025; all passenger vehicles sold to be zero emissions by 2050	No
United States	New York City	Municipal	2,000 more EVs in municipal fleet by 2025; 100% electric buses by 2040	No

Note:

Yes = the city's e-mobility and renewable energy targets are directly linked

No = the city's e-mobility and renewable energy targets are not directly linked

N/A = the city does not have a specific renewable energy target.

Source: see endnote 3 for this chapter

■ GLOSSARY

Auction. See Tendering.

Biodiesel. A fuel produced from oilseed crops such as soy, rapeseed (canola) and palm oil, and from other oil sources such as waste cooking oil and animal fats. Biodiesel is used in diesel engines installed in cars, trucks, buses and other vehicles, as well as in stationary heat and power applications. Most biodiesel is made by chemically treating vegetable oils and fats (such as palm, soy and canola oils, and some animal fats) to produce fatty acid methyl esters (FAME). (Also see Hydrotreated vegetable oil (HVO) and hydrotreated esters and fatty acids (HEFA).)

Bioenergy. Energy derived from any form of biomass (solid, liquid or gaseous) for heat, power and transport. (Also see Biofuel.)

Biofuel. A liquid or gaseous fuel derived from biomass, primarily ethanol, biodiesel and biogas. Biofuels can be combusted in vehicle engines as transport fuels and in stationary engines for heat and electricity generation. They also can be used for domestic heating and cooking (for example, as ethanol gels). Conventional biofuels are principally ethanol produced by fermentation of sugar or starch crops (such as wheat and corn), and FAME biodiesel produced from oil crops such as palm oil and canola and from waste oils and fats. Advanced biofuels are made from feedstocks derived from the lignocellulosic fractions of biomass sources or from algae. They are made using biochemical and thermochemical conversion processes, some of which are still under development.

Biogas/Biomethane. Biogas is a gaseous mixture consisting mainly of methane and carbon dioxide produced by the anaerobic digestion of organic matter (broken down by microorganisms in the absence of oxygen). Organic material and/or waste is converted into biogas in a digester. Suitable feedstocks include agricultural residues, animal wastes, food industry wastes, sewage sludge, purpose-grown green crops and the organic components of municipal solid wastes. Raw biogas can be combusted to produce heat and/or power; it also can be transformed into biomethane through a process known as scrubbing that removes impurities including carbon dioxide, siloxanes and hydrogen sulphides, followed by compression. Biomethane can be injected directly into natural gas networks and used as a substitute for natural gas in internal combustion engines without risk of corrosion.

Biomass. Any material of biological origin, excluding fossil fuels or peat, that contains a chemical store of energy (originally received from the sun) and that is available for conversion to a wide range of convenient energy carriers.

Biomass, traditional (use of). Solid biomass (including fuel wood, charcoal, agricultural and forest residues, and animal dung), that is used in rural areas of developing countries with traditional technologies such as open fires and ovens for cooking and residential heating. Often the traditional use of biomass leads to high pollution levels, forest degradation and deforestation.

Biomass energy, modern. Energy derived from combustion of solid, liquid and gaseous biomass fuels in high-efficiency conversion systems, which range from small domestic appliances to large-scale industrial conversion plants. Modern applications

include heat and electricity generation, combined heat and power (CHP) and transport.

Biomass pellets. Solid biomass fuel produced by compressing pulverised dry biomass, such as waste wood and agricultural residues. Pellets typically are cylindrical in shape with a diameter of around 10 millimetres and a length of 30–50 millimetres. Pellets are easy to handle, store and transport and are used as fuel for heating and cooking applications, as well as for electricity generation and CHP.

Building energy codes and standards. Rules specifying the minimum energy standards for buildings. These can include standards for renewable energy and energy efficiency that are applicable to new and/or renovated and refurbished buildings.

Capacity. The rated power of a heat or electricity generating plant, which refers to the potential instantaneous heat or electricity output, or the aggregate potential output of a collection of such units (such as a wind farm or set of solar panels). Installed capacity describes equipment that has been constructed, although it may or may not be operational (e.g., delivering electricity to the grid, providing useful heat or producing biofuels).

Capital subsidy. A subsidy that covers a share of the upfront capital cost of an asset (such as a solar water heater). These include, for example, consumer grants, rebates or one-time payments by a utility, government agency or government-owned bank.

Combined heat and power (CHP) (also called co-generation). CHP facilities produce both heat and power from the combustion of fossil and/or biomass fuels, as well as from geothermal and solar thermal resources. The term also is applied to plants that recover “waste heat” from thermal power generation processes.

Community energy. An approach to renewable energy development that involves a community initiating, developing, operating, owning, investing and/or benefiting from a project. Communities vary in size and shape (e.g., schools, neighbourhoods, partnering city governments, etc.); similarly, projects vary in technology, size, structure, governance, funding and motivation.

Competitive bidding. See Tendering.

Concentrating solar thermal power (CSP) (also called solar thermal electricity, STE). Technology that uses mirrors to focus sunlight into an intense solar beam that heats a working fluid in a solar receiver, which then drives a turbine or heat engine/generator to produce electricity. The mirrors can be arranged in a variety of ways, but they all deliver the solar beam to the receiver. There are four types of commercial CSP systems: parabolic troughs, linear Fresnel, power towers and dish/engines. The first two technologies are line-focus systems, capable of concentrating the sun’s energy to produce temperatures of 400°C, while the latter two are point-focus systems that can produce temperatures of 800°C or higher.

Crowdfunding. The practice of funding a project or venture by raising money – often relatively small individual amounts – from a relatively large number of people (“crowd”), generally using the Internet and social media. The money raised through crowdfunding does not necessarily buy the lender a share in the venture, and there is no guarantee that money will be repaid if the venture is successful. However, some types of crowdfunding

reward backers with an equity stake, structured payments and/or other products.

Curtailement. A reduction in the output of a generator, typically on an involuntary basis, from what it could produce otherwise given the resources available. Curtailement of electricity generation has long been a normal occurrence in the electric power industry and can occur for a variety of reasons, including a lack of transmission access or transmission congestion.

Demand-side management. The application of economic incentives and technology in the pursuit of cost-effective energy efficiency measures and load-shifting on the customer side, to achieve least-cost overall energy system optimisation.

Demand response. Use of market signals such as time-of-use pricing, incentive payments or penalties to influence end-user electricity consumption behaviours. Usually used to balance electrical supply and demand within a power system.

Digitalisation. The application of digital technologies across the economy, including energy.

Digitisation. The conversion of something (e.g., data or an image) from analogue to digital.

Distributed generation. Generation of electricity from dispersed, generally small-scale systems that are close to the point of consumption.

Distributed renewable energy. Energy systems are considered to be distributed if 1) the systems are connected to the distribution network rather than the transmission network, which implies that they are relatively small and dispersed (such as small-scale solar PV on rooftops) rather than relatively large and centralised; or 2) generation and distribution occur independently from a centralised network. Specifically for the purpose of the chapter on Distributed Renewables for Energy Access, "distributed renewable energy" meets both conditions. It includes energy services for electrification, cooking, heating and cooling that are generated and distributed independent of any centralised system, in urban and rural areas of the developing world.

Distribution grid. The portion of the electrical network that takes power off the high-voltage transmission network via substations (at varying stepped-down voltages) and distributes electricity to customers.

Electric vehicle (EV) (also called electric drive vehicle). A vehicle that uses one or more electric motors for propulsion. A battery electric vehicle is a type of EV that uses chemical energy stored in rechargeable battery packs. A plug-in hybrid EV can be recharged by an external source of electric power. Fuel cell vehicles are EVs that use pure hydrogen (or gaseous hydrocarbons before reformation) as the energy storage medium.

Energy. The ability to do work, which comes in a number of forms including thermal, radiant, kinetic, chemical, potential and electrical. Primary energy is the energy embodied in (energy potential of) natural resources, such as coal, natural gas and renewable sources. Final energy is the energy delivered for end-use (such as electricity at an electrical outlet). Conversion losses occur whenever primary energy needs to be transformed for final energy use, such as combustion of fossil fuels for electricity generation.

Energy conservation. Any change in behaviour of an energy consuming entity for the specific purpose of affecting an energy demand reduction. Energy conservation is distinct from energy efficiency in that it is predicated on the assumption that an otherwise preferred behaviour of greater energy intensity is abandoned. See Energy efficiency and Energy intensity.

Energy efficiency. The measure that accounts for delivering more services for the same energy input, or the same amount of services for less energy input. Conceptually, this is the reduction of losses from the conversion of primary source fuels through final energy use, as well as other active or passive measures to reduce energy demand without diminishing the quality of energy services delivered. Energy efficiency is technology-specific and distinct from energy conservation, which pertains to behavioural change. Both energy efficiency and energy conservation can contribute to energy demand reduction.

Energy service company (ESCO). A company that provides a range of energy solutions including selling the energy services from a (renewable) energy system on a long-term basis while retaining ownership of the system, collecting regular payments from customers and providing necessary maintenance service. An ESCO can be an electric utility, co-operative, non-governmental organisation or private company, and typically installs energy systems on or near customer sites. An ESCO also can advise on improving the energy efficiency of systems (such as a building or an industry) as well as on methods for energy conservation and energy management.

Energy subsidy. A government measure that artificially reduces the price that consumers pay for energy or that reduces energy production cost.

Ethanol (fuel). A liquid fuel made from biomass (typically corn, sugar cane or small cereals/grains) that can replace petrol in modest percentages for use in ordinary spark-ignition engines (stationary or in vehicles), or that can be used at higher blend levels (usually up to 85% ethanol, or 100% in Brazil) in slightly modified engines, such as those provided in "flex-fuel" vehicles. Ethanol also is used in the chemical and beverage industries.

Fatty acid methyl esters (FAME). See Biodiesel.

Feed-in policy (feed-in tariff or feed-in premium). A policy that typically guarantees renewable generators specified payments per unit (e.g., USD per kWh) over a fixed period. Feed-in tariff (FIT) policies also may establish regulations by which generators can interconnect and sell power to the grid. Numerous options exist for defining the level of incentive, such as whether the payment is structured as a guaranteed minimum price (e.g., a FIT), or whether the payment floats on top of the wholesale electricity price (e.g., a feed-in premium).

Final energy. The part of primary energy, after deduction of losses from conversion, transmission and distribution, that reaches the consumer and is available to provide heating, hot water, lighting and other services. Final energy forms include, among others, electricity, district heating, mechanical energy, liquid hydrocarbons such as kerosene or fuel oil, and various gaseous fuels such as natural gas, biogas and hydrogen.

(Total) Final energy consumption (TFEC). Energy that is supplied to the consumer for all final energy services such as transport, cooling and lighting, building or industrial heating or mechanical work. Differs from total final consumption (TFC), which includes all energy use in end-use sectors (TFEC) as well as for non-energy applications, mainly various industrial uses, such as feedstocks for petrochemical manufacturing.

Fiscal incentive. An incentive that provides individuals, households or companies with a reduction in their contribution to the public treasury via income or other taxes.

Generation. The process of converting energy into electricity and/or useful heat from a primary energy source such as wind, solar radiation, natural gas, biomass, etc.

Geothermal energy. Heat energy emitted from within the earth's crust, usually in the form of hot water and steam. It can be used to generate electricity in a thermal power plant or to provide heat directly at various temperatures.

Green bond. A bond issued by a bank or company, the proceeds of which will go entirely into renewable energy and other environmentally friendly projects. The issuer will normally label it as a green bond. There is no internationally recognised standard for what constitutes a green bond.

Green energy purchasing. Voluntary purchase of renewable energy – usually electricity, but also heat and transport fuels – by residential, commercial, government or industrial consumers, either directly from an energy trader or utility company, from a third-party renewable energy generator or indirectly via trading of renewable energy certificates (such as renewable energy credits, green tags and guarantees of origin). It can create additional demand for renewable capacity and/or generation, often going beyond that resulting from government support policies or obligations.

Heat pump. A device that transfers heat from a heat source to a heat sink using a refrigeration cycle that is driven by external electric or thermal energy. It can use the ground (geothermal/ground-source), the surrounding air (aerothermal/air-source) or a body of water (hydrothermal/water-source) as a heat source in heating mode, and as a heat sink in cooling mode. A heat pump's final energy output can be several multiples of the energy input, depending on its inherent efficiency and operating condition. The output of a heat pump is at least partially renewable on a final energy basis. However, the renewable component can be much lower on a primary energy basis, depending on the composition and derivation of the input energy; in the case of electricity, this includes the efficiency of the power generation process. The output of a heat pump can be fully renewable energy if the input energy is also fully renewable.

Hydropower. Electricity derived from the potential energy of water captured when moving from higher to lower elevations. Categories of hydropower projects include run-of-river, reservoir-based capacity and low-head in-stream technology (the least developed). Hydropower covers a continuum in project scale from large (usually defined as more than 10 MW of installed capacity, but the definition varies by country) to small, mini, micro and pico.

Investment. Purchase of an item of value with an expectation of favourable future returns. In this report, new investment in renewable energy refers to investment in: technology research and development, commercialisation, construction of manufacturing facilities and project development (including the construction of wind farms and the purchase and installation of solar PV systems). Total investment refers to new investment plus merger and acquisition (M&A) activity (the refinancing and sale of companies and projects).

Joule. A joule (J) is a unit of work or energy equal to the work done by a force equal to one newton acting over a distance of one metre. One joule is equal to one watt-second (the power of one watt exerted over the period of one second). The potential chemical energy stored in one barrel of oil and released when combusted is approximately 6 gigajoules (GJ); a tonne of oven-dry wood contains around 20 GJ of energy.

Levelised cost of energy/electricity (LCOE). The cost per unit of energy from an energy generating asset that is based on the present value of its total construction and lifetime operating costs, divided by total energy output expected from that asset over its lifetime.

Mandate/Obligation. A measure that requires designated parties (consumers, suppliers, generators) to meet a minimum – and often gradually increasing – standard for renewable energy (or energy efficiency), such as a percentage of total supply, a stated amount of capacity, or the required use of a specified renewable technology. Costs generally are borne by consumers. Mandates can include renewable portfolio standards (RPS); building codes or obligations that require the installation of renewable heat or power technologies (often in combination with energy efficiency investments); renewable heat purchase requirements; and requirements for blending specified shares of biofuels (biodiesel or ethanol) into transport fuel.

Mini-grid/Micro-grid. For distributed renewable energy systems for energy access, a mini-grid/micro-grid typically refers to an independent grid network operating on a scale of less than 10 MW (with most at very small scale) that distributes electricity to a limited number of customers. Mini-/micro-grids also can refer to much larger networks (e.g., for corporate or university campuses) that can operate independently of, or in conjunction with, the main power grid. However, there is no universal definition differentiating mini- and micro-grids.

Municipal solid waste. Waste materials generated by households and similar waste produced by commercial, industrial or institutional entities. The wastes are a mixture of renewable plant and fossil-based materials, with the proportions varying depending on local circumstances. A default value that assumes that at least 50% of the material is “renewable” is often applied.

Net metering/Net billing. A regulated arrangement in which utility customers with on-site electricity generators can receive credits for excess generation, which can be applied to offset consumption in other billing periods. Under net metering, customers typically receive credit at the level of the retail electricity price. Under net billing, customers typically receive credit for excess power at a rate that is lower than the retail electricity price. Different jurisdictions may apply these terms in different ways, however.

Ocean power. Refers to technologies used to generate electricity by harnessing from the ocean the energy potential of ocean waves, tidal range (rise and fall), tidal streams, ocean (permanent) currents, temperature gradients (ocean thermal energy conversion) and salinity gradients. The definition of ocean power used in this report does not include offshore wind power or marine biomass energy.

Pay-as-you-go (PAYG). A business model that gives customers (mainly in areas without access to the electricity grid) the possibility to purchase small-scale energy-producing products, such as solar home systems, by paying in small instalments over time.

Pico solar devices/pico solar systems. Small solar systems such as solar lanterns that are designed to provide only a limited amount of electricity service, usually lighting and in some cases mobile phone charging. Such systems are deployed mainly in areas that have no or poor access to electricity. The systems usually have a power output of 1-10 watts and a voltage of up to 12 volts.

Power. The rate at which energy is converted into work, expressed in watts (joules/second).

Power purchase agreement (PPA). A contract between two parties, one that generates electricity (the seller) and one that is looking to purchase electricity (the buyer). Power-to-gas (P2G). The conversion of electricity, either from renewable or conventional sources, to a gaseous fuel (for example, hydrogen or methane).

Primary energy. The theoretically available energy content of a naturally occurring energy source (such as coal, oil, natural gas, uranium ore, geothermal and biomass energy, etc.) before it undergoes conversion to useful final energy delivered to the end-user. Conversion of primary energy into other forms of useful final energy (such as electricity and fuels) entails losses. Some primary energy is consumed at the end-user level as final energy without any prior conversion.

Primary energy consumption. The direct use of energy at the source, or supplying users with unprocessed fuel.

Product and sectoral standards. Rules specifying the minimum standards for certain products (e.g., appliances) or sectors (industry, transport, etc.) for increasing energy efficiency.

Production tax credit. A tax incentive that provides the investor or owner of a qualifying property or facility with a tax credit based on the amount of renewable energy (electricity, heat or biofuel) generated by that facility.

Prosumer. An individual, household or small business that not only consumes energy but also produces it. Prosumers may play an active role in energy storage and demand-side management.

Public financing. A type of financial support mechanism whereby governments provide assistance, often in the form of grants or loans, to support the development or deployment of renewable energy technologies.

Pumped storage. Plants that pump water from a lower reservoir to a higher storage basin using surplus electricity, and that reverse the flow to generate electricity when needed. They are

not energy sources but means of energy storage and can have overall system efficiencies of around 80-90%.

Regulatory policy. A rule to guide or control the conduct of those to whom it applies. In the renewable energy context, examples include mandates or quotas such as renewable portfolio standards, feed-in tariffs and technology/fuel specific obligations.

Renewable energy certificate (REC). A certificate awarded to certify the generation of one unit of renewable energy (typically 1 MWh of electricity but also less commonly of heat). In systems based on RECs, certificates can be accumulated to meet renewable energy obligations and also provide a tool for trading among consumers and/or producers. They also are a means of enabling purchases of voluntary green energy.

Renewable portfolio standard (RPS). An obligation placed by a government on a utility company, group of companies or consumers to provide or use a predetermined minimum targeted renewable share of installed capacity, or of electricity or heat generated or sold. A penalty may or may not exist for non-compliance. These policies also are known as “renewable electricity standards”, “renewable obligations” and “mandated market shares”, depending on the jurisdiction.

Reverse auction. See Tendering.

Sector integration (also called sector coupling). The integration of energy supply and demand across electricity, thermal and transport applications, which may occur via co-production, combined use, conversion and substitution.

Smart energy system. An energy system that aims to optimise the overall efficiency and balance of a range of interconnected energy technologies and processes, both electrical and nonelectrical (including heat, gas and fuels). This is achieved through dynamic demand- and supply-side management; enhanced monitoring of electrical, thermal and fuel-based system assets; control and optimisation of consumer equipment, appliances and services; better integration of distributed energy (on both the macro and micro scales); as well as cost minimisation for both suppliers and consumers.

Smart grid. Electrical grid that uses information and communications technology to co-ordinate the needs and capabilities of the generators, grid operators, end-users and electricity market stakeholders in a system, with the aim of operating all parts as efficiently as possible, minimising costs and environmental impacts and maximising system reliability, resilience and stability.

Smart grid technology. Advanced information and control technology that is required for improved systems integration and resource optimisation on the grid.

Smart inverter. An inverter with robust software that is capable of rapid, bidirectional communications, which utilities can control remotely to help with issues such as voltage and frequency fluctuations in order to stabilise the grid during disruptive events.

Solar collector. A device used for converting solar energy to thermal energy (heat), typically used for domestic water heating but also used for space heating, for industrial process heat or to drive thermal cooling machines. Evacuated tube and flat plate

collectors that operate with water or a water/glycol mixture as the heat-transfer medium are the most common solar thermal collectors used worldwide. These are referred to as glazed water collectors because irradiation from the sun first hits a glazing (for thermal insulation) before the energy is converted to heat and transported away by the heat transfer medium. Unglazed water collectors, often referred to as swimming pool absorbers, are simple collectors made of plastics and used for lower temperature applications. Unglazed and glazed air collectors use air rather than water as the heat-transfer medium to heat indoor spaces or to pre-heat drying air or combustion air for agriculture and industry purposes.

Solar cooker. A cooking device for household and institutional applications, that converts sunlight to heat energy that is retained for cooking. There are several types of solar cookers including box cookers, panel cookers, parabolic cookers, evacuated tube cookers and trough cookers.

Solar home system (SHS). A stand-alone system composed of a relatively low-power photovoltaic module, a battery and sometimes a charge controller that can provide modest amounts of electricity for home lighting, communications and appliances, usually in rural or remote regions that are not connected to the electricity grid. The term solar home system kit is also used to define systems that usually are branded and have components that are easy for users to install and use.

Solar photovoltaics (PV). A technology used for converting light directly into electricity. Solar PV cells are constructed from semiconducting materials that use sunlight to separate electrons from atoms to create an electric current. Modules are formed by interconnecting individual cells. Building-integrated PV (BIPV) generates electricity and replaces conventional materials in parts of a building envelope, such as the roof or facade.

Solar photovoltaic-thermal (PV-T). A solar PV-thermal hybrid system that includes solar thermal collectors mounted beneath PV modules to convert solar radiation into electrical and thermal energy. The solar thermal collector removes waste heat from the PV module, enabling it to operate more efficiently.

Solar-plus-storage. A hybrid technology of solar PV with battery storage. Other types of renewable energy-plus-storage plants also exist.

Solar water heater (SWH). An entire system consisting of a solar collector, storage tank, water pipes and other components. There are two types of solar water heaters: pumped solar water heaters use mechanical pumps to circulate a heat transfer fluid through the collector loop (active systems), whereas thermosyphon solar water heaters make use of buoyancy forces caused by natural convection (passive systems).

Storage battery. A type of battery that can be given a new charge by passing an electric current through it. A lithium-ion battery uses a liquid lithium-based material for one of its electrodes. A lead-acid battery uses plates made of pure lead or lead oxide for the electrodes and sulphuric acid for the electrolyte, and remains common for off-grid installations. A flow battery uses two chemical components dissolved in liquids contained within the system and most commonly separated by a membrane. Flow batteries can be recharged almost instantly by

replacing the electrolyte liquid, while simultaneously recovering the spent material for re-energisation.

Target. An official commitment, plan or goal set by a government (at the local, state, national or regional level) to achieve a certain amount of renewable energy or energy efficiency by a future date. Targets may be backed by specific compliance mechanisms or policy support measures. Some targets are legislated, while others are set by regulatory agencies, ministries or public officials.

Tender (also called auction/reverse auction or tender). A procurement mechanism by which renewable energy supply or capacity is competitively solicited from sellers, who offer bids at the lowest price that they would be willing to accept. Bids may be evaluated on both price and non-price factors.

Thermal energy storage. Technology that allows the transfer and storage of thermal energy.

Transmission grid. The portion of the electrical supply distribution network that carries bulk electricity from power plants to substations, where voltage is stepped down for further distribution. High-voltage transmission lines can carry electricity between regional grids in order to balance supply and demand.

Variable renewable energy (VRE). A renewable energy source that fluctuates within a relatively short time frame, such as wind and solar energy, which vary within daily, hourly and even subhourly time frames. By contrast, resources and technologies that are variable on an annual or seasonal basis due to environmental changes, such as hydropower (due to changes in rainfall) and thermal power plants (due to changes in temperature of ambient air and cooling water), do not fall into this category.

Vehicle fuel standard. Rule specifying the minimum fuel economy of automobiles.

Virtual power plant (VPP). A network of decentralised, independently owned and operated power generating units combined with flexible demand units and possibly also with storage facilities. A central control station monitors operation, forecasts demand and supply, and dispatches the networked units as if they were a single power plant. The aim is to smoothly integrate a high number of renewable energy units into existing energy systems; VPPs also enable the trading or selling of power into wholesale markets.

Virtual power purchase agreement (PPA). A contract under which the developer sells its electricity in the spot market. The developer and the corporate off-taker then settle the difference between the variable market price and the strike price, and the off-taker receives the electricity certificates that are generated. This is in contrast to more traditional PPAs, under which the developer sells electricity to the off-taker directly.

Watt. A unit of power that measures the rate of energy conversion or transfer. A kilowatt is equal to 1 thousand watts; a megawatt to 1 million watts; and so on. A megawatt-electrical (MW) is used to refer to electric power, whereas a megawatt-thermal (MWth) refers to thermal/heat energy produced. Power is the rate at which energy is consumed or generated. A kilowatt-hour is the amount of energy equivalent to steady power of 1 kW operating for one hour.

■ LIST OF ABBREVIATIONS

ADB	Asian Development Bank	LVC	Land value capture
AUD	Australian dollar	MSW	Municipal solid waste
BEV	Battery electric vehicle	MW/MWh	Megawatt/Megawatt-hour
BRIICS	Brazil, Russian Federation, India, Indonesia, China and South Africa	MW _{th}	Megawatt-thermal
CCA	Community choice aggregation	MXN	Mexican peso
CHP	Combined heat and power	NDC	Nationally determined contribution
CNG	Compressed natural gas	NIMBY	Not in my back yard
CO ₂	Carbon dioxide	NUP	National urban policy
CSP	Concentrating solar thermal power	OECD	Organisation for Economic Co-operation and Development
DHC	District heating and cooling	PACE	Property Assessed Clean Energy
ESCO	Energy service company	PAYG	Pay as you go
EU	European Union	PHEV	Plug-in hybrid electric vehicle
EUR	Euro	PJ	Petajoule
EV	Electric vehicle	PM _{2.5}	Fine particulate matter
FIT	Feed-in tariff	PPA	Power purchase agreement
GDP	Gross domestic product	PPI	Private participation in infrastructure
GSR	Global Status Report	PV	Photovoltaic
GW/GWh	Gigawatt/gigawatt-hour	REC	Renewable energy certificate
GW _{th}	Gigawatt-thermal	SDG	Sustainable Development Goal
HUF	Hungarian forint	TW/TWh	Terawatt/Terawatt-hour
ICE	Internal combustion engine	UAE	United Arab Emirates
ICT	Information and communications technology	UK	United Kingdom
JPY	Japanese yen	ULEZ	Ultra-low emissions zone
km ²	Square kilometre	UN	United Nations
kW/kWh	Kilowatt/kilowatt-hour	US	United States
LED	Light-emitting diode	USD	United States dollar
LNG	Liquefied natural gas		



For the *Renewables in Cities 2019 Global Status Report* REN21 collected data in several ways:

- 1. City questionnaire:** Contributors from around the world submitted information on renewable energy in their respective cities or cities of interest. The questionnaire covers information about drivers for renewables; existing targets, policies and finance mechanisms; market trends; and how municipalities engage citizens in the energy transition. Each data point is provided with a source and verified independently by the REN21 team.
- 2. Expert interviews:** REN21's global community consists of a wide range of professionals who provide their input on renewable energy trends in cities through interviews and personal communications with the REN21 Secretariat and chapter authors. Most of the information is backed up by primary sources.
- 3. Data-sharing agreements:** REN21 holds several data sharing agreements with some of the largest and most reliable data providers/aggregators in the energy sector and city sphere.
- 4. Desk research:** To fill in remaining data gaps in the *Renewables in Cities 2019 Global Status Report*, the REN21 Secretariat and the chapter authors conduct extensive desk research.
- 5. Peer review:** To further collect data and project examples and to ensure that significant developments have not been overlooked, REN21 invites contributors and reviewers to participate in an open peer-review. Peer-review is open to all interested experts.
- 6. Data validation:** REN21 ensures the accuracy and reliability of its reports by conducting data validation and fact-checking as a continuous process. All data provided by contributors, whether written or verbal, are validated by primary sources, which are published alongside the full report.

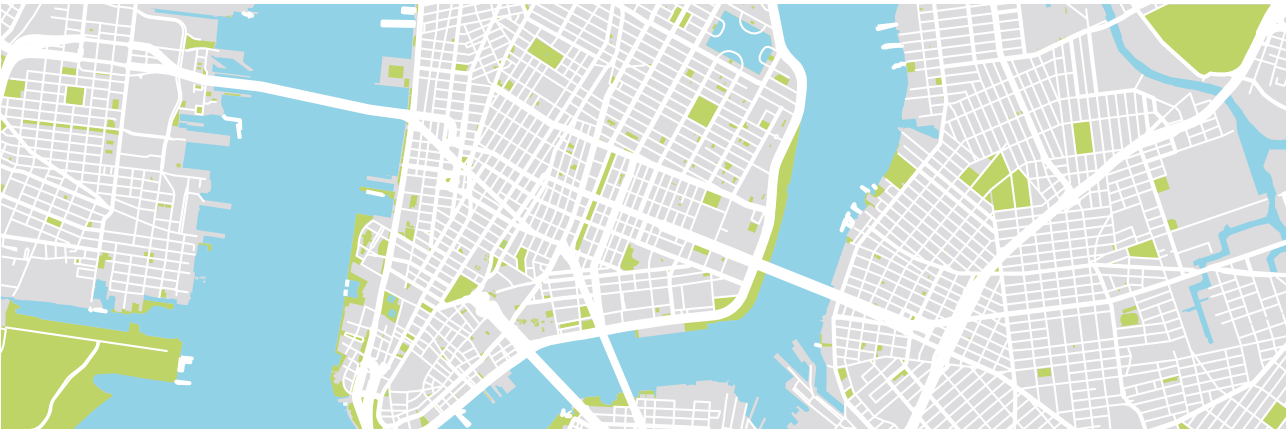
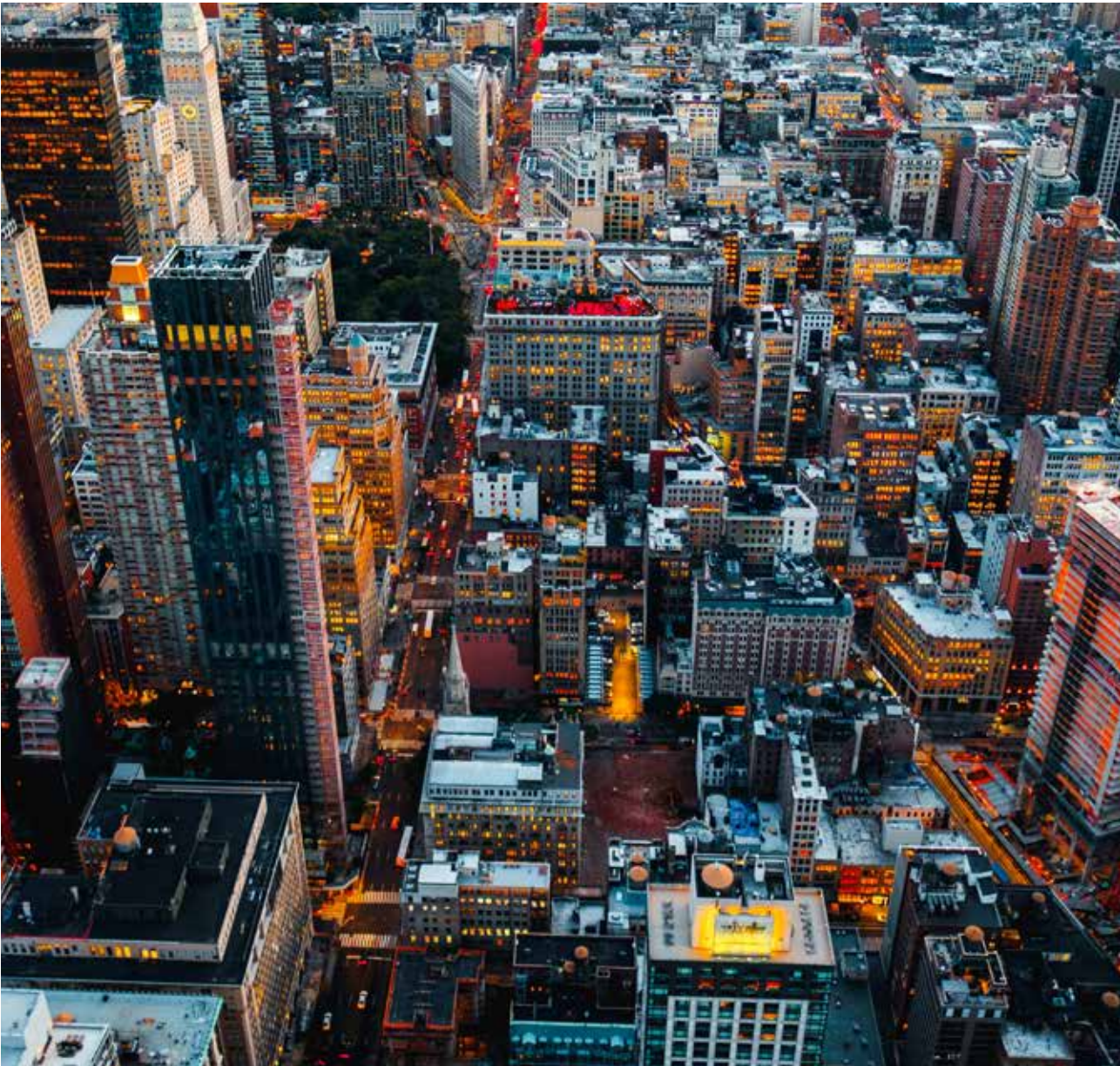


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REN21 Secretariat
c/o UN Environment
1 rue Miollis
Building VII
75015 Paris
France

www.ren21.net

