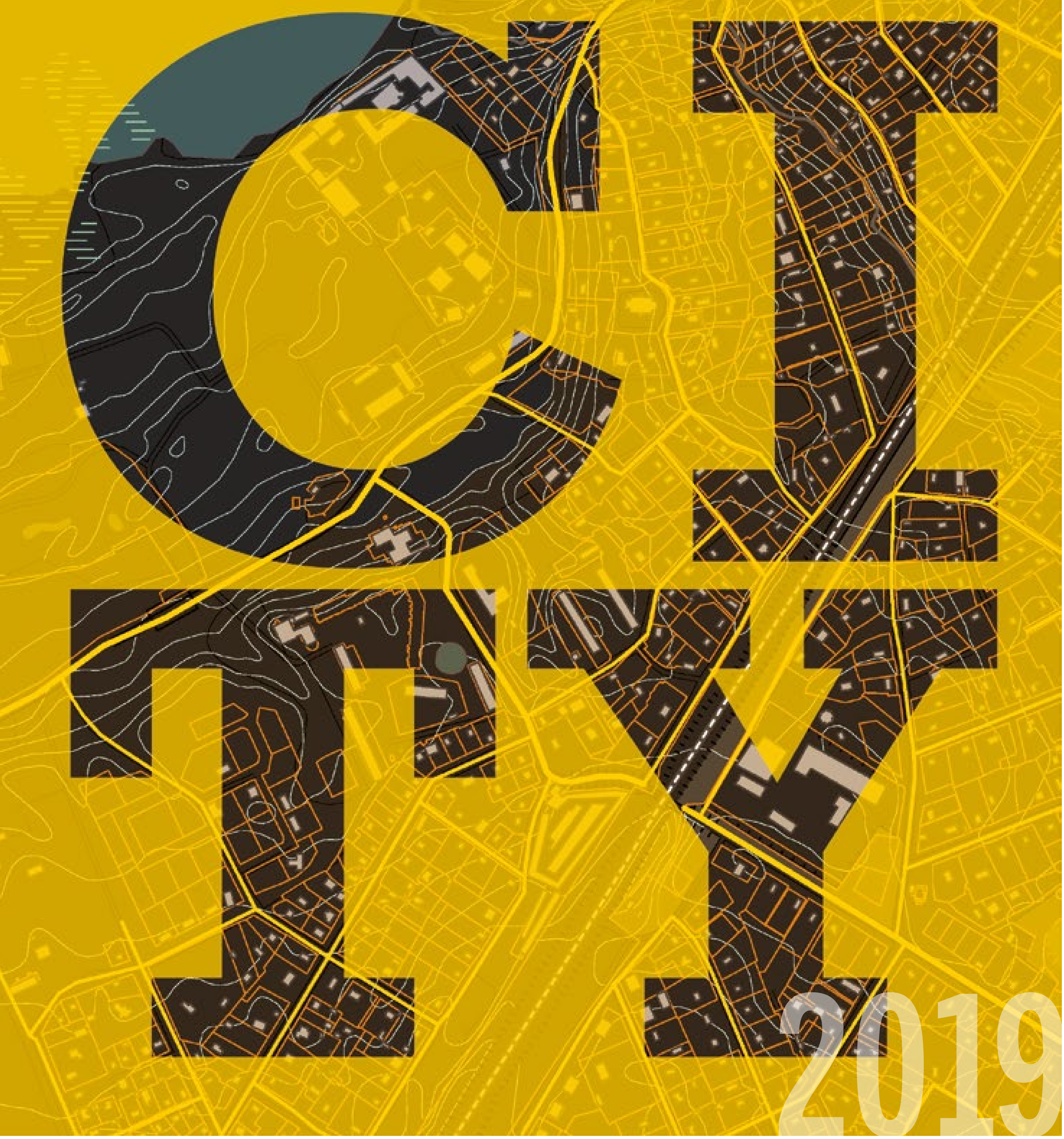
REN21
RENEWABLES NOW

RENEWABLES IN CITIES
2019 GLOBAL STATUS REPORT



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REN21 COMMUNITY

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.

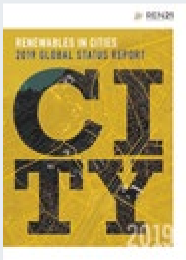
REN21 changes the way we think about renewable energy.

SHAPE THE FUTURE

KNOWLEDGE

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.



RENEWABLES IN CITIES – GLOBAL STATUS REPORT (REC-GSR)

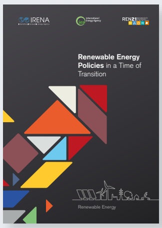
The cities report is the first comprehensive resource to map out the current trends and renewable energy developments in cities. It uses the same rigorous standards found in the *Renewables Global Status Report* series.

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.

REN21
RENEWABLES NOW

COMMUNITY

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.

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.

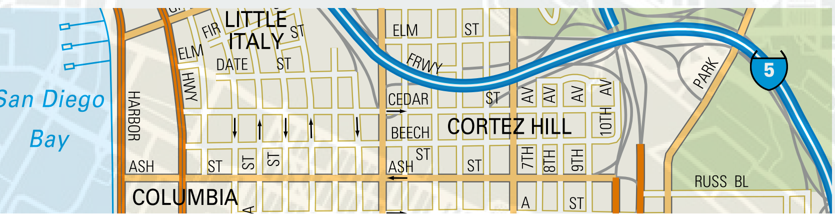
Since the first edition of the GSR in 2005, REN21 has continuously expanded its reporting. To highlight regional trends, REN21 has developed a *Regional Renewable Energy and Energy Efficiency Status Report* series and is now including reporting on renewable energy development in cities, considering the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

www.ren21.net/GSR
www.ren21.net/cities

Bridging and building the energy future.

www.ren21.net



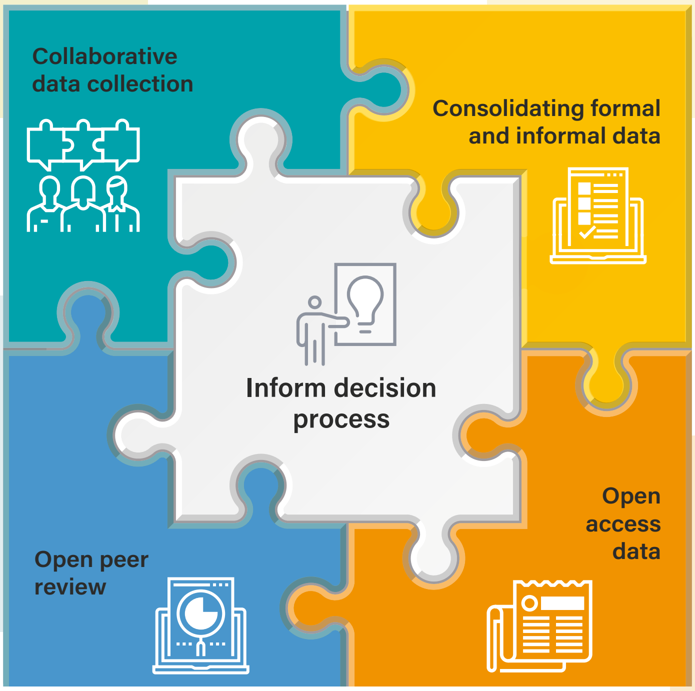
REN21 DATA AND REPORTING CULTURE

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:

Developing **data collection processes** that build on an international community of experts, allowing access to dispersed data and information that frequently are not consolidated and are difficult to collect.

Consolidating formal (official) and informal (unofficial/unconventional) data gathered from a wide range of sources in a collaborative and transparent way (e.g., by using extensive referencing).



Complementing and validating data and information in an open peer-review process.

Using validated data and information to **provide fact-based evidence** and to develop a supportive narrative to shape the global debate on the energy transition, monitor advancements and inform decision processes.

Making data and information openly available so they can be used by people in their work to advocate for renewable energy.

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.

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
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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.

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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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REPORT CITATION
REN21, 2019. *Renewables in Cities 2019 Global Status Report* (Paris: REN21 Secretariat)
ISBN: 978-3-9818911-9-5

Endnotes: see full version online at www.ren21.net/cities

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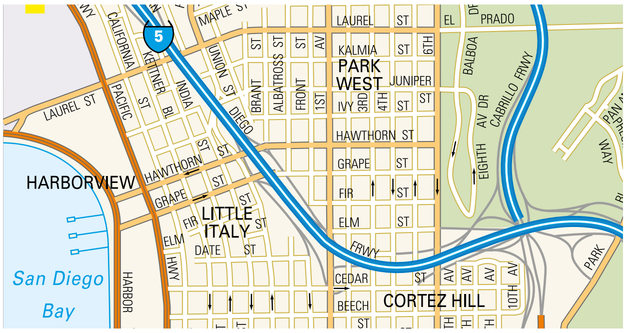

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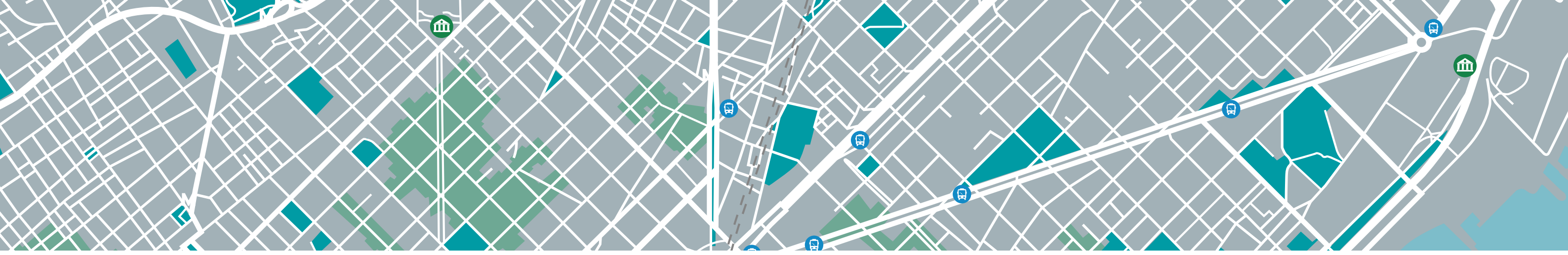
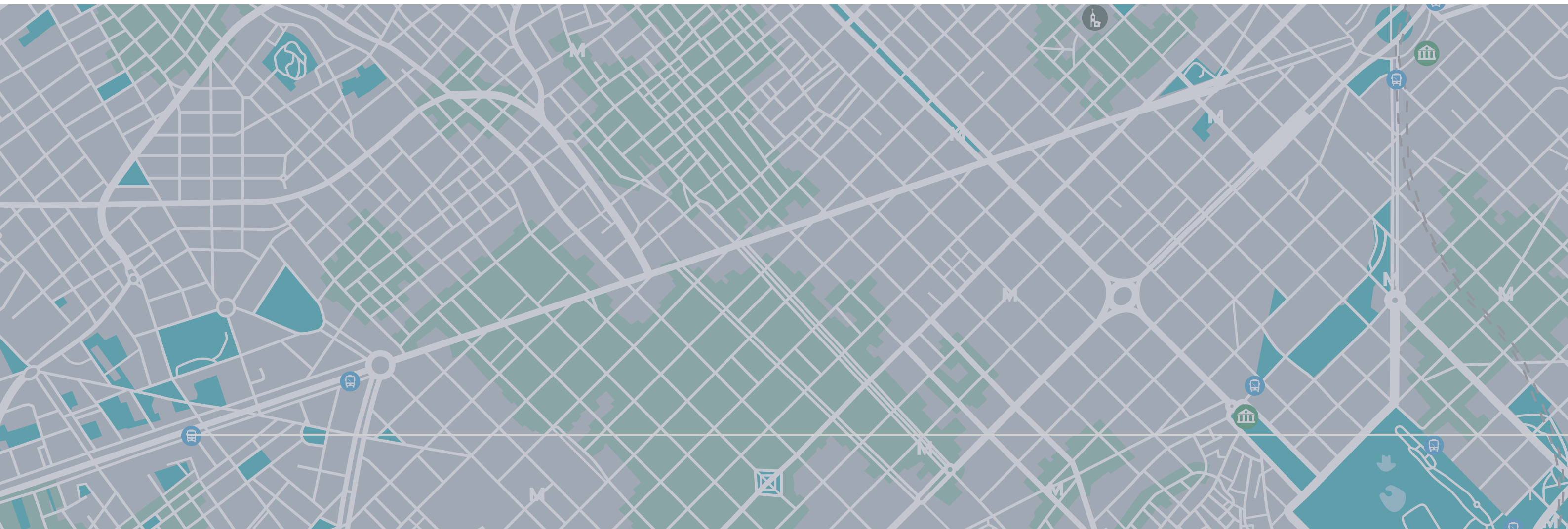


EXECUTIVE SUMMARY



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 (CO_2) emissions.

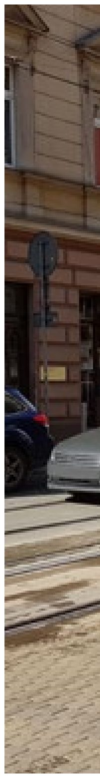
In addition, cities account for 55% of the global population and for more than 80% of global gross domestic product. Thus, shifting to renewable energy in cities is critical to decarbonising the global energy system. At the same time, cities offer a lever to advance the transition towards renewable energy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

Cities account for an estimated **75%** of global CO_2 emissions.

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 their own financial resources, access to external financing, the size of the tax base, economic growth and the local administrative capacity and authority.



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 businesses 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.**

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.

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.

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 CO_2 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 CO_2 emissions.

MOBILISING FINANCE AND ENABLING BUSINESS MODELS

More and more city governments are developing urban renewable energy projects. However, many challenges remain, such as limitation to 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 limitations to a municipality's own funds and lack 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.

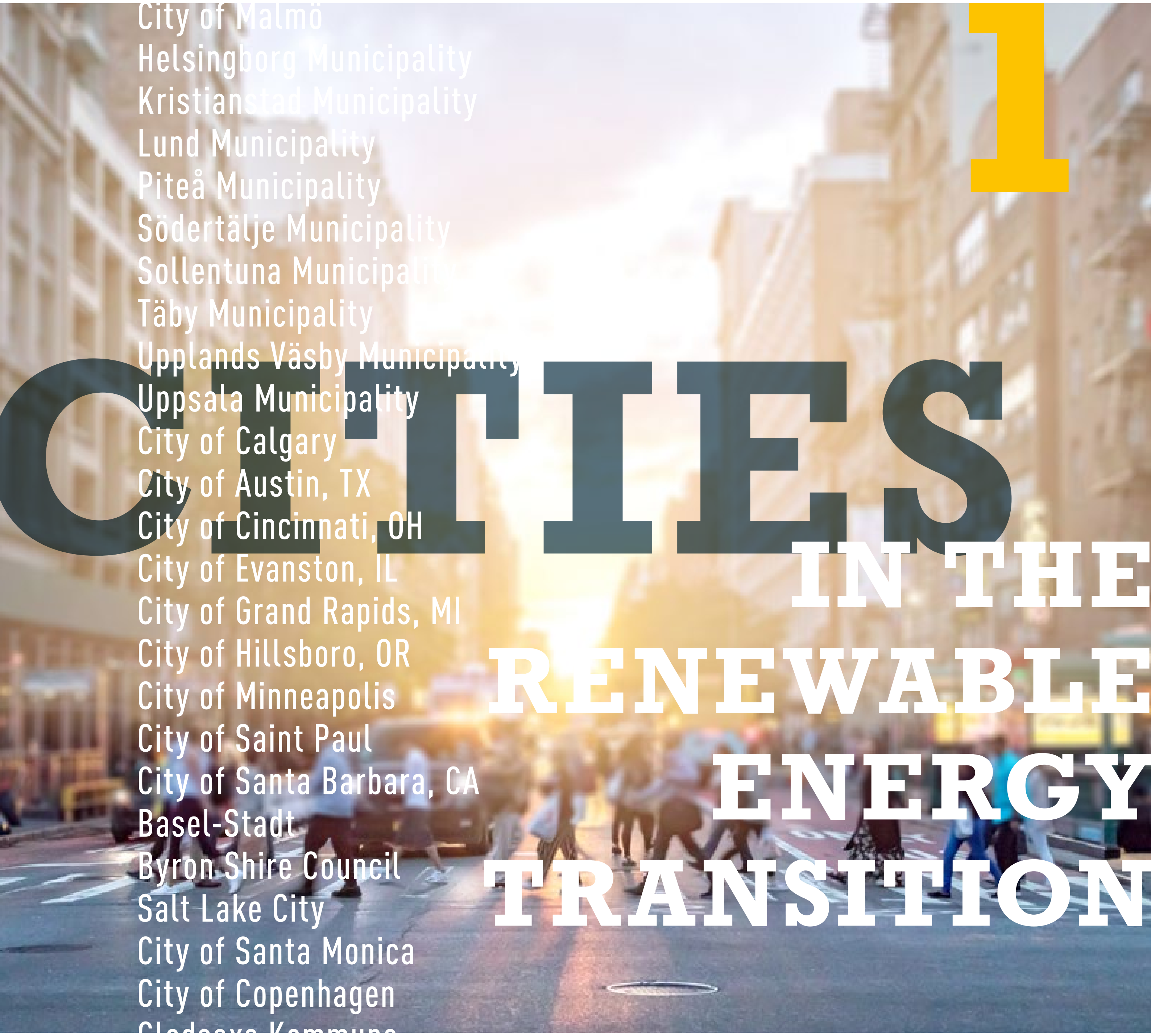
Around the world, citizens are playing an increasingly active role in advancing renewable energy deployment. City residents can contribute in many different ways, including by choosing renewable energy tariffs, switching to green suppliers, and becoming prosumers by installing their own systems or by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

Although frequently associated with 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 are 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 (CO_2) 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 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 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, cooling[i] 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:

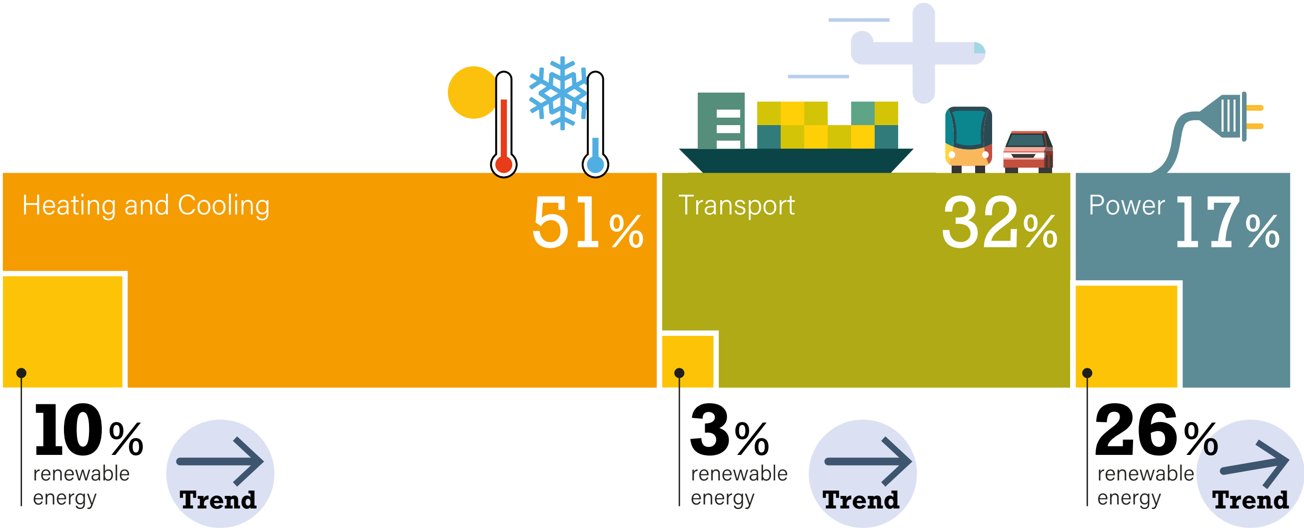
- municipal targets and policies to promote renewables in the power, heating and cooling, and transport sectors, both for municipal operations and for city-wide energy uses;
- shares of renewables in municipal and city-wide energy use;
- generation capacities for renewable electricity, heating and cooling, 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 better engaging cities in 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 Report.
Electricity also supplies final energy demand in the heating and cooling sector (7.1% in 2016), and transport sector (1.1% 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 CO_2 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[i],[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 CO_2 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.

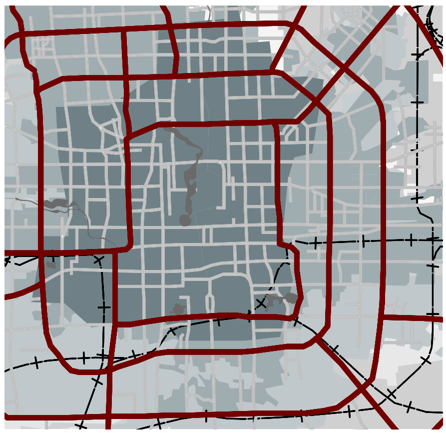
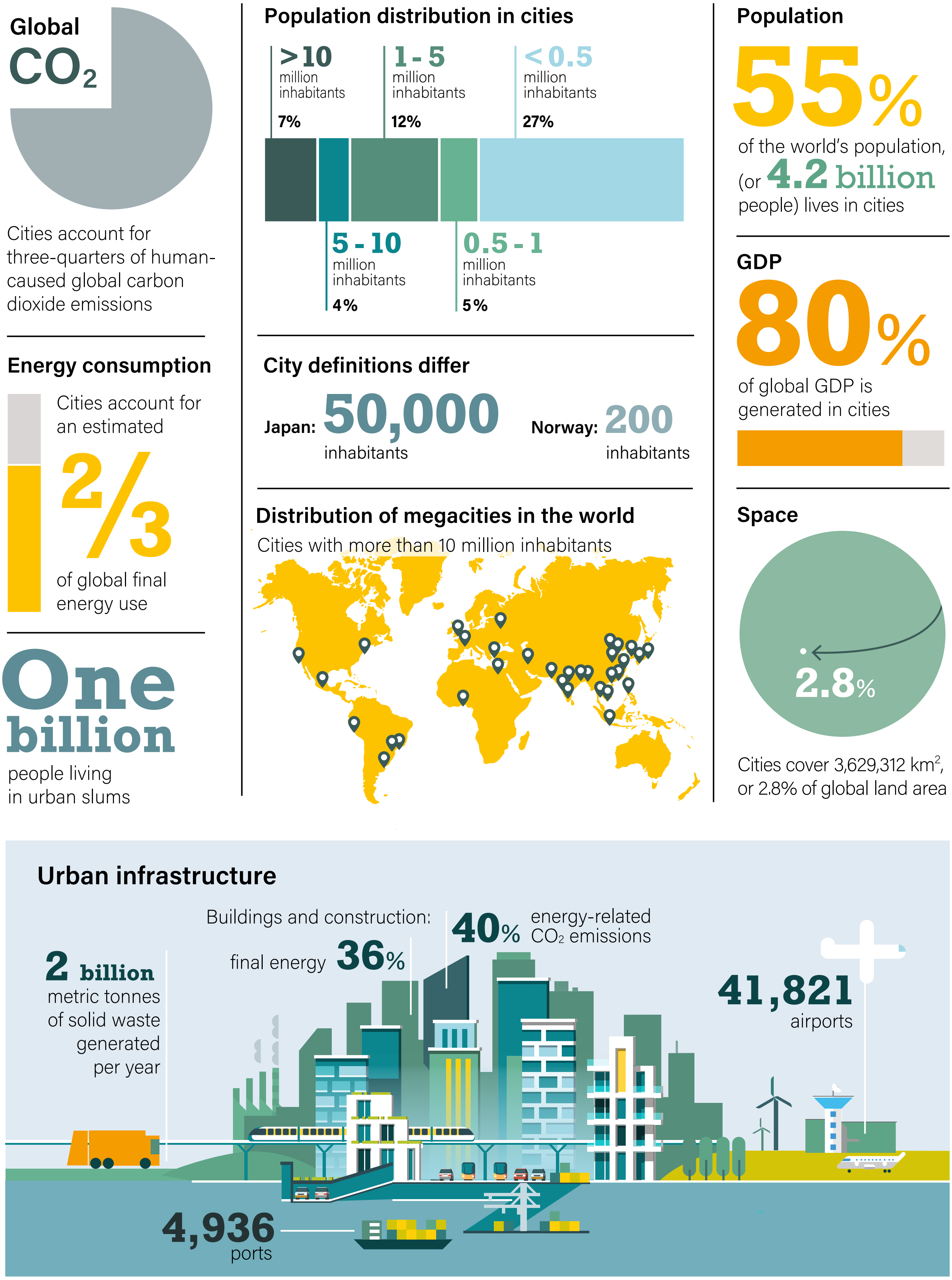


FIGURE 2. Cities in the World



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-urban[i] 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 city[i], 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.

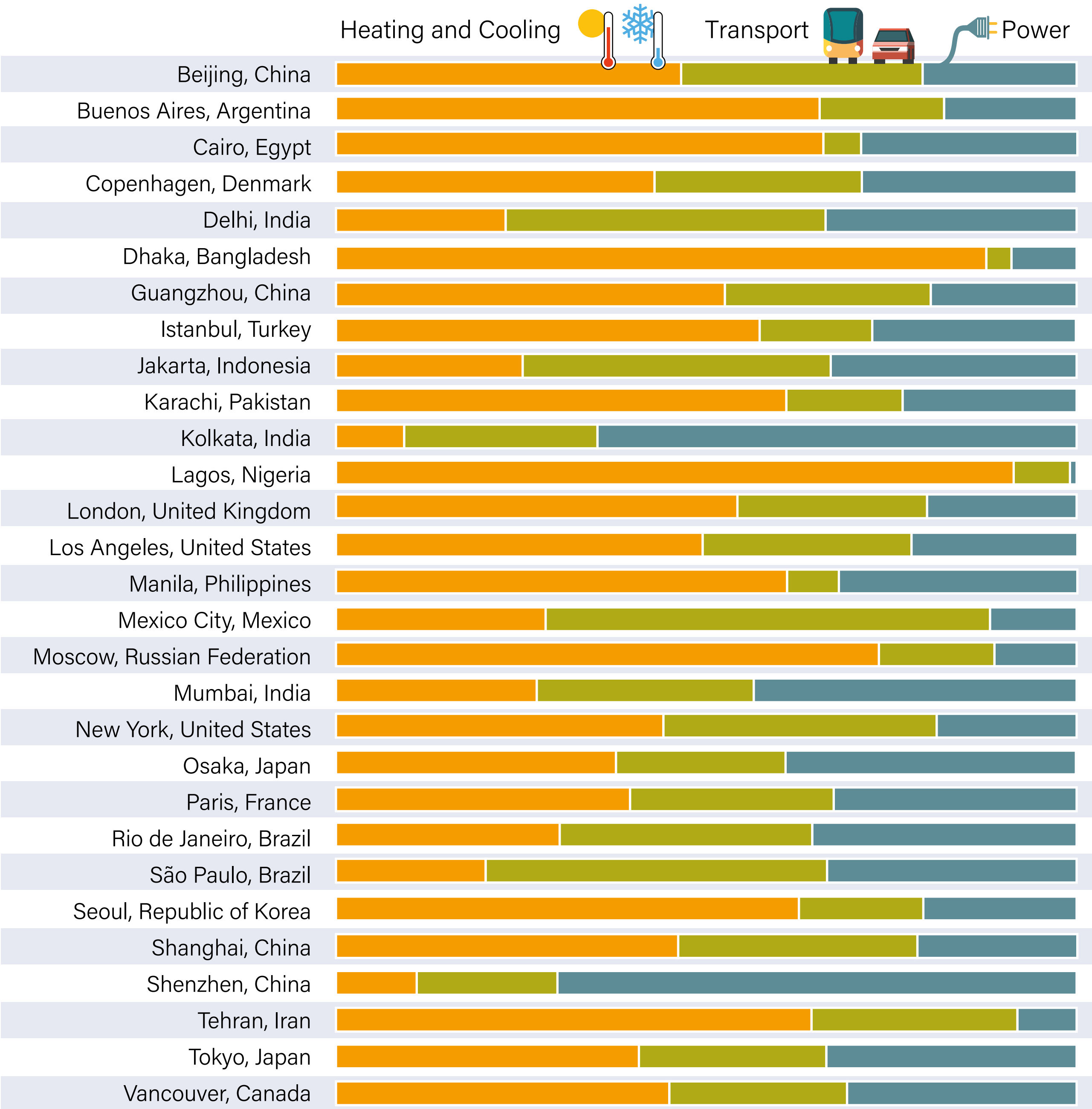
Buildings account for approximately half of all energy demand worldwide, and most built structures are located in and around urban centres.[25] For heating and cooling systems, where energy production is more localised and tends to occur close to the point of demand, the development of urban renewable 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 CO_2 emissions from road transport[ii].[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 mobility[iii].

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 CO_2 emissions, from International Transport Forum, "How transport CO_2 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 CO_2 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 also meet energy demands in the heating, cooling and transport sectors. 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.

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 cites 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 effect[i] 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:

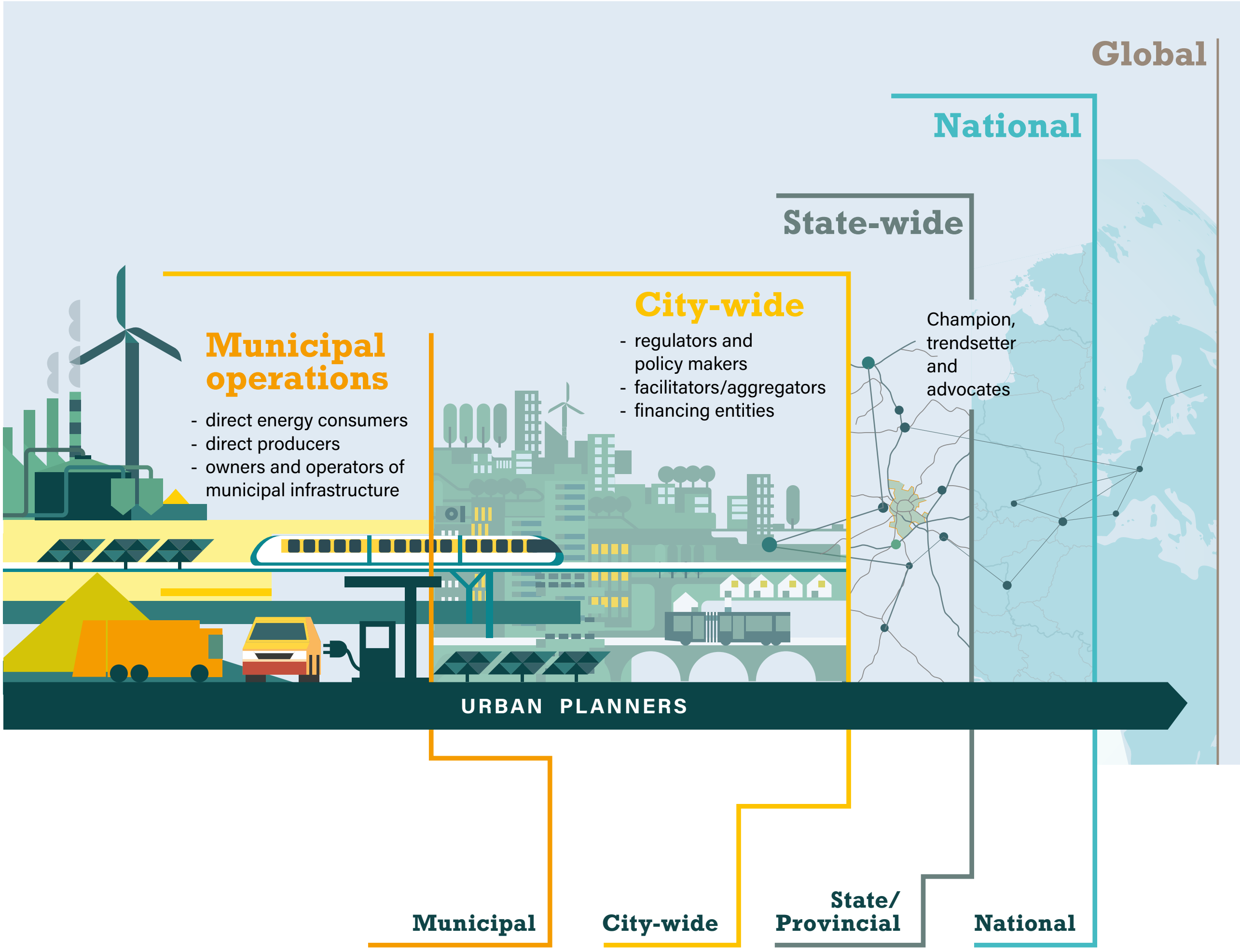
Target setters. Many municipal governments have adopted ambitious climate and energy targets, covering both municipal operations as well as city-wide emissions and energy use. For many cities, setting a target can act as a catalytic step in the shift to renewables, signalling ambition and helping to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



	Municipal	City-wide	State/ Provincial	National
Target setters	■■■	■■■	■■	■
Energy consumers	■■■	■■	■■	■
Energy producers	■■■	■■	■■	■
Owners & operators of infrastructure	■■■	■■■	■■	■
Regulators & policy makers	■■■	■■■	■■	■
Facilitators/aggregators	■■■	■■■	■■	■
Financing entities	■■■	■■■	■■	■
Urban planners	■■■	■■■	■■	■
Champions, trendsetters and advocates	■■■	■■■	■■■	■■■

■■■ Direct city influence ■■ Secondary city influence ■ Marginal city influence

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] Effective 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 integration[i] 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 subsidiarity[ii] 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, on its 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 (km^2) and roughly 95 inhabitants per km^2.[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 km^2.[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]

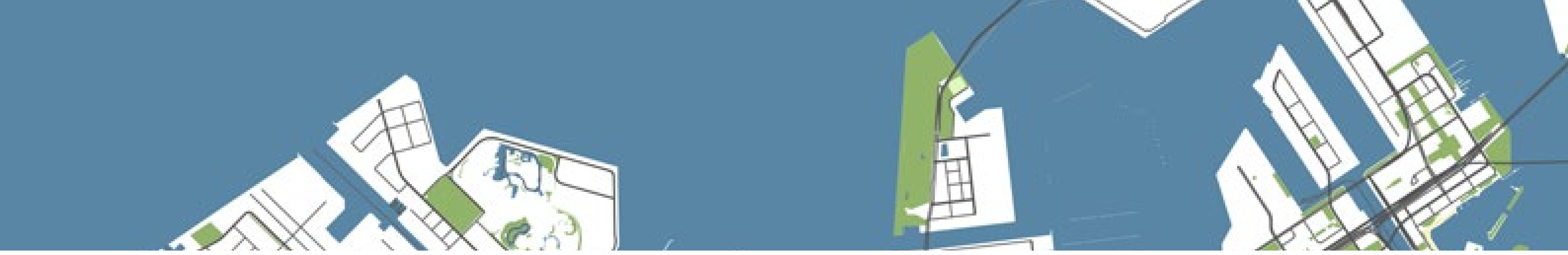
In **North America**, the urbanisation rate in both the United States and Canada is 82%.[77] However, the urban share varies widely by state and province, at less than 40% in Maine (US) and 48% in New Brunswick (Canada).[78] The distribution of cities and local governments also varies: for example, the 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]



2

DRIVERS FOR RENEWABLE ENERGY IN CITIES

The Hague
Abita Springs, LA
Amherst, MA
Angel Fire, NM
Atlanta
Berkeley, CA
Blacksburg, VA
Breckenridge, Colorado
Chula Vista
Clarkston, CA
Concord, NH
Cornish, New Hampshire
Culver City
Del Mar, California
Denton, TX
Denver, CO
Downington 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
Madison, WI

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 transport[i], 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]

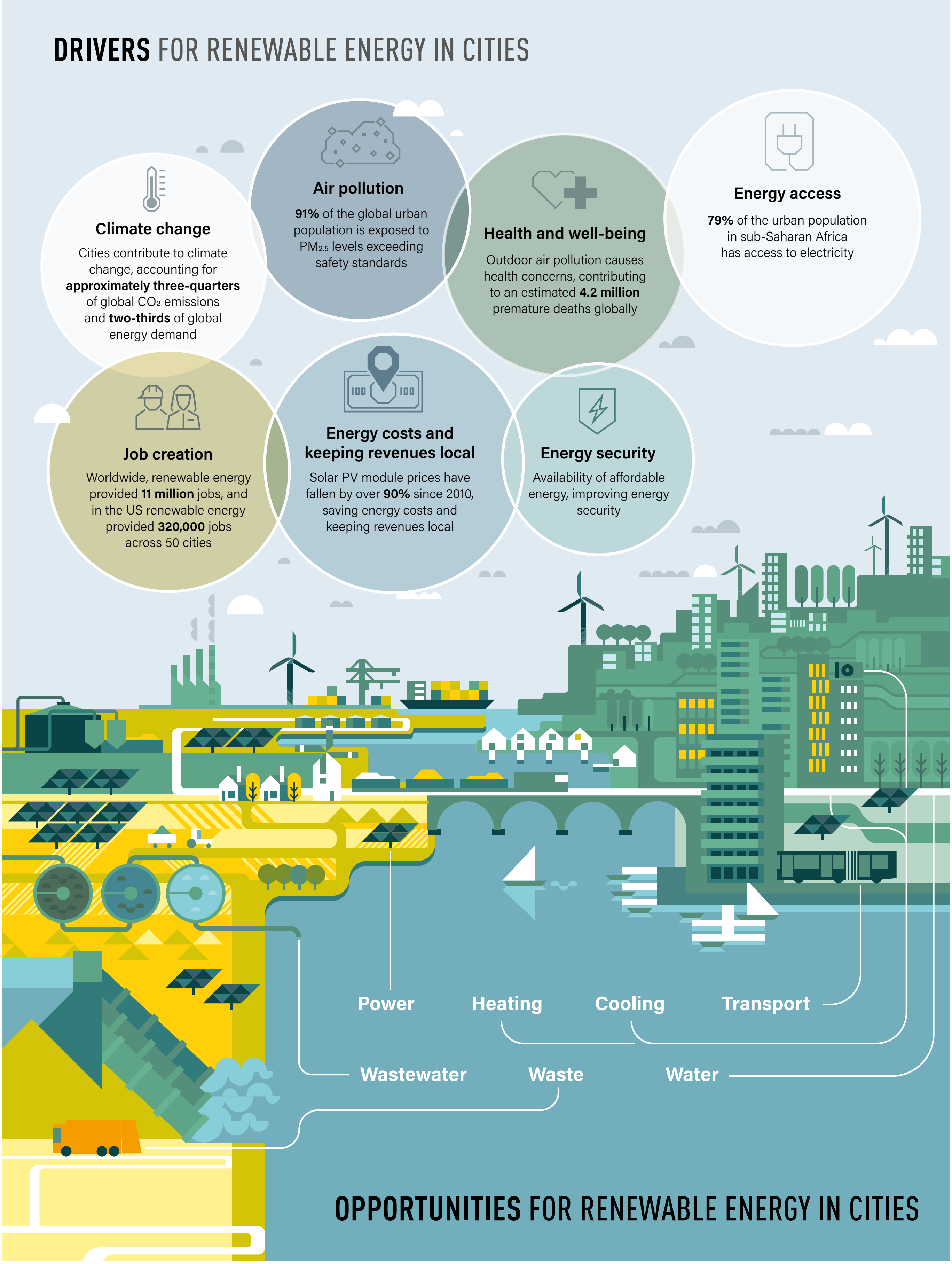
An estimated 9 out of 10 people worldwide regularly encountered polluted air in 2018.[3] In 2016, as much as 91% of the global urban population was exposed to air pollution – measured in the form of fine particulate matter ($PM_{2.5}$) – and more than half of the urban population faced $PM_{2.5}$ levels 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 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 (Kuwait) 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]

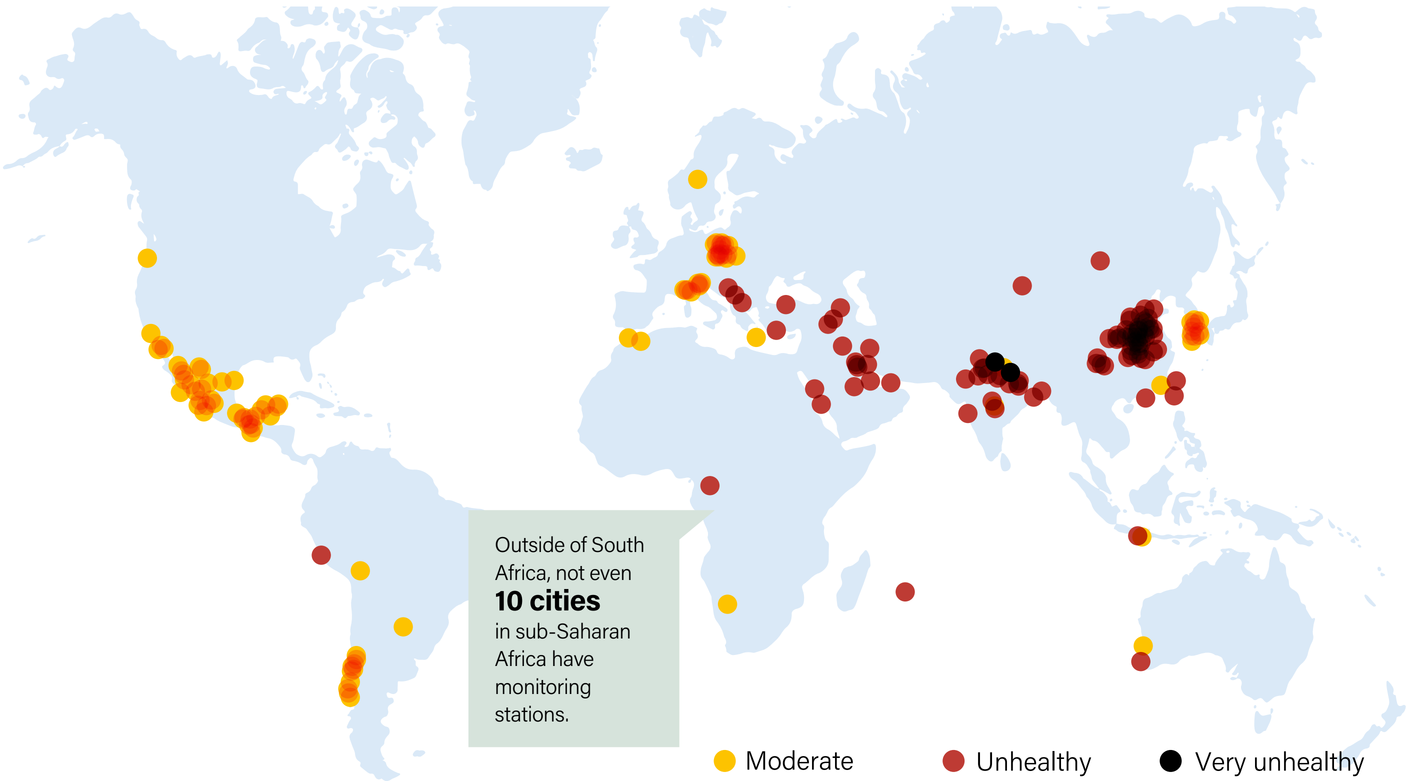
Air pollution is the world's fourth-leading contributor to early mortality.[8] In 2016, high levels of outdoor air pollution were responsible for the deaths of some 4.2 million people due to increases in cancer and in heart and lung disease.[9] Most of the premature deaths occurred in low- and middle-income 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, 2018



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-emission[i] 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-benefits[ii] 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 CO_2 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 settlements[i] 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 the transport sector, several cities have strategies to decarbonise the sector, including Oslo (Norway) and Stockholm (Sweden).[45]

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

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*).[46] 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]

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[i]. 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.

The number of jobs in renewable energy worldwide increased to some

11 million

in 2018.

Cities with high shares of renewables are well positioned to **attract new industries**, creating direct and indirect jobs[i] 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 eThekwini (of which Durban is a part) has built the eThekwini 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 example, coupling thermal with power systems to integrate and balance out variability.[94] Skive (Denmark) is building Europe's

i 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.

largest power-to-gas facility, which will convert surplus wind energy into carbon-free methane and contribute to the city's goal of CO_2 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]

More than
109 million urban residents
worldwide (and 840 million people in total) still lacked electricity as of 2017.

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*).

ACCESS TO ENERGY

Many cities, mainly in the developing world, are adopting renewable energy policies and targets to expand energy access[i] 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]

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

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]

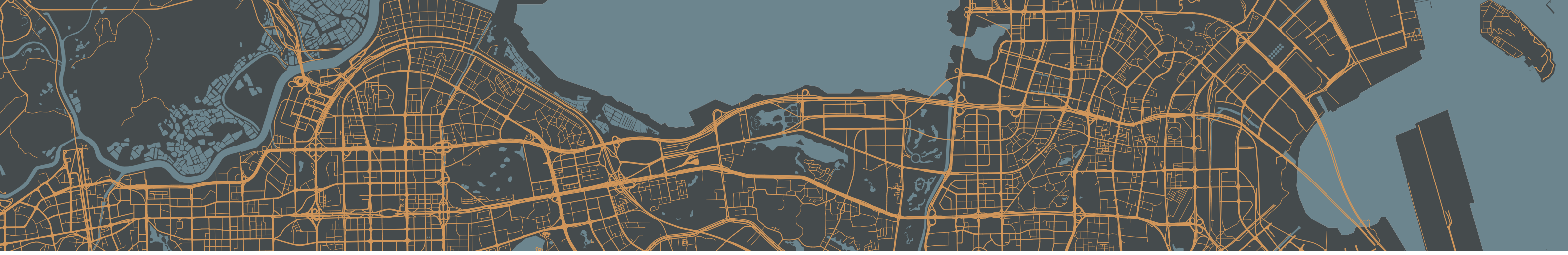
Urban energy access is closely related to **ensuring energy affordability**. Urban energy poverty is determined by expenditures on items such as transport, housing, electricity and cooking and tends to be concentrated in lower-income, suburban neighbourhoods.[117] On average, the urban poor have less 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 (m^2).[121] Elsewhere, Rajkot (India) has installed solar PV in connection to social housing developments, with the potential to reduce 35 tonnes of CO_2-equivalent emissions per year.[122]

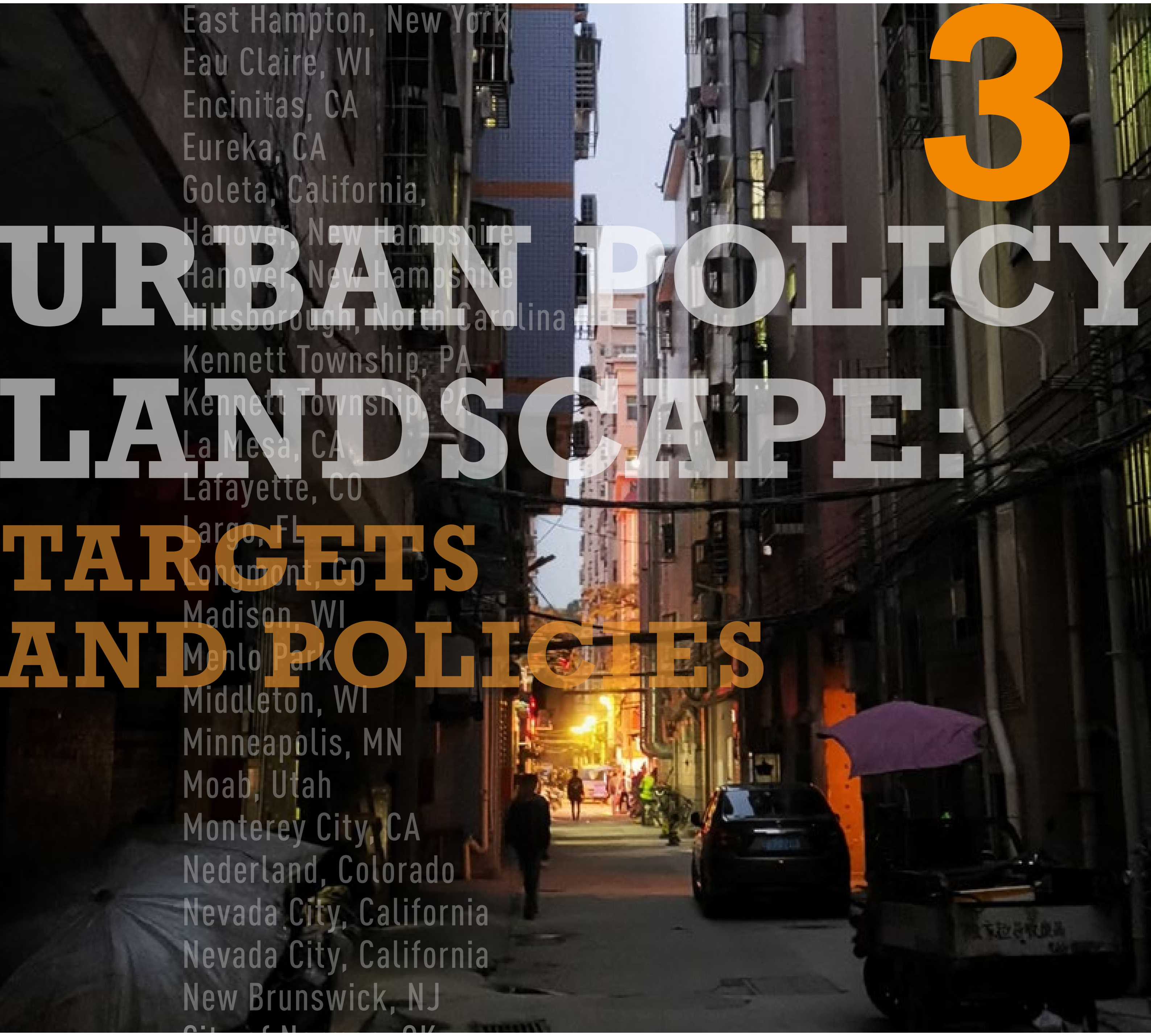
Energy poverty is best measured by assessing the quality of energy sources and the ability to purchase energy for essential uses and basic human needs. Urban dwellers may, for instance, limit the number of meals they eat in order to save money on fuels and food.[123] Under conditions of energy poverty, 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]

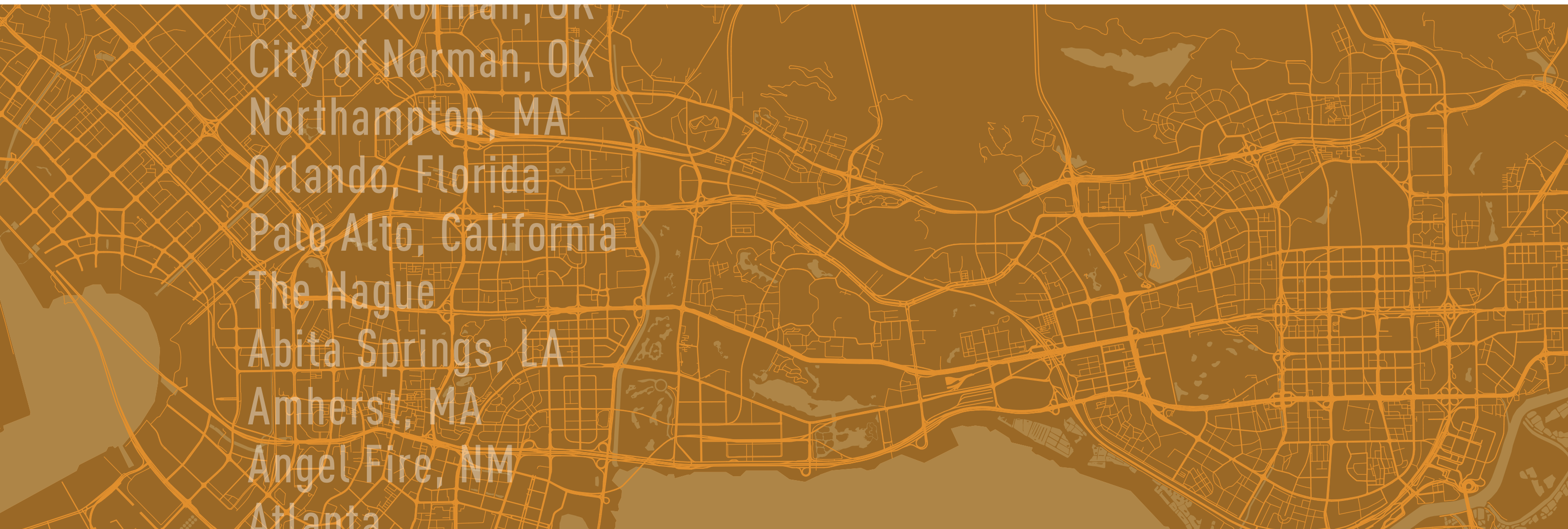
Access to energy for urban populations is greatly influenced by the **reliability of the energy supply**. While energy network failures happen in cities around the world, they are more frequent in developing countries.[126] Introducing and expanding the use of renewables in urban energy systems, especially 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]

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





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*).

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]

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

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]

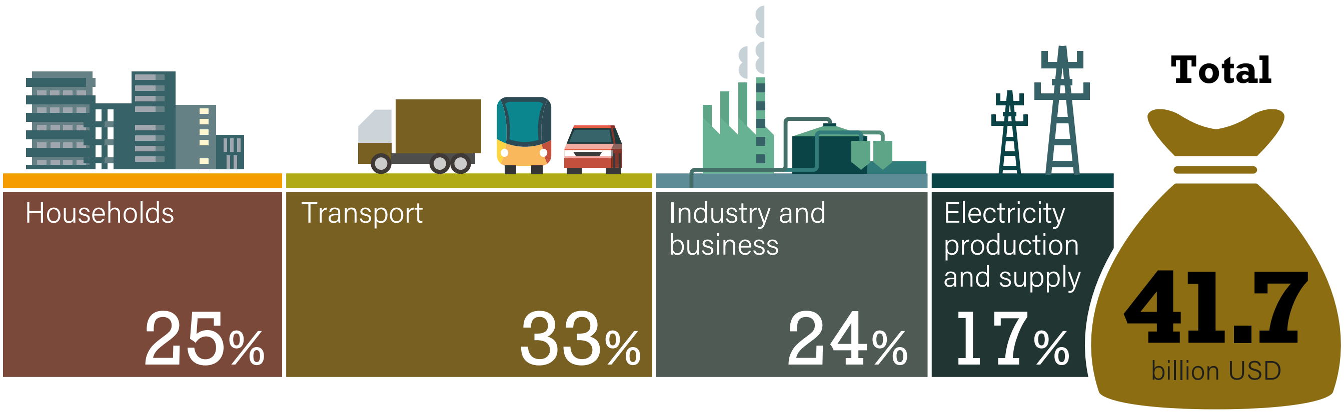
Policies at the national or state/provincial levels, such as national building codes and regulations on vehicle or appliance efficiency, have a direct influence not only on municipal strategies and operations, but also on city-wide energy use.[10] Other areas, such as taxation, environmental regulation 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 7*).[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]

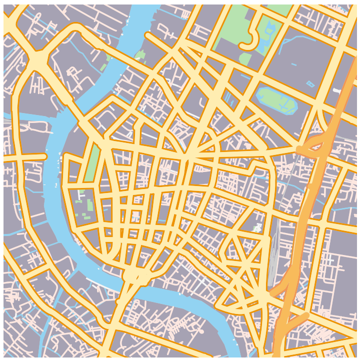
Some national governments are promoting National Urban Policies (NUPs) as a way to align policies in different sectors, complementing municipal policies and creating an institutional framework that integrates cities into overall national development plans; this helps to implement and monitor progress.[18] 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 Co-operation 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[i].[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 initiatives (→ *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 greatly 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 CO_2-equivalent emissions[i] 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 CO_2 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[i]. 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 commitments[i] 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 8*).[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]

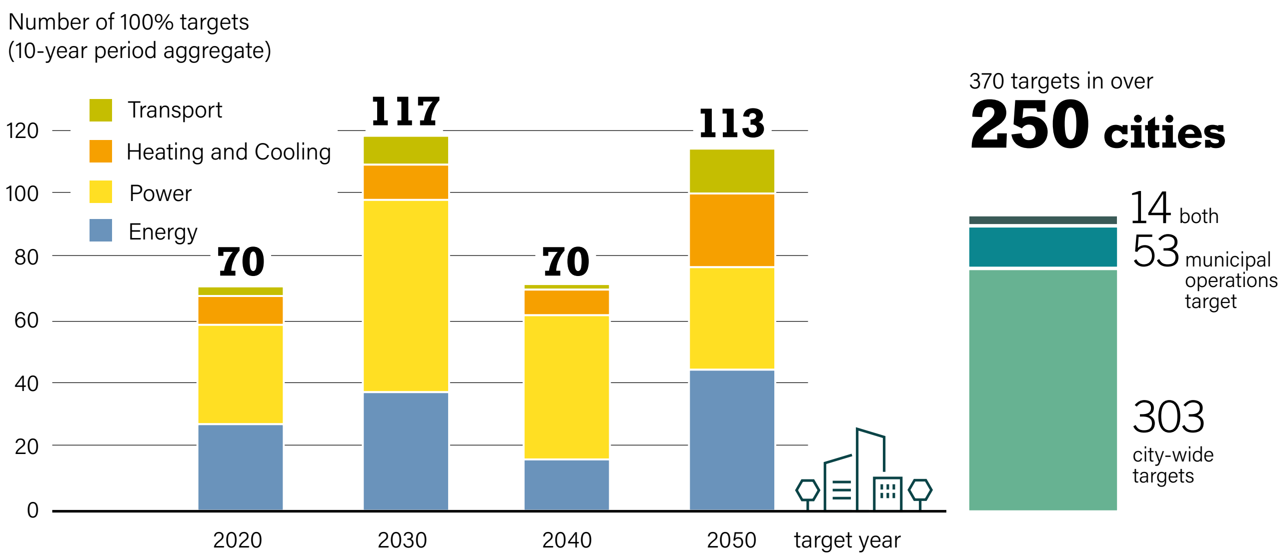
Some city governments have opted to use targets based on renewable power capacity instead, which can be easier to monitor[iv] (→ *see Reference Table R5*). Capacity-based targets are prominent in China: for example, by the end of 2020 Beijing aims to add 1.16 GW of solar PV and 650 MW of wind power capacity; 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



Note: By mid-2019, 370 targets in over 250 cities have been identified. In addition, several 100% target exist in villages as well as provinces around the world. Data included in this figure were compiled by REN21, ICLEI and The Global 100% Renewable Energy Platform with material provided by a variety of stakeholders, including CDP, Climate Action Network, C40, IRENA, Sierra Club, Renewable Cities (2018), and may not be comprehensive.

Source: See endnote 46 for this chapter.

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 them to the heating, cooling and/or 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.

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 three end-use 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, Hew 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 targets to become fossil-fuel free. 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 level[i], although more are emerging at the city level. 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]

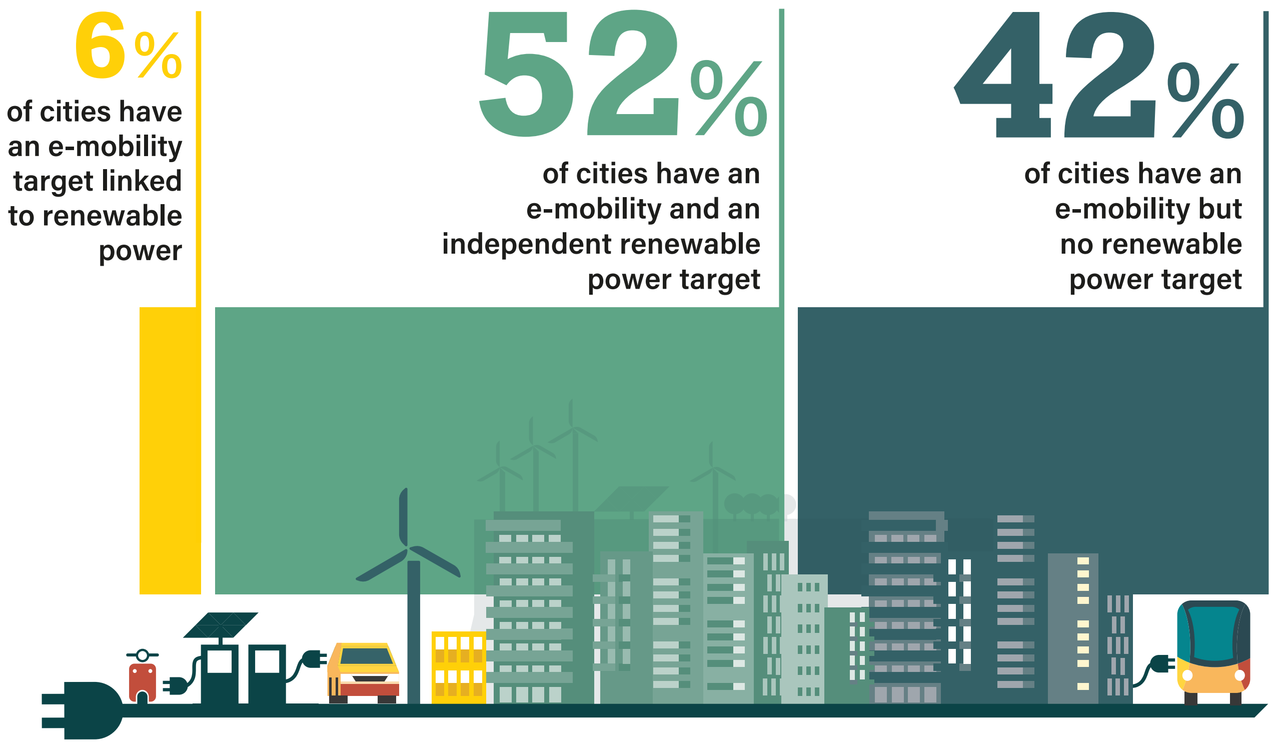
Driven in part by efforts to improve local air quality, cities have adopted targets to increase the share of EVs in their municipal fleets. Globally, most municipal EV targets are not linked directly to renewable energy (whether through direct EV charging with renewables or parallel efforts to increase renewables in the electricity mix). Of the more than 50 cities worldwide with identified e-mobility targets as of mid-2019, less than 6% 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 9 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[ii].[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 Medellin (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 GSR 2019.

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, as of Mid-2019



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*).[61] Increasing the use of renewables in municipal operations and city-wide, and expanding 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 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 CO_2 emissions by 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. Urban Climate and Air Pollution Targets, as of Mid-2019

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]

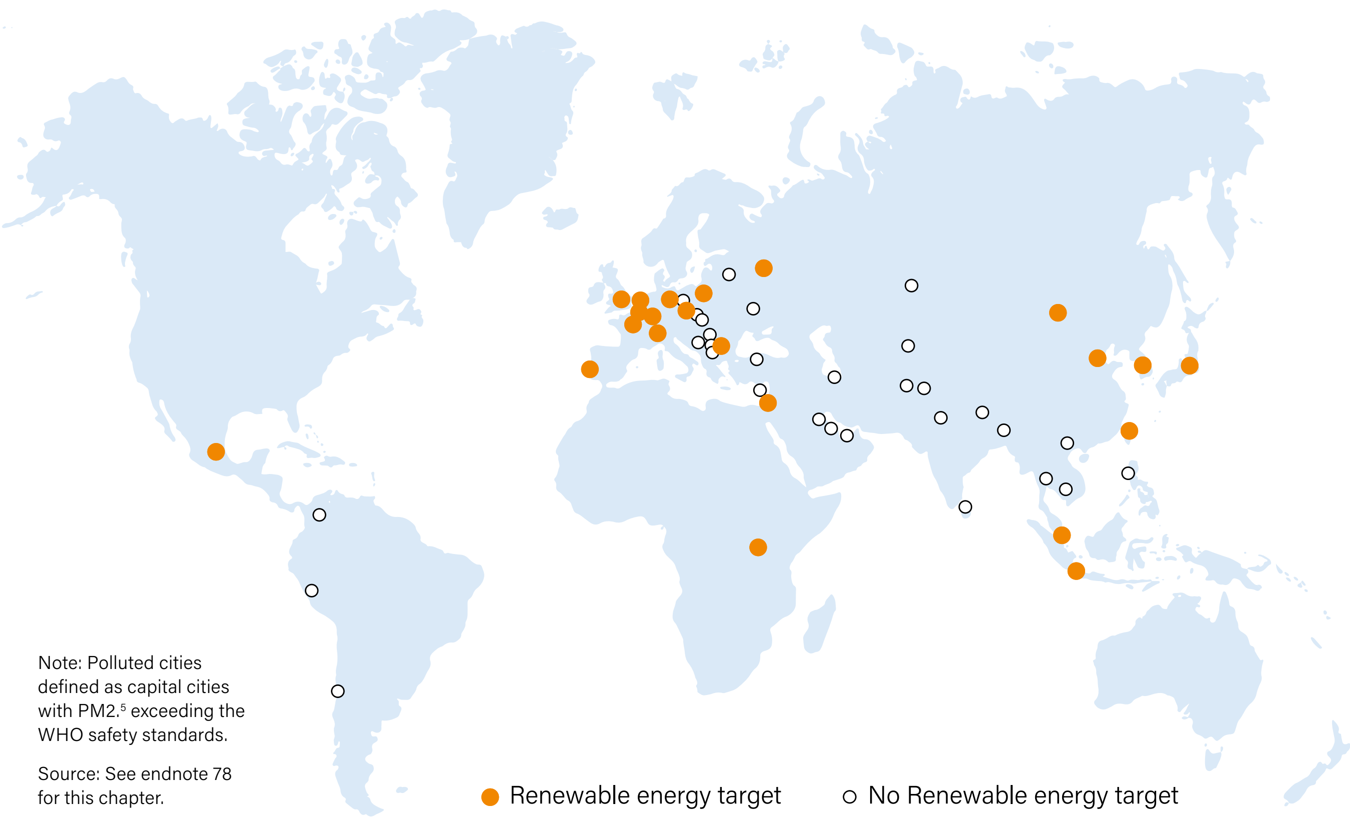
Through the uptake of renewables and the development of cleaner transport, cities have the opportunity to combat local air pollution and improve public health. Although no global review has been conducted on the link between air pollution and renewable energy targets, data suggest that municipal governments 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 10 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. Renewable Energy Targets in the Most-Polluted Capital Cities, As of Mid-2019



Note: Polluted cities defined as capital cities with PM2.[5] exceeding the WHO safety standards.

Source: See endnote 78 for this chapter.

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]

Cities often face **challenges** in rapidly scaling up renewables.

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.

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 Mobilising Finance chapter*).

TABLE 2. City-level Policies by Sector

		Electricity Sector	Heating and Cooling Sector	Transport Sector
Municipal Operations	**City Procurement**	• 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	• 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	• 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	**Mandates and Obligations**	• 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, though community choice aggregation)	• 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	• 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	• Property Assessed Clean Energy (PACE) financing • Rebate programmes • Low-interest loans • Revolving loan funds • Etc.	• Property Assessed Clean Energy (PACE) financing • Rebate programmes • Low-interest loans • Revolving loan funds • Etc.	• 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 Table 3*).[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 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 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 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 agreements[i] – 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".

TABLE 3. Municipal Ownership of Utilities

Full municipal ownership → **No ownership**

100% municipal ownership	**Partial municipal ownership**	**Privately owned**, but still structured as a municipal utility that the city can influence as a key "city stakeholder"	**No municipal energy utility**; all customers buy their energy from a regional, national or other local supplier
Examples: Barcelona (Spain); Munich (Germany); Nottingham (UK); Olongapo (Philippines); and 1,843 utilities in the United States including in Austin (Texas), Burlington (Vermont), Oak Ridge (Tennessee) and Sacramento (California)	**Examples:** Freiburg (Germany)	**Examples:** Boulder (Colorado, US); Metro Manila (Philippines)	**Examples:** Denver (Colorado, US); Chicago (Illinois, US); Nairobi (Kenya); Tunis (Tunisia); London (UK)

Source: See endnote 86 for this chapter.

POWER

In the United States, more than 1,800 municipal utilities supply over

15 million

electricity customers.

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 generation from 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 tenants, to opt 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 unbundling of electricity markets also has enabled city governments (and businesses) to sign power purchase agreements (PPAs) or solar leasing agreements with specific renewable electricity generators (→ *see Mobilising 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 are required to separate control over generation (i.e., power plants) from control over the transmission and distribution network. This typically enables more competition in both the generation and retail market segments.

As electricity markets become unbundled, more customers can choose their supplier and have greater say over their electricity mix. In particular, cities that do not control their own municipal utilities have benefited from the process of unbundling, enabling them to more directly control their electricity mix. However, cities can still face challenges. As of November 2019, Cape Town (South Africa) was involved 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.

Although the development of competitive electricity markets has been uneven around the world, 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 Mobilising Finance chapter*).

Source: See endnote 98 for this chapter.

CITY PROCUREMENT

City procurement 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 other electricity suppliers, whether through tenders or auctions that result in PPAs[i], 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 electricity 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 Philipp 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]

> Although
> **FITs**
> have been implemented mostly at the national level, some cities have designed and implemented them for renewable energy projects.

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.[117]

In this same manner, 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 level[ii], 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 drive solar PV deployment.[121] The LA Department of Water and

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.

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 net metering (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, in part 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 certifies the ownership of 1 MWh of renewable electricity and can be bought and sold separately from electricity and be used to comply with relevant legislation.[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 pathway 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 PV 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 electricity 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 customers[ii]. 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 reissues a tender for 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] Though exceptions do exist, mandates 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.

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 2020.[144] Tübingen (Germany) introduced a mandate in 2018 that

i Virtual net metering refers to the ability to generate power at a location different from 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.

requires the installation of solar PV on all new buildings in the city, a move that New York City (US) 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 on-site or off-site.[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 m^2, 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 building 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[i],[155]

With regard to tax incentives, Medellin (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 cities[ii], 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 by 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 are not generally considered 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. See endnote 55.

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 its flagship Middlegrunden offshore wind power project, Copenhagen (Denmark) 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 co-operatively financed.[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[i],[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 even 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 globally, 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.

Furthermore, 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

Mandates have become an important part of the renewable energy policy toolkit, helping to drive market demand and to reduce the costs of renewable heating and cooling systems.

Although certain 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 Urban Renewable Energy 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 several 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] Medellin (Colombia) has invested in district cooling for public buildings since 2013.[195]

District cooling systems are not only 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 AND BUILDING CODES

City mandates[i] 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-CO_2 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 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 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 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 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 Urban Renewable Energy 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 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.

EVs and hydrogen fuel cell vehicles offer **significant potential** for greater penetration of renewables and reduced emissions.

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 city-wide, city governments are starting to directly invest in infrastructure for wider constituencies, including residents, businesses, logistics companies and 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

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 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 light-duty 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]

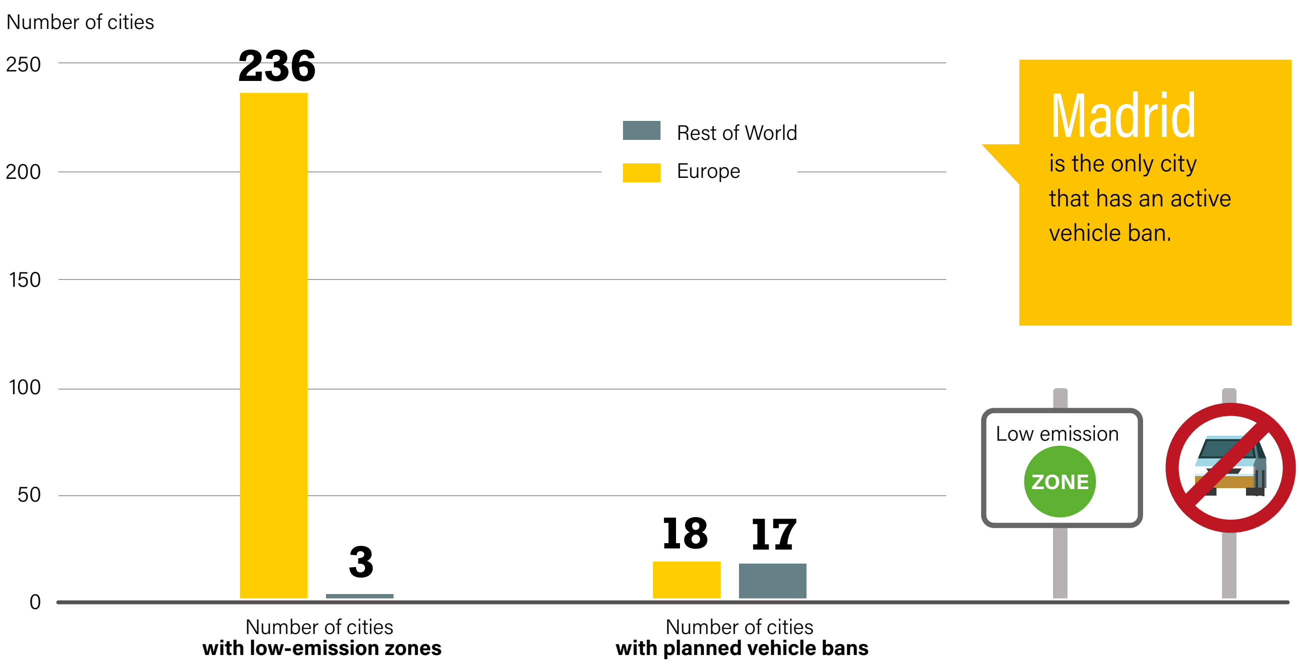
In an example of how city actions are supported by actions at other levels of government, some states and provinces such as Colorado (US) and Quebec (Canada) have introduced mandates that require local auto manufacturers, retailers and dealerships – or owners and operators of fleet vehicles – to sell 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 m^2) offer EV charging facilities on premises.[265] A few cities also now require that new buildings be "EV ready"[i], 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 vehicles[ii], especially diesel ones (→ *see Figure 11*).[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 Planned 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 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 CO_2 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 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 deadline differentiated pricing 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 6 in Urban Renewable Energy 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 such 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]

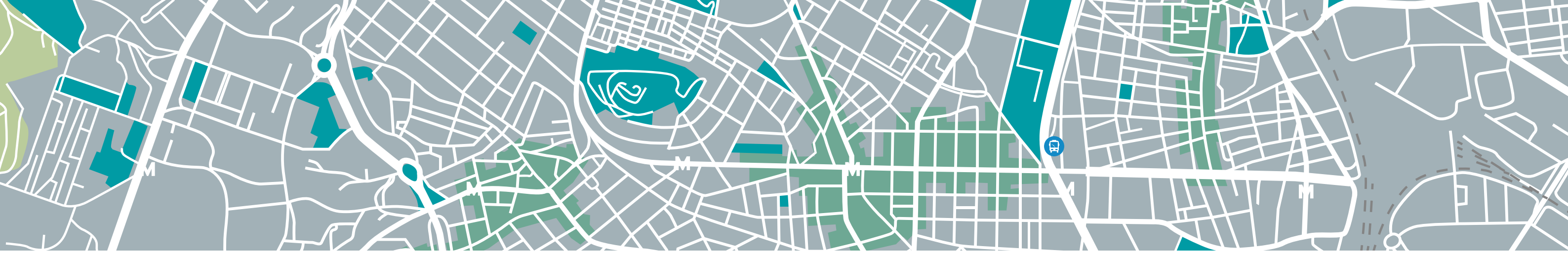
Related ways that cities can directly support infrastructure include making public land available either for free or at a discounted rate specifically for renewable fuel stations and EV charging companies (as is being done in Stockholm, Sweden), and investing in the construction of depots or re-purposing 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 m^2 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]

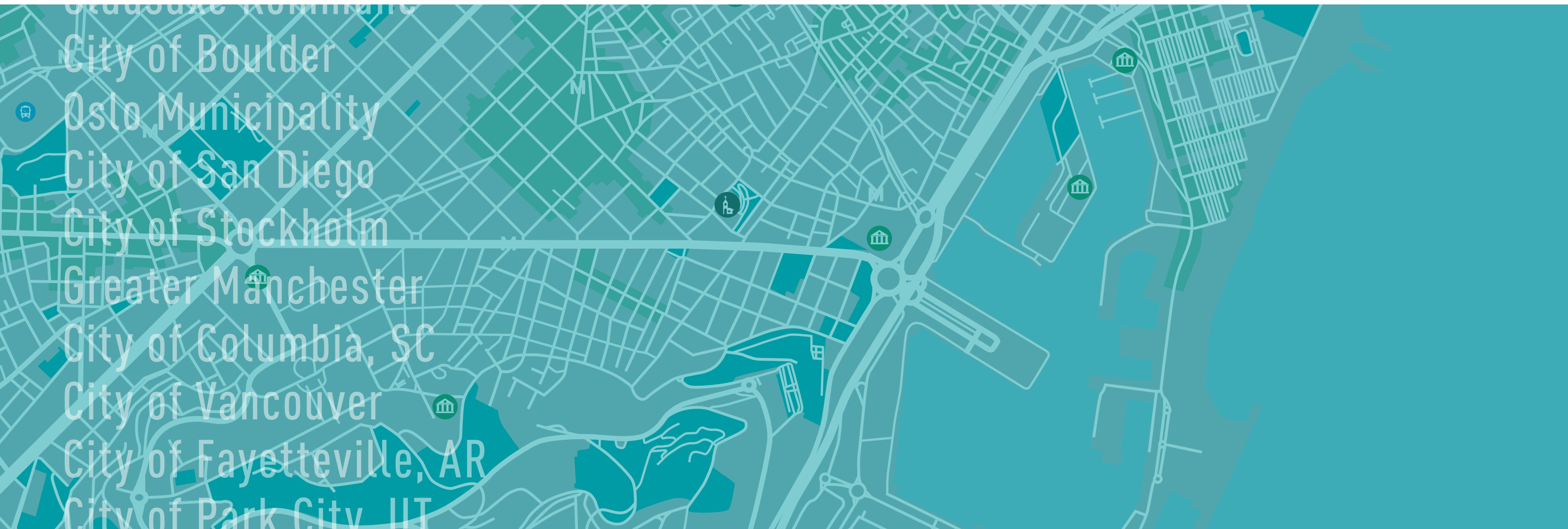
To encourage greater interest in EVs, Berlin and Stuttgart (Germany) and Paris (France) have created low-emission zones that restrict the use of more-polluting vehicles, imposing fines for non-compliance while in many cases offering incentives for cleaner biogas, biomethane, electric and hydrogen fuel 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 fallen sharply.[304]



4

URBAN RENEWABLE ENERGY MARKETS



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 usage[i]. 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 CDP[ii] in 2018, 340 cities cited some share of renewables in the urban electricity mix during 2017 (→ *see Figure 12*).[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]

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

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 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 electricity[iii].

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

iii Only the organic part of waste is considered renewable.

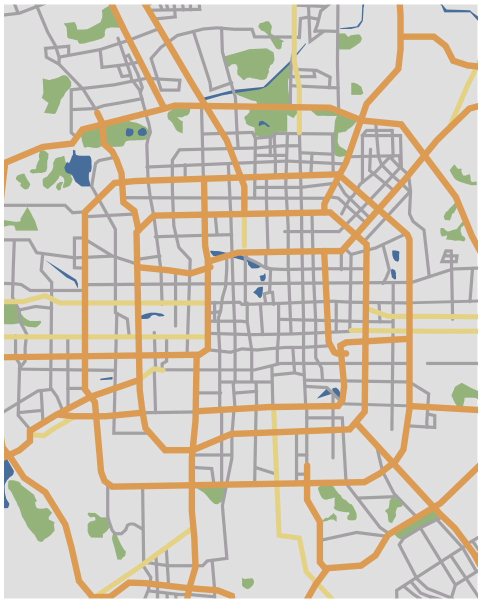
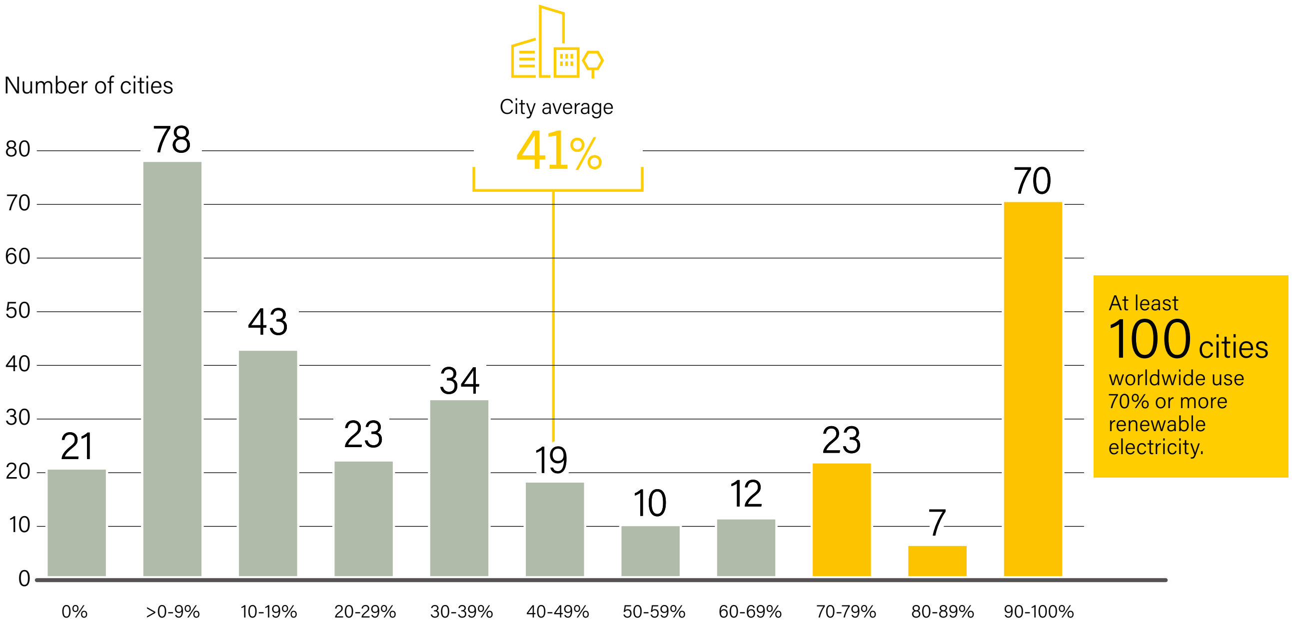


FIGURE 12. Number of Cities by Share of Renewable Electricity, 2017



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 PV [i], 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 GW [ii,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 [iii], 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 Including rooftop, commercial, industrial and micro-grid solar PV.

ii Led by commercial/industrial applications.

iii 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 costs[i] and the need for a disaster-resilient power supply (→ *see Box 3*).[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

i 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 3. 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 5: Urban Waste-to-Energy

Cities typically are responsible for managing the large volumes of waste produced by residents and by diverse urban activities. 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 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 coal[i]. 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 CO_2), 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, Sabarà (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 Jaboatão 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 almost 17,800 anaerobic digestion facilities, around 16% of which were sewage and wastewater treatment plants.

The biogas produced can be upgraded to 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 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 incineration plants. 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 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 CO_2 and USD 7.2 billion) and 1,280 TWh cumulatively by 2040 (equivalent to 1 billion tonnes of CO_2 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.*)

Municipal public lighting can account for up to

40%

of the municipal electricity budget.

SIDEBAR 6: Net Zero[i] 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 cities[ii] 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 m^2 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 CO_2 emissions either by balancing carbon emissions with carbon removal or by completely eliminating CO_2 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 Strategy[i], 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 m^2 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 cooling[ii] 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]

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 renewable sources.[93] Boise (Idaho) heats more than 90 buildings (0.5 million m^2) 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]

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/1c40gpgdeoriginal-21092017534.pdf.

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]

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

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[i],[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]

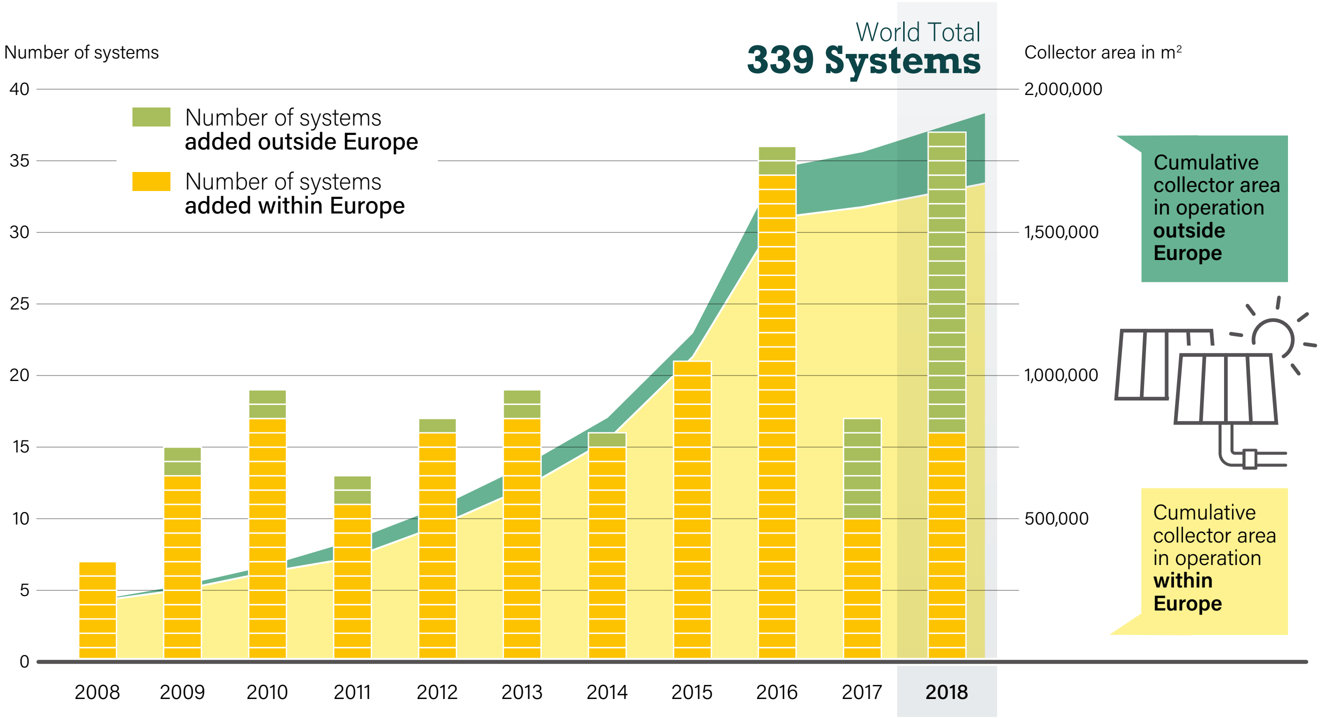
Germany had 37 relatively small (40 MW_{th} or less) geothermal district heat plants as of the end of 2018 (totalling 336 MW_{th} of thermal capacity), which were used mainly[ii] for district heat production; construction also was under way on new facilities.[110] Munich (Germany) was building a new 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 m^2) 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 13*).[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 Ecoenergias 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)[i], 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 CO_2 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 CO_2 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]

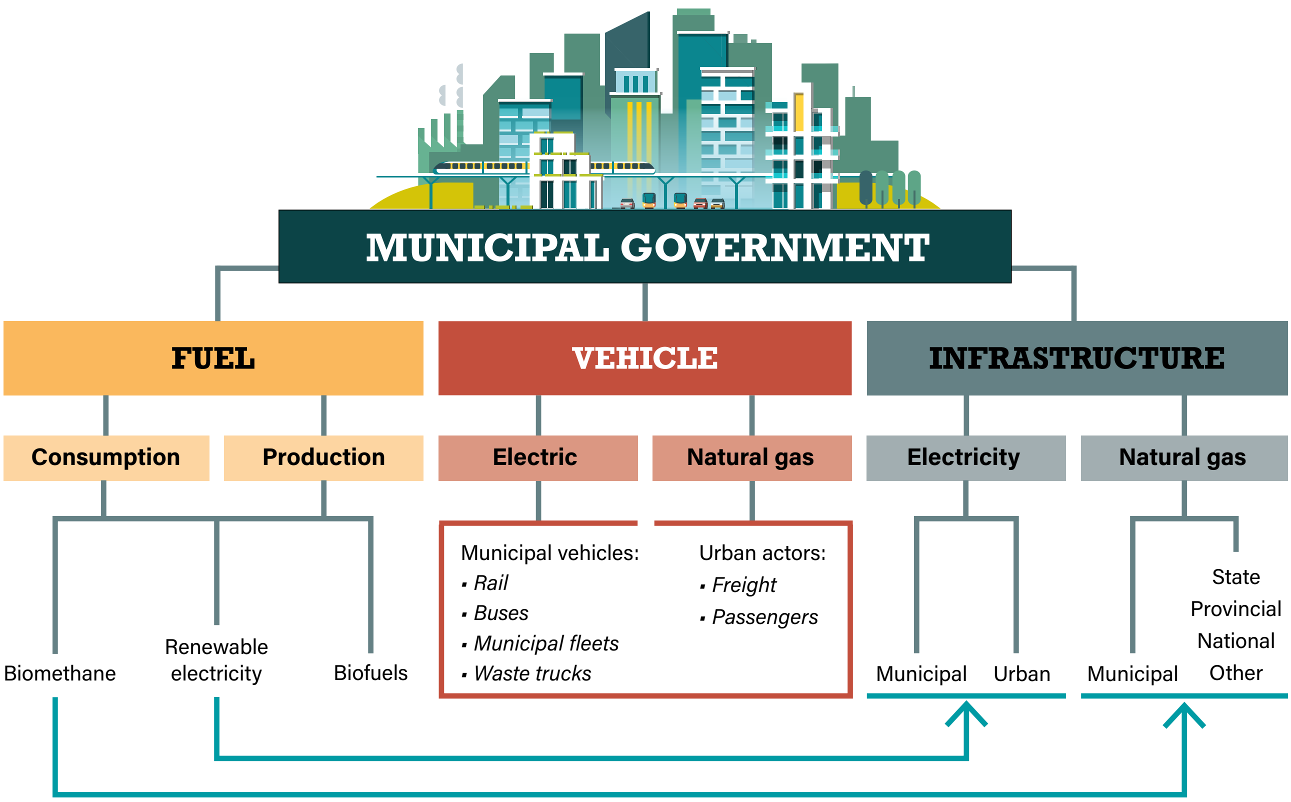
City governments also have been embracing broader efforts towards sustainable transport[ii], driven by the need to reduce local air pollution and CO_2 emissions and to deal with other consequences of climate change and urbanisation (such as congestion, noise and energy security). These measures include 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.

FIGURE 14. Entry Points for Renewable Energy in Urban Transport



Source: See endnote 144 for this chapter.

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-in[i] hybrid vehicles and of hydrogen, synthetic fuels and electro-fuels[ii], provided that the electricity is itself renewable (→ *see Figure 14*).[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.

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 biomethane[i] 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]

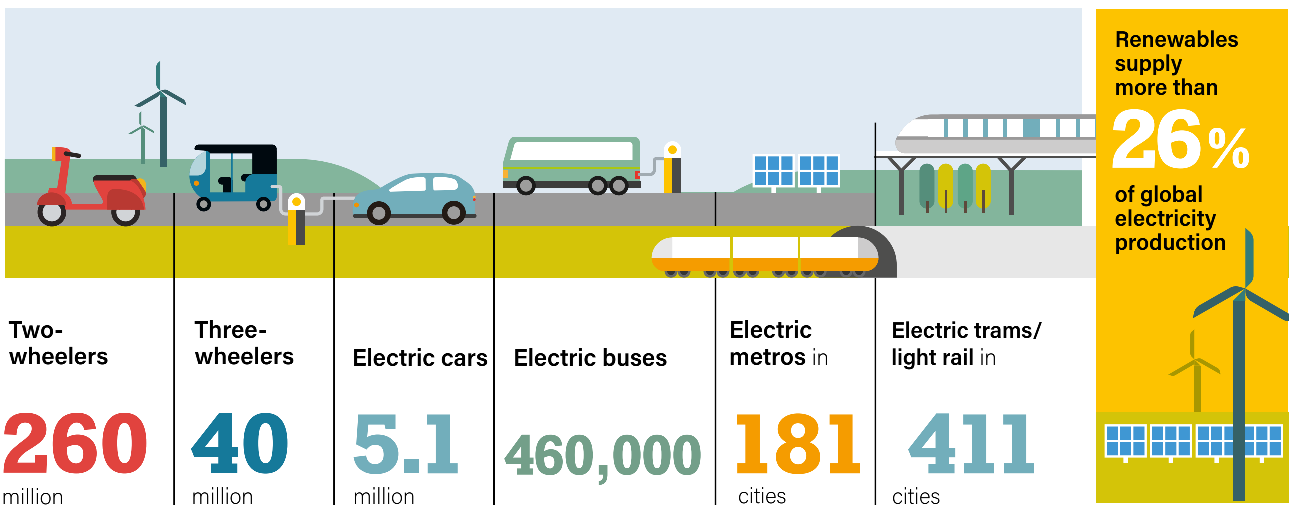
Several facilities to upgrade biogas to biomethane were opened in Europe in 2018, and three new countries (Belgium, Estonia and Ireland) connected biomethane facilities to national gas grids for the first time.[163] Biomethane plants also are developing rapidly in China.[164]

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 15*).[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 7: 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 pathways[i]. Although less than 0.1% of global dedicated hydrogen production comes from water electrolysis[ii], 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, Akuo Energy and Atawey 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[i] **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/cck-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]

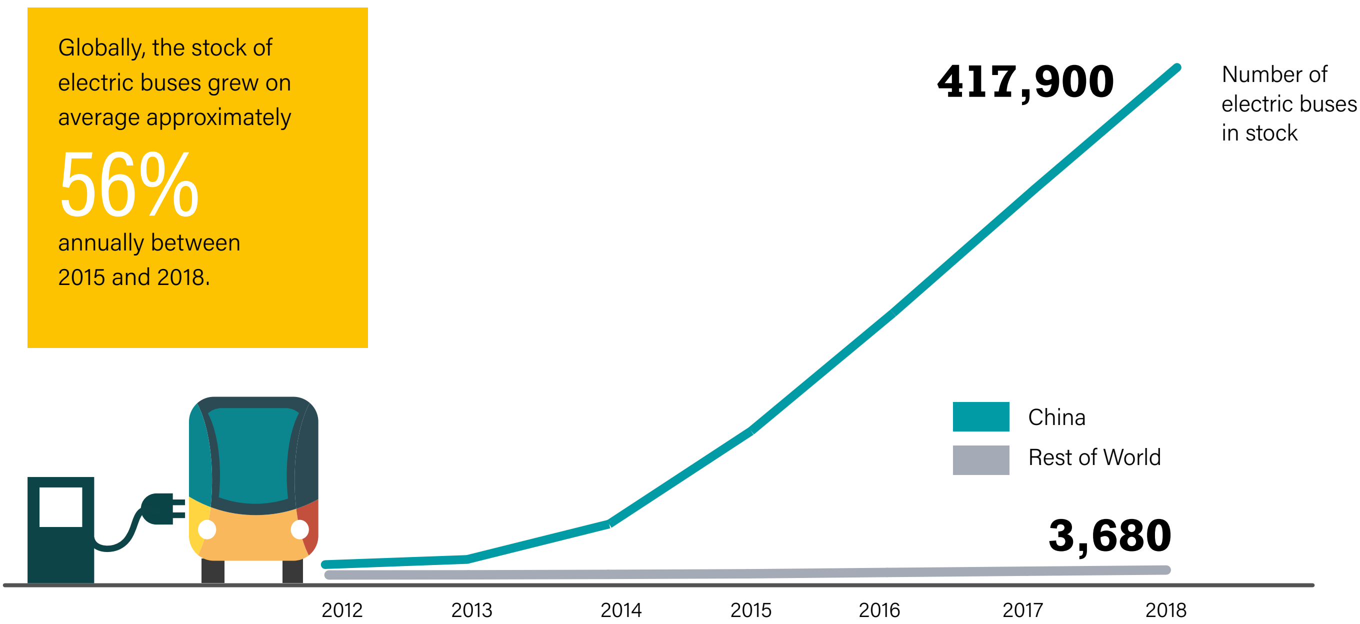
Almost all of the world's electric buses (more than 98%) in 2018 were deployed in China (→ *see Figure 16*); by one estimate, around 18% of China's total bus fleet was electrified as of year's end.[219] Shenzhen, for example, has more than 16,000 electric buses in operation, driven by the need to reduce 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 17*).[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]

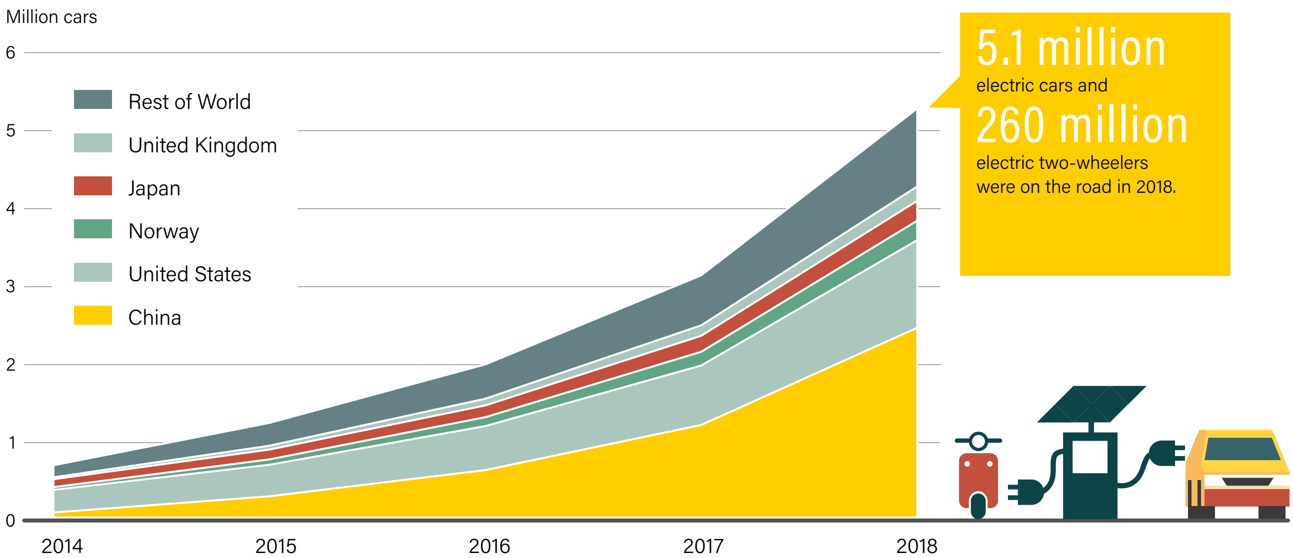
Global electric car sales neared 2 million in 2018, up 68% from the previous year.[243] Sales of plug-in electric passenger cars grew as a share of the total market for new vehicles, from 1.3% in 2017 to 2.1% in 2018.[244] While these numbers reflect all markets, not only urban ones, cities play an important 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 CO_2 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 CO_2 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]

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

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]

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 Targets and Policies chapter*), more and more delivery companies are exploring the opportunity of integrating biomethane 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]

More than
30 companies
have committed to purchasing over 200,000 EVs by 2030.

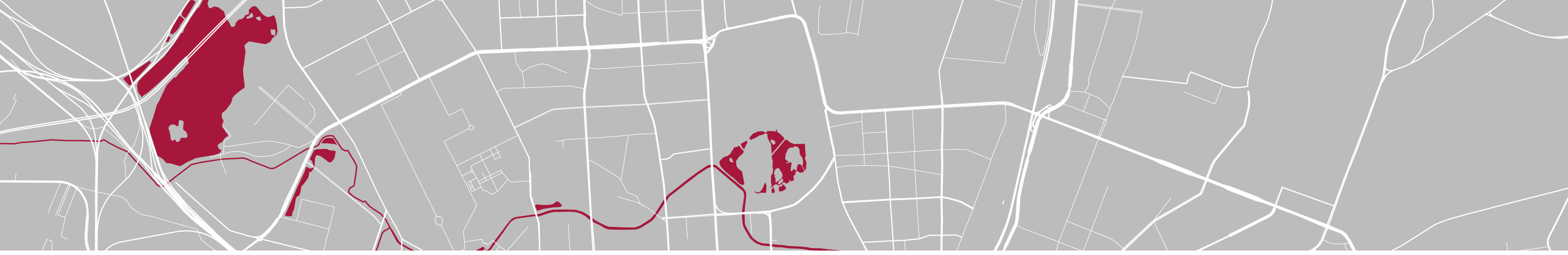
UPS, FedEx, Ryder Systems and Dillion Transport recently began purchasing growing shares of **natural gas** trucks to renew their fleets; UPS in particular plans to buy biomethane converted from waste sources to power its fleet of natural gas vehicles.[296] UPS also launched the world's first **hydrogen 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 also have 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]



5

MOBILISING FINANCE AND ENABLING BUSINESS MODELS

Eagle Nest
East Hampton, New York
Eau Claire, WI
Encinitas
Eureka, CA
Goleta, California
Hanover, New Hampshire
Hillsborough, North Carolina
Kennett Township, PA
Kennett Township, PA
La Mesa, CA
Lafayette, CO
Largo, FL
Longmont, CO
Lund Municipality
Piteå 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

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*).

Global investment in renewable power and fuels totalled

USD 288.9 billion

in 2018.

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.

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, Norrkoping 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-in[i] 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 finance[ii] 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 Herzogovina) 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

By mid-2019, green banks had invested or committed **USD 8.8 billion** in renewable energy projects.

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]

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]

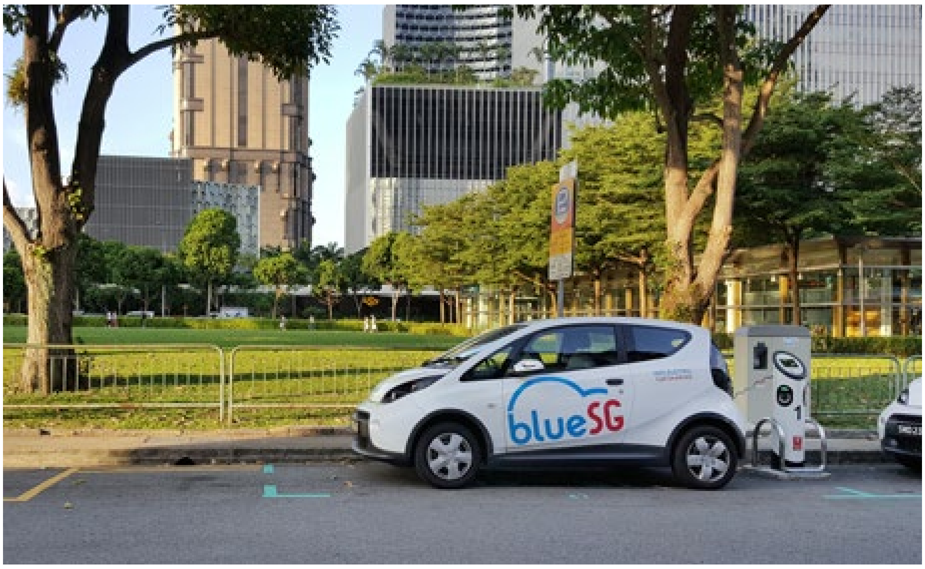
By leasing e-buses for their fleets, cities are able to support the integration of renewable energy into their transport systems. For example, in Santiago (Chile), the city's bus operator has leased 100 e-buses that are refuelled using electric charging terminals that draw power primarily from the country's 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]

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

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[i].[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[ii].[18] It remains to be seen what this change means for Danish district heating systems.

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 prosumer[iii].[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 Targets and Policies 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 projects[i] 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 4.*).[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 4. 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]

City administrations support community energy projects, for example by allocating a specific quota for local ownership of **new renewable energy projects.**

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 m^2 of solar PV panels.[82]

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 economy[i] (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 5*).[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[ii],[95]

BOX 5. 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 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]

Participatory governance is a growing trend, mainly in Europe but also in other places around the world.

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 Transition[ii], 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), Slocan (100% by 2050), Victoria (100% by 2050)	Calgary (30% by 2030), Edmonton (10% by 2035), Nelson (100% by 2050), Saanich (100% by 2050), Slocan (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), Fürstenfeldbruck (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 (1.18% 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), eThekwini (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); Downington, 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	eThekwini (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% byb 2020), Säffle (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, Massachussetts (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, Massachussetts (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	eThekwini (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), Säffle (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
Japan	Yokohama	City-wide	589 MW renewable energy by 2030
Japan	Yokohama	City-wide	429 MW renewable energy by 2020
Korea, Republic of	Seoul	City-wide	1 GW solar PV by 2022
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
Portugal	Lisbon	City-wide	103 MW renewable energy by 2030
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 2 for this section.

■ 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
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
Korea, Republic of	Seoul	City-wide	120,000 EVs on streets by 2020; 100,000 motorcycles replaced by electric ones by 2025	No
Korea, Republic of	Seoul	Municipal	Procure only zero emission buses by 2025; run all buses on clean natural gas, electricity or hydrogen by 2027	No
Korea, Republic of	Seoul	Municipal	50% of bus fleet to be electric by 2020; 100% by 2025	No
Korea, Republic of	Ulsan	Municipal	100% fuel cell bus fleet by 2035	N/A
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	Amsterdam	Municipal	Procure only zero emission buses by 2025	No
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
Russian Federation	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
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 section.

■ TABLE R7. Overview of Existing Renewable Energy Targets in the Most-Polluted Capital Cities, As of Mid-2019

Country	City	$PM_{2.5}$ Level	Climate Target	Air Pollution Policy	Other Related Policy	All-Energy Target	Power Target	Heating and Cooling Target	Transport Target
Afghanistan	Kabul	61,8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Austria	Vienna	15,2	Reduce per capita greenhouse gas emissions at least 35% by 2030 and 80% by 2050 (compared to 1990)	N/A		More than 20% renewable energy in gross final energy consumption by 2030; more than 50% by 2050	N/A	N/A	Use no conventional propulsion technologies in motorised individual traffic within municipal boundaries by 2050
Bahrain	Manama	59,8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bangladesh	Dhaka	97,1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Belgium	Brussels	14,1	Reduce greenhouse gas emissions at least 40% (compared to 1990)	If air pollution is high for 48 hours, make all public transit and bikesharing free; lower speed limits; ban wood burning for any home that possesses an alternative heat source		27% renewable energy	N/A	N/A	N/A
Bosnia and Herzegovina	Sarajevo	38,4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bulgaria	Sofia	28,2	N/A	N/A		N/A	N/A	N/A	N/A
Cambodia	Phnom Penh	20,1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chile	Santiago	29,4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
China	Beijing	50,9	N/A	N/A	N/A	8% renewable energy by 2020	35% renewable power by 2030		N/A
Chinese Taipei	Taipei	14,9	Reduce emissions 20% by 2026 (compared to 2006)	N/A	12,502 MW installed renewable energy capacity by 2030	N/A	12% renewable power by 2020	N/A	N/A
Colombia	Bogota	13,9	N/A	N/A	N/A		N/A	N/A	N/A
Cyprus	Nicosia	17,4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Czech Republic	Prague	17,4	N/A	Construct high-capacity ring road network; support high-quality public transport; support use of alternative fuels in traffic, etc.	N/A	N/A	N/A	N/A	N/A
France	Paris	15,6	Carbon neutral by 2050	Less than 10% of Parisians are to be exposed to pollution levels exceeding limit values in 2020; reduce this to zero by 2024 through compliance with limit values for all pollutants	100% renewable energy by 2050	N/A	100% renewable power by 2050	"Zero oil-fired heating by 2030, via incentives to replace oil-fired central heating systems"	100% renewable energy in transport by 2050
Germany	Berlin	11,7	Climate neutral by 2050	Ban older diesel cars from eight roads in the city; create dozens of zones with 30 km/hour speed limit	N/A	100% renewable energy	Phase out coal-based power generation by 2030	Phase out coal-based heat generation by 2030	N/A
Hungary	Budapest	16,5	N/A	N/A	N/A	N/A	N/A	N/A	N/A

■ TABLE R7. Overview of Existing Renewable Energy Targets in the Most-Polluted Capital Cities, As of Mid-2019 (continued)

Country	City	$PM_{2.5}$ Level	Climate Target	Air Pollution Policy	Other Related Policy	All-Energy Target	Power Target	Heating and Cooling Target	Transport Target
India	New Delhi	113,5	N/A	Shut down brick kilns and factories; vehicle restrictions (odd-even traffic rationing scheme)	N/A	N/A	N/A	N/A	N/A
Indonesia	Jakarta	45,3	N/A	Expand odd-even licence plate policy from 9 to 25 roads	N/A	30% renewable energy by 2030	N/A	N/A	N/A
Iran	Teheran	26,1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Israel	Tel Aviv-Yafo	19,5	Reduce emissions 20% by 2020	N/A		N/A	N/A	N/A	N/A
Japan	Tokyo	13,1	Zero emissions by 2050	Zero emission buses	20% renewable energy by 2024		30% renewable power by 2030	N/A	N/A
Kazakhstan	Astana	29,8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Korea, Republic of	Seoul	23,3	Reduce CO_2 emissions by 10 million tons by 2020	Ban old diesel vehicles; ban engine idling; subsidise EV purchases		N/A	20% renewable power by 2020; 1 GW solar power; 1 million households with solar panels; 3% solar energy generation	N/A	N/A
Kosovo	Pristina	30,4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kuwait	Kuwait City	56	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithuania	Vilnius	18,2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Luxembourg	Luxembourg City	11,2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Macedonia, FYR	Skopje	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mexico	Mexico City	19,7	Reduce CO_2 emissions 30% by 2020	N/A		N/A	350 MW solar PV by 2024	N/A	N/A
Mongolia	Ulaanbaatar	58,5		Decrease air pollutants 80% by 2025	N/A	N/A	67% renewable power by 2050		N/A
Nepal	Kathmandu	54,4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands	Amsterdam	11,5	Reduce energy use per resident 20% by 2020 (compared to 2013)	N/A	N/A	20% more renewable energy production in 2020 compared to 2013 (based on generated energy not capacity)	25% renewable power by 2025, 50% by 2040	Use district heating for at least 200,000 houses by 2040 (using biogas, woody biomass and waste heat)	N/A
Pakistan	Islamabad	38,6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Peru	Lima	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Philippines	Manila	14,3	N/A	N/A	N/A		N/A	N/A	N/A
Poland	Warsaw	24,2	Reduce CO_2 emissions 20% by 2020 compared to 2007	N/A	N/A	20% renewable energy by 2020	N/A	N/A	N/A
Portugal	Lisbon	11,7	Reduce CO_2 emissions 70% by 2030; carbon neutral by 2050	N/A	N/A	N/A	17% renewable power by 2020	N/A	N/A
Romania	Bucharest	20,3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Russian Federation	Moscow	10,1	N/A	N/A	4% renewable energy by 2020	N/A	1% renewable power by 2020	N/A	N/A

TABLE R7. Overview of Existing Renewable Energy Targets in the Most-Polluted Capital Cities, As of Mid-2019 (continued)

Country	City	$PM_{2.5}$ Level	Climate Target	Air Pollution Policy	Other Related Policy	All-Energy Target	Power Target	Heating and Cooling Target	Transport Target
Serbia	Belgrade	23,9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Singapore	Singapore	14,8	Reduce emission intensity 36% by 2030 (compared to 2005)	Achieve an annual mean of 12µg/m³ of PM2.5 by 2020	N/A	N/A	2 GWp renewable power by 2030	N/A	N/A
Slovakia	Bratislava	17,2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sri Lanka	Colombo	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Switzerland	Bern	12,8	N/A	N/A	N/A		80% renewable power by 2035	70% renewable heating by 2035	N/A
Thailand	Bangkok	25,2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Turkey	Ankara	19,6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Uganda	Kampala	40,8	Reduce emissions 22% from business as usual	N/A	Generate 20% of cooking energy from renewable sources by 2020	15% renewable energy	N/A	N/A	N/A
Ukraine	Kyiv	13,8	N/A	N/A	N/A		N/A	N/A	N/A
United Arab Emirates	Abu Dhabi	48,8	N/A	N/A	N/A		7% renewable power by 2020	N/A	N/A
United Kingdom	London	12	Zero carbon by 2050	N/A	N/A	100 MW solar PV by 2030; 2 GW by 2050	N/A	15% of energy demand met with renewables	N/A
Uzbekistan	Tashkent	34,3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vietnam	Hanoi	40,8	N/A	Ban motorcycles by 2030	N/A	N/A	N/A	N/A	N/A

Note: N/A = data not available

Source: See endnote 4 for this section.

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).

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.

Curtailment. A reduction in the output of a generator, typically on an involuntary basis, from what it could produce otherwise given the resources available. Curtailment 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.

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 ovendry 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.

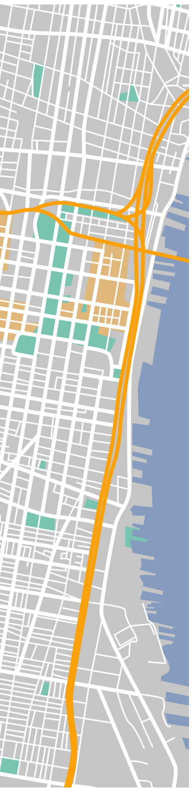
Watt. A unit of power that measures the rate of energy conversion or transfer. A kilowatt is equal to 1 thousand watts; a megawatt to 1 million watts; and so on. A megawatt-electrical (MW) is used to refer to electric power, whereas a megawatt-thermal (MWth) refers to thermal/heat energy produced. Power 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
AUD	Australian dollar
BEV	Battery electric vehicle
BRIICS	Brazil, Russian Federation, India, Indonesia, China and South Africa
CCA	Community choice aggregation
CHP	Combined heat and power
CO_2	Carbon dioxide
CSP	Concentrating solar thermal power
DHC	District heating and cooling
ESCO	Energy service company
EU	European Union
EUR	Euro
EV	Electric vehicle
FIT	Feed-in tariff
GDP	Gross domestic product
GSR	Global Status Report
GW/GWh	Gigawatt/gigawatt-hour
GW_{th}	Gigawatt-thermal
HUF	Hungarian forint
ICE	Internal combustion engine
ICT	Information and communications technology
JPY	Japanese yen
km^2	Square kilometre
kW/kWh	Kilowatt/kilowatt-hour
LED	Light-emitting diode
LVC	Land value capture
MSW	Municipal solid waste
MW/MWh	Megawatt/Megawatt-hour
MW_{th}	Megawatt-thermal
MXN	Mexican peso
NDC	Nationally determined contribution
NIMBY	Not in my back yard
NUP	National urban policy
OECD	Organisation for Economic Co-operation and Development
PACE	Property Assessed Clean Energy
PAYG	Pay as you go
PJ	Petajoule
$PM_{2.5}$	Fine particulate matter
PPA	Power purchase agreement
PPI	Private participation in infrastructure
PV	Photovoltaic
REC	Renewable energy certificate
SDG	Sustainable Development Goal
TW/TWh	Terawatt/Terawatt-hour
UAE	United Arab Emirates
UK	United Kingdom
ULEZ	Ultra-low emissions zone
UN	United Nations
US	United States
USD	United States dollar

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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CITIES IN THE RENEWABLE ENERGY TRANSITION

1 Renewable Energy Policy Network for the 21st Century (REN21), *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/gsr-2019/; International Renewable Energy Agency (IRENA), Organisation for Economic Co-operation and Development (OECD) / International Energy Agency (IEA) and REN21, *Renewable Energy Policies in a Time of Transition* (Abu Dhabi: 2018), https://www.ren21.net/2018-renewable-energy-policies-in-a-time-of-transition/.

2 International Transport Forum (ITF), "How transport CO_2 reduction pledges fall short", 19 November 2018, https://www.itf-oecd.org/CO2-reduction-pledges.

3 OECD/IEA, *World Energy Outlook 2018* (Paris: 2018), p. 27, https://www.iea.org/weo2018/; REN21, op. cit. note 1.

4 Myles Allen et al., *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (Geneva: Intergovernmental Panel on Climate Change (IPCC), 2018), https://www.ipcc.ch/sr15/, as reported in REN21, op. cit. note 1.

5 Ibid.

6 United Nations (UN) Sustainable Development Goals Knowledge Platform, "Sustainable Development Goal 7", https://sustainabledevelopment.un.org/sdg7, viewed 27 April 2019; IEA et al., *Tracking SDG7: The Energy Progress Report 2019* (Washington, DC: World Bank, 2019), https://www.worldbank.org/en/topic/energy/publication/tracking-sdg7-the-energy-progress-report-2019.

7 Ibid., both sources; Michelle Froese, "Onshore wind & solar lead as cheapest source of new bulk power, finds BNEF", Windpower Engineering & Development, 19 November 2018, https://www.windpowerengineering.com/business-news-projects/researchreports/onshore-wind-solar-lead-as-cheapest-source-of-newbulk-power-finds-bnef/.

8 Froese, op. cit. note 7.

9 Ibid.; Institute for Energy Economics and Financial Analysis, "BNEF says new wind, solar now cheaper than existing coal generation in Australia", 8 May 2019, https://ieefa.org/bnef-says-new-wind-solar-now-cheaper-than-existing-coal-generation-in-australia/.

10 REN21, *Perspectives of the Global Renewable Energy Transition: Takeaways from the REN21 Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/gsr-2019/pages/perspectives/perspectives/; Peter Newman, "The renewable cities revolution", in Peter Droege, *Urban Energy Transition: Renewable Strategies for Cities and Regions* (Amsterdam: Elsevier, 2018), https://www.elsevier.com/books/urban-energy-transition/droege/978-0-08-102074-6.

11 **Figure 1** based on OECD/IEA, *World Energy Balances and Statistics, 2018 edition* (Paris: 2018), https://www.iea.org/statistics/balances/.

12 REN21, op. cit. note 1.

13 Ibid.

14 Ibid.

15 **Figure 2** based on the following sources: United Nations Department of Economic and Social Affairs (UN DESA), *The World's Cities in 2018* (New York: 2018), p. 1, https://sustainabledevelopment.un.org/sdg7; UN DESA, "68% of the world population projected to live in urban areas by 2050, says UN", https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html, viewed 3 May 2019; World Bank, "Urban population (% of total)", https://data.worldbank.org/indicator/sp.urb.totl.in.zs, viewed 31 July 2019; World Bank, "Urban development", 1 April 2019, https://www.worldbank.org/en/topic/urbandevelopment/overview; Richard Florida, "The economic power of cities compared to nations", CityLab, 16 March 2017, https://www.citylab.com/life/2017/03/the-economic-power-of-global-cities-compared-to-nations/519294/; World Bank, "Urban land area (sq. km)", https://data.worldbank.org/indicator/AG.LND.TOTL.UR.K2, viewed 10 September 2019; UN DESA, *World Urbanization Prospects: The 2018 Revision* (New York: 2018), https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf; OECD/IEA, "Cities are at the frontline of the energy transition", press release (Paris: 7 September 2016), https://www.iea.org/newsroom/news/2016/september/cities-are-at-the-frontline-of-the-energy-transition.html; Johnny Wood, "Here's what you need to know about the megacities of the future", World Economic Forum, 10 October 2018, https://www.weforum.org/agenda/2018/10/these-are-the-megacities-of-the-future/; World Bank, "Solid waste management", http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management, updated 1 April 2019; World Bank, *What a Waste: A Global Review of Solid Waste Management* (Washington, DC: 2012), https://openknowledge.worldbank.org/handle/10986/17388; UN-Habitat, "Slum", 2 March 2014, http://unhabitat.org/tag/slum/; World Bank, "Sustainable Energy for All (SE4ALL) database", in World Bank, IEA and Energy Sector Management Assistance Program, eds., https://datacatalog.worldbank.org/dataset/sustainable-energy-all, 2019; US Central Intelligence Agency, "Country Comparison: Airports", The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/rankorder/2053rank.html; http://www.worldportsource.com/. **Box 1** based on the following sources: Lewis Dijkstra, Hugo Poelman and Paolo Veneri, "The EU-OECD definition of a functional urban area", July 2019, https://www.oecd.org/cfe/regional-policy/THE%20EU-OECD%20DEFINITION%20OF%20A%20FUNCTIONAL%20URBAN%20AREA.pdf; European Commission, "What is a city", https://urban.jrc.ec.europa.eu/thefutureofcities/what-is-a-city#the-chapter, viewed 2 October 2019; Cities Alliance, *Managing Systems of Secondary Cities* (Brussels: 2014), https://www.citiesalliance.org/sites/default/files/1d%20(i)%20-%20Managing%20Systems%20of%20Secondary%20Cities%20Book_low_res.pdf.

16 UN DESA, *The World's Cities in 2018*, op. cit. note 15, p. 1; UN DESA, "68% of the world population projected to live in urban areas by 2050, says UN", op. cit. note 15; World Bank, "Urban population (% of total)", op. cit. note 15.

17 World Bank, "Urban development", op. cit. note 15.

18 Karen C. Seto et al., "Human settlements, infrastructure and spatial planning", in Ottmar Edenhofer et al., eds., *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK and New York, NY: Cambridge University Press, 2014), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter12.pdf; OECD/IEA, op. cit. note 15; UN DESA, *World Urbanisation Prospects*, op. cit. note 15.

19 UN-Habitat, UN Habitat Brief on Migration and Cities (Nairobi: 2018), https://unhabitat.org/wp-content/uploads/2018/12/Migration_Brochure_10122018.pdf.

20 United Nations Environment Programme (UNEP), *The Weight of Cities: Resource Requirements of Future Urbanisation* (Nairobi: 2018), https://www.resourcepanel.org/reports/weight-cities.

21 Antonio Augusto Morini, Manuel J. Ribeiro and Dachamir Hotza, "Early stage materials selection based on embodied energy and carbon footprint", *Materials & Design*, vol. 178 (September 2019), p. 107861, https://www.sciencedirect.com/science/article/pii/S0264127519302990.

22 Seto et al., op. cit. note 18; UN DESA, *The World's Cities in 2018, op. cit. note 15; Coalition for Urban Transitions, Climate Emergency, Urban Opportunity: How National Governments Can Secure Economic Prosperity and Avert Climate Catastrophe by Transforming Cities* (New York: 2019), https://urbantransitions.global/wp-content/uploads/2019/09/Climate-Emergency-Urban-Opportunity-report.pdf.

23 REN21, op. cit. note 1.

24 **Figure 3** from the following sources: Christopher A. Kennedy et al., "World's largest cities – energy and material flows of megacities", *PNAS*, vol. 112, no. 19 (2015), pp. 5985-90, https://www.pnas.org/content/112/19/5985; City of Vancouver, *Renewable City Strategy 2015-2050* (Vancouver, Canada: 2015), https://vancouver.ca/files/cov/renewable-city-strategy-booklet-2015.pdf; Aalborg University, Copenhagen Energy Vision (Aalborg, Denmark: 2015), https://vbn.aau.dk/ws/portalfiles/portal/209592938/Copenhagen_Energy_Vision_2050_report.pdf.

25 REN21, op. cit. note 1.

26 Ibid.

27 OECD/IEA, *World Energy Outlook 2019* (Paris: 2019), https://www.iea.org/weo2019/; UNEP DTU Partnership, *International Energy Report 2019: Transforming Urban Mobility* (Lyngby, Denmark: 2019), https://unepdtu.org/wp-content/uploads/2019/10/dtu-international-energy-report-2019.pdf; ITF, op. cit. note 2.

28 Matthew J. Burke and Jennie C. Stephens, "Political power and renewable energy futures: A critical review", *Energy Research & Social Science*, vol. 35 (January 2018), pp. 78-93, https://doi.org/10.1016/j.erss.2017.10.018.

29 Ibid.

30 Ibid.

31 International Renewable Energy Agency (IRENA), *Global Energy Transformation: A Roadmap to 2050* (Abu Dhabi: 2019), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Apr/IRENA_Global_Energy_Transformation_2019.pdf.

32 Droege, op. cit. note 10.

33 Ralph Sims et al. "Transport", in Edenhofer et al., eds., op. cit. note 18, https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf; Susan Anenberg et al., *A Global Snapshot of the Air Pollution-related Health Impacts of Transportation Sector Emissions in 2010 and 2015* (Washington, DC: International Council on Clean Transportation, 2019), https://theicct.org/publications/health-impacts-transport-emissions-2010-2015.

34 Global 100% Renewable Energy Platform, with material provided by a variety of stakeholders, including CDP, Climate Action Network, C40 Cities, ICLEI–Local Governments for Sustainability, IRENA, The Sierra Club and Renewable Cities; Anne Bringault, Miriam Eisermann and Sylvie Lacassagne, *Cities Heading Towards 100% Renewable Energy by Controlling Their Consumption: Food for Thought and Action* (Brussels: Energy Cities, November 2016), p. 8, http://www.energy-cities.eu/IMG/pdf/publi_100pourcent_final-web_en.pdf; REN21, op. cit. note 1; Elle Hunt, "More than 100 cities now mostly powered by renewable energy, data shows", *The Guardian* (UK), 27 February 2018, https://www.theguardian.com/cities/2018/feb/27/cities-powered-clean-energy-renewable; CDP, "Over 100 global cities get majority of electricity from renewables", 27 February 2018, https://www.cdp.net/en/articles/cities/over-100-global-cities-get-majority-of-electricity-from-renewables. See also Reference Tables R1-R4.

35 **Figures 4** compiled by REN21 based on Droege, op. cit. note 10, and on IRENA, *Renewable Energy in Cities* (Abu Dhabi: 2016), https://www.irena.org/publications/2016/Oct/Renewable-Energy-in-Cities.

36 IRENA, op. cit. note 35.

37 Janet L. Sawin and Kristen Hughes, "Energizing cities", in Worldwatch Institute, *State of the World 2007: Our Urban Future* (New York: W.W. Norton & Company, 2007), pp. 103-04, https://www.taylorfrancis.com/books/e/9781849773881/chapters/10.4324/9781849773881-12.

38 Bringault, Eisermann and Lacassagne, op. cit. note 34.

39 Yanhong Yin, Shoshi Mizokami and Takuya Maruyama, "An analysis of the influence of urban form on energy consumption by individual consumption behaviors from a microeconomic viewpoint", *Energy Policy*, vol. 61 (2013), pp. 909-19, https://ideas.repec.org/a/eee/enepol/v61y2013icp909-919.html; Subhrajit Guhathakurta and Eric Williams, "Impact of urban form on energy use in Central City and suburban neighborhoods: Lessons from the Phoenix Metropolitan Region", *Energy Procedia*, vol. 75 (2015), pp. 2928-33, https://www.sciencedirect.com/science/article/pii/S1876610215013624; Chaosu Li, Yan Song and Nikhil Kaza, "Urban form and household electricity consumption: A multilevel study", *Energy and Buildings*, vol. 158 (2017), pp. 181-93, https://www.sciencedirect.com/science/article/abs/pii/S0378778817321436.

40 UNEP DTU Partnership, op. cit. note 27.

41 IRENA, op. cit. note 35.

42 Ibid.

43 C40, *Clean Energy Business Model Manual* (London: 2018), https://c40-production-images.s3.amazonaws.com/other_uploads/images/2008_C40_Clean_Energy_Business_Model_Manual_-_Ezgi_Kelleher.original.pdf.

44 IRENA, op. cit. note 35.

45 Ibid.

46 REN21, Institute for Sustainable Energy Policies and ICLEI –Local Governments for Sustainability, *Global Status Report on Local Renewable Energy Policies* (Paris: 2011), http://www.ren21.net/Portals/0/documents/Resources/REN21_Local_Renewables_Policies_2011.pdf.

47 Ibid.

48 IRENA, op. cit. note 35.

49 Thomas Hoppe and Ellen van Bueren, "Guest editorial: Governing the challenges of climate change and energy transition in cities", *Energy, Sustainability and Society*, vol. 5, no. 19 (2015), pp. 1-9, https://research.utwente.nl/en/publications/guest-editorial-governing-the-challenges-of-climate-change-and-en.

50 Sustainable Energy Africa, *How to Implement Renewable Energy and Energy Efficiency Options: Support for South African Local Government* (Cape Town, South Africa: 2009), http://www.cityenergy.org.za/uploads/resource_19.pdf; City Energy, *Exploring the Challenges and Niche Innovations of Energy Service Delivery in Urban South Africa: An Overview of Seven Cities* (Cape Town, South Africa: 2018), http://www.cityenergy.org.za/uploads/resource_483.pdf.

51 Peter Droege, *Renewable City: Comprehensive Guide to an Urban Revolution* (Hoboken, NJ: Wiley, 2007), https://www.wiley.com/en-us/The+Renewable+City%3A+A+comprehensive+guide+to+an+urban+revolution-p-9780470019269.

52 Caroline Kuzembo, "Re-scaling IPE: Local government, sustainable energy and change", *Review of International Political Economy*, vol. 26, no. 1 (2019), pp. 80-113, https://www.tandfonline.com/doi/full/10.1080/09692290.2018.1527239; World Future Council and 100% Renewables, *How to Achieve 100% Renewable Energy* (Hamburg, Germany: 2014), https://www.idaea.csic.es/sites/default/files/How-to-achieve-100-percent-renewable-energy.pdf.

53 Ibid, both sources.

54 Coalition for Urban Transitions, op. cit. note 22.

55 Ibid.

56 European Parliament, Directorate-General for Internal Policies, *Policy Department: Citizen's Rights and Constitutional Affairs* (Brussels: 2017), http://www.europarl.europa.eu/RegData/etudes/STUD/2017/596813/IPOL_STU(2017)596813_EN.pdf; Steven G. Calabresi and Lucy Bickford, *Federalism and Subsidiarity: Perspectives from U.S. Constitutional Law*, Northwestern University School of Law Scholarly Commons, Faculty Working Papers (Evanston, IL: 2011), https://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=1214&context=facultyworkingpapers; The USA Online, "Government", https://www.theusaonline.com/government/state-local-government.htm, viewed 9 October 2019.

57 Florida, op. cit. note 15.

58 United Nations Population Fund, Asia & The Pacific, "Population trends", https://asiapacific.unfpa.org/en/node/15207, viewed 9 October 2019; Geography Realm, "Continents and population density", 15 November 2014, https://www.geographyrealm.com/continents-population-density/.

59 UN DESA, *The World's Cities in 2018, op. cit. note 15*.

60 IQ Air, AirVisual, "World most polluted cities 2018 ($PM_{2.5}$)", https://www.airvisual.com/world-most-polluted-cities, viewed 10 October 2019.

61 Hannah Ellis-Petersen, "India: Five million pollution masks to be handed to Delhi residents", *The Guardian* (UK), 2 November 2019, https://www.theguardian.com/world/2019/nov/02/five-million-pollution-masks-to-be-handed-to-delhi-residents; "Delhi restricts cars in attempt to lessen pollution", *The Guardian* (UK), 4 November 2019, https://www.theguardian.com/world/2019/nov/04/delhi-restricts-cars-in-attempt-to-lessen-pollution.

62 REN21, op. cit. note 1.

63 Ibid.

64 Ibid.; Atul Mudaliar and Jasmeet Khurana, "Picking up the pace – India Inc. accelerated the electric mobility transition", The Climate Group, 10 July 2019, https://www.theclimategroup.org/news/picking-pace-india-inc-accelerates-electric-mobility-transition.

65 REN21, op. cit. note 1.

66 Adrienne Arsht, "Urbanization in Latin America", Atlantic Council, 5 February 2014, https://www.atlanticcouncil.org/commentary/article/urbanization-in-latin-america/.

67 Uwe Hessler, "German wind energy stalls amid public resistance and regulatory hurdles", Deutsche Welle, 4 September 2019, https://www.dw.com/en/german-wind-energy-stalls-amid-public-resistance-and-regulatory-hurdles/a-50280676; Benjamin Wehrmann, "Limits to growth: REsistance against wind power in Germany", Clean Energy Wire, 27 March 2019, https://www.cleanenergywire.org/factsheets/fighting-windmills-when-growth-hits-resistance; Giorgio Carau and Marco Rosa-Clot, "Supplying historic buildings with energy, without impinging on their historic and cultural values", *Energy Procedia*, vol. 134 (October 2017), pp. 244-55, https://www.sciencedirect.com/science/article/pii/S1876610217347483;

FOSTEr in MED, *Guidelines on Building Integration of Photovoltaic in the Mediterranean Area* (Cagliari, Italy: undated), http://www.enpicbcmed.eu/sites/default/files/guidelines_on_building_integration_of_photovoltaic_in_the_mediterranean_area.pdf.

68 Fridays for Future, "About #FridaysForFuture", https://www.fridaysforfuture.org/about, viewed 21 October 2019; Extinction Rebellion, https://rebellion.earth/, viewed 10 October 2019.

69 REN21, op. cit. note 1.

70 Ibid.

71 European Bioenergy Day, "Helsinki transport goes renewable by 2020", http://www.europeanbioenergyday.eu/helsinki-transport-goes-renewable-by-2020/, viewed 17 November 2019; "European Commission approves Italy's EUR 4.7 billion support scheme for advanced biomass and biofuels", Bioenergy International, 2 March 2018, https://bioenergyinternational.com/policy/european-commission-approves-italys-eur-4-7-billion-support-scheme-advanced-biomethane-biofuels; REN21, op. cit. note 1.

72 Arsht, op. cit. note 66.

73 UN DESA, "68% of the world population projected to live in urban areas by 2050, says UN", op. cit. note 15.

74 Felicia Jackson, "Latin America EV sales up 90% as transport transformation continues", *Forbes*, 4 July 2019, https://www.forbes.com/sites/feliciajackson/2019/07/04/latin-america-ev-sales-up-90-as-transport-transformation-continues; Wartsila, "Latin America: The power of one", 23 August 2018, https://www.wartsila.com/twentyfour7/energy/latin-america-the-power-of-one.

75 Musa McKee et al., *Demographic and Economic Material Factors in the MENA Region*, MENARA Working Papers (Barcelona, Spain: October 2017), http://menaraproject.eu/wp-content/uploads/2017/10/menara_wp_3.pdf.

76 Dominic Dudley, "Can the Middle East make a success of renewable energy? It may not have a choice", *Forbes*, 14 February 2018, https://www.forbes.com/sites/dominicdudley/2018/02/14/can-the-middle-east-make-a-success-of-renewable-energy-it-may-not-have-a-choice/; Tarek Bazza, "Energy Minister: Morocco to invest $30 billion in renewable energy by 2030", Morocco World News, 2 October 2018, https://www.moroccoworldnews.com/2018/10/254477/energy-minister-morocco-to-invest-30-billion-in-renewable-energy-by-2030/; "Investment in renewable energy exceeds 4 billion mark", *Jordan Times*, 22 April 2019, http://www.jordantimes.com/news/local/%E2%80%98investment-renewable-energy-exceed-4b-mark%E2%80%99; Neha Bhatia, "UAE, KSA lead MENA renewable and solar energy sector", Construction Week, 20 May 2018, https://www.constructionweekonline.com/article-49353-uae-ksa-lead-mena-renewable-and-solar-energy-sector.

77 UN DESA, *The World's Cities in 2018*, op. cit. note 15; Index Mundi, "Canada urbanization", https://www.indexmundi.com/canada/urbanization.html, updated 20 January 2018.

78 Iowa State University, Iowa Community Indicators Program, "Urban percentage of the population for states, historical", https://www.icip.iastate.edu/tables/population/urban-pct-states, viewed 17 November 2019; Thomas M. Beckley, "New Brunswick", in Canadian Rural Revitalization Foundation, *State of Rural Canada* (Toronto: 2015), http://sorc.crrf.ca/nb/.

79 National League of Cities, "Number of municipal governments & population distribution", https://www.nlc.org/number-of-municipal-governments-population-distribution, viewed 9 October 2019.

80 US Energy Information Administration, "Most states have Renewable Portfolio Standards", Today in Energy, 2 February 2012, https://www.eia.gov/todayinenergy/detail.php?id=4850.

81 Bloomberg Philanthropies, "American Cities Climate Challenge", https://www.bloomberg.org/program/environment/climatechallenge/, viewed 17 November 2019; Sierra Club, "Ready for 100", https://www.sierraclub.org/ready-for-100, viewed 15 October 2019; We Are Still In, "Sign the declaration and commit to climate action", https://www.wearestillin.com/, viewed 15 October 2019; Renewable Cities, "Supporting cities through the transition to 100% renewable energy and increased energy efficiency", https://www.renewablecities.ca/, viewed 15 October 2019.

82 REN21, op. cit. note 1.

83 Ibid.

84 Jamal Saghir, *Urbanization in Sub-Saharan Africa* (Washington, DC: Center for Strategic and International Studies, April 2018), https://www.csis.org/analysis/urbanization-sub-saharan-africa; UN-Habitat, *The State of African Cities* (Nairobi: 2014), http://mirror.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3528; UN DESA, *The World's Cities in 2018*, op. cit. note 15.

85 African Development Bank (AfDB), OECD and United Nations Development Programme (UNDP), *African Economic Outlook: Sustainable Cities and Structural Transformation* (Paris: 2016), https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/AEO_2016_Report_Full_English.pdf; World Bank, "Population living in slums (% of urban population)", https://data.worldbank.org/indicator/EN.POP.SLUM.UR.ZS?locations%C2%BCZG, viewed 9 October 2019.

86 Edgar Pieterse and Susan Parnell, "Africa's urban revolution in context", in Susan Parnell and Edgar Pieterse, eds., *Africa's Urban Revolution* (Cape Town, South Africa: 2014), pp. 1-17, https://www.press.uchicago.edu/ucp/books/book/distributed/A/bo20841904.html; David Castells-Quintana, "Malthus living in a slum: Urban concentration, infrastructure and economic growth", *Journal of Urban Economics*, no. 92 (2016), pp. 31-47, https://www.sciencedirect.com/science/article/abs/pii/S0094119016000115; Sebastian Kriticos, "Urban giants: The cost of primacy in sub-Saharan Africa", *Urbanisation in Developing Countries*, 4 May 2017, https://urbanisation.econ.ox.ac.uk/blog/urban-giants-the-costs-of-primacy-in-africa.

87 Simon Bawakyillenuo et al., "Sustainable energy transitions in Sub-Saharan African cities: The role of local government", in Droege, op. cit. note 10.

88 AfDB, OECD and UNDP, op. cit. note 85; Bawakyillenuo et al., op. cit. note 87.

89 Odd-Hege Fjeldstad, Gérard Chambas and Jean-François Brun, *Local Government Taxation in Sub-Saharan Africa* (Bergen, Norway: International Centre for Tax and Development and Chr Michelsen Institute, March 2014), https://www.cmi.no/publications/file/5098-local-government-taxation-in-sub-saharan-africa.pdf; Saghir, op. cit. note 84.

90 UN-Habitat, op. cit. note 84.

91 Fjeldstad, Chambas and Brun, op. cit. note 89; Saghir, op. cit. note 84.

92 Lighting Global, *Off-Grid Solar Market Trends Report 2018* (Washington, DC: 2018), https://www.lightingglobal.org/wp-content/uploads/2018/02/2018_Off_Grid_Solar_Market_Trends_Report_Summary.pdf.

93 GOGLA, *Global Off-Grid Solar Market Report: Semi-annual Sales and Impact Data* (Utrecht, The Netherlands: 2018), https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h2_2018_opt.pdf

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1 **Figure 5** based on the following sources: Janet L. Sawin et al., *Renewable Energy and Sustainable Development: Accounting for Impacts on the Path to 100% RE* (Hamburg, Germany: World Future Council, August 2016), https://www.worldfuturecouncil.org/renewable-energy-sustainable-development/; Organisation for Economic Co-operation and Development (OECD)/International Energy Agency (IEA), "Cities are at the frontline of the energy transition", 7 September 2016, https://www.iea.org/newsroom/news/2016/september/cities-are-at-the-frontline-of-the-energy-transition.html; Sustainable Mobility for All, *Global Mobility Report 2017: Tracking Sector Performance* (Washington, DC: 2017), p. 90, https://openknowledge.worldbank.org/bitstream/handle/10986/28542/120500.pdf?sequence=6; World Health Organization (WHO), "Ambient (Outdoor) Air Quality and Health", fact sheet (Geneva: 2018), http://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health; World Bank, "Access to electricity, urban (% of urban population)", https://data.worldbank.org/indicator/EG.ELC.ACCS.UR.ZS, viewed 3 May 2019; International Renewable Energy Agency (IRENA), *Renewable Power Generation Costs in 2018* (Abu Dhabi: 2019), http://www.irena.org/costs; IRENA, *Renewable Energy and Jobs – Annual Review 2018* (Abu Dhabi: 2018), https://www.irena.org/publications/2018/May/Renewable-Energy-and-Jobs-Annual-Review-2018.

2 Vladimir Kendrovski, WHO, "Health benefits of energy efficiency in urban environment", presentaton, https://unfccc.int/sites/default/files/04_who_kendrovski.pdf, viewed 14 October 2019.

3 WHO, "9 out of 10 people worldwide breathe polluted air, but more countries are taking action", press release (Geneva: 2 May 2018), https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action.

4 Ibid.

5 IQ Air, AirVisual, "World most polluted cities 2018 (PM2.5)", https://www.airvisual.com/world-most-polluted-cities, viewed 10 October 2019; UNICEF, "Mongolia's air pollution child health crisis", press release (Ulaanbaatar, Mongolia: 21 February 2018), https://www.unicef.org/eap/press-releases/mongolias-air-pollution-child-health-crisis **Figure 6** from the following sources: OECD countries from OECD, "Air pollution exposure", https://data.oecd.org/air/air-pollution-exposure.htm, viewed 15 November 2019; non-OECD countries from "WHO Global Air Quality Database (update 2018) edition", https://www.who.int/airpollution/data/cities/en/, viewed 20 November 2019. According to IQAir, AirVisual, https://www.airvisual.com/, as of mid-2019 there were a total of 3,476 non-government monitoring stations and 11,803 government stations, broken down as follows: Africa (25 non-government; 78 government), Central Asia (4; 5), East Asia (40; 4,473), Europe (259; 3,910), Latin America and Caribbean (68; 341), Middle East (21; 350), North America (2,611; 1,892), Oceania (46; 4,195), South Asia (56; 369) and Southeast Asia (346; 190).

6 IQ Air, "World most polluted cities 2018 (PM2.5)", op. cit. note 5.

7 UNICEF, *Silent Suffocation in Africa* (Geneva: 2019), https://www.unicef.org/media/55081/file/Silent%20suffocation%20in%20africa%20air%20pollution%202019%20.pdf.

8 WHO, op. cit. note 3.

9 Ibid.

10 Ibid.

11 Wuxiang Xie et al., "Relationship between fine particulate air pollution and ischaemic heart disease morbidity and mortality", Heart, vol. 101, no. 4 (2015), pp. 257–263, https://doi.org/10.1136/heartjnl-2014-306165; M. Wang et al., "Association between long-term exposure to ambient air pollution and change in quantitatively assessed emphysema and lung function", *JAMA*, vol. 322, no. 6 (2019), pp.546-556 https://jamanetwork.com/journals/jama/article-abstract/2747669; Jennifer S. Wang and Peter Orris, *The Health Impacts of Energy Choices* (Healthy Energy Initiative, 2015), http://www.healthyenergyinitiative.org/wp-content/uploads/2015/10/Health-Impacts-of-Energy-Choices_DigitalVersion_lowres.pdf; O. Raaschou-Nielsen et al., "Particulate matter air pollution components and risk for lung cancer", *Environment international*, vol. 87 (2016), pp. 66-73 https://www.ncbi.nlm.nih.gov/pubmed/26641521; Sonia Elks, "Poor air quality leads to depression and bipolar disorder, study finds", World Economic Forum, 23 August 2019, https://www.weforum.org/agenda/2019/08/air-pollution-mental-health.

12 World Bank, *Regulatory Indicators for Sustainable Energy: A Global Scorecard for Policy Makers* (Washington, DC: 2017), http://documents.worldbank.org/curated/en/538181487106403375/Regulatory-indicators-for-sustainable-energy-a-global-scorecard-for-policy-makers

13 Ibid.

14 WHO, "Household air pollution and health", 8 May 2018, https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.

15 OECD, *The Cost of Ambient Air Pollution Thus Far in the 21st Century: Results from the BRIICS and the OECD Countries* (Paris: 2017), https://www.oecd-ilibrary.org/environment/the-rising-cost-of-ambient-air-pollution-thus-far-in-the-21st-century_d1b2b844-en

16 H. Yin, L. Xu and Y. Cai, "Monetary valuation of PM10-related health risks in Beijing China: The necessity for PM10 pollution indemnity", *International Journal of Environmental Research and Public Health, vol. 12, no. 8* (2015), pp. 12,9967-9987, https://www.ncbi.nlm.nih.gov/pubmed/26308020

17 Sergio Sanchez et al., Clean Air Institute, "Air pollution and health in Latin America and the Caribbean – An overview", presentation at NASA Goddard Space Flight Centre, 17 November 2016, https://science.gsfc.nasa.gov/610/applied-sciences/air_quality_health_showcase/Sanchez_AQ_Health_Showcase.pdf; OECD, op. cit. note 29

18 Wang and Orris, op. cit. note 11.

19 Joanne McCarthy, "Muswellbrook councillor joins calls for temporary mine shutdowns to ease air pollution", *Newcastle Herald*, 2 July 2018, https://www.newcastleherald.com.au/story/5470343/dust-is-killing-us-slowly-calls-for-temporary-mine-shutdowns/; Lock the Gate Alliance, "Record coal mine air pollution in the Hunter Valley casts cloud over future of United Wambo", 12 December 2018, https://www.lockthegate.org.au/record_coal_mine_air_pollution_in_the_hunter_valley_casts_cloud_over_future_of_united_wambo.

20 Aiswarya Ragothaman and William A. Anderson, "Air quality impacts of petroleum refining and petrochemical industries", *Environments*, vol. 4, no. 3 (2017), p. 66, https://doi.org/10.3390/environments4030066; N.R. Eugenio, M. McLaughlin and D. Pennock, *Soil Pollution: A Hidden Reality* (Rome: UN Food and Agriculture Organization, 2018), http://www.fao.org/3/I9183EN/i9183en.pdf

21 *Environmental Integrity Project, Preparing for the Next Storm* (Washington, DC: 2018), https://www.environmentalintegrity.org/reports/preparing-for-the-next-storm/; J.A. Horney et al., "Comparing residential contamination in a Houston environmental justice neighborhood before and after Hurricane Harvey", *PLOS ONE*, vol. 13 (2018), p. e0192660, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0192660

22 Stephen Chen, "Beijing shuts down its last coal-fired power plant as part of bid to clear air", *South China Morning Post*, 19 March 2017, https://www.scmp.com/news/china/society/article/2080270/beijing-shuts-down-its-last-coal-fired-power-plant-part-bid-clear.

23 Yang Yi, ed. "Beijing sees renewable energy growth", *Xinhua*, 8 September 2018, http://www.xinhuanet.com/english/2018-09/08/c_137454885.htm.

24 James Griffiths, "22 of the top 30 most polluted cities in the world are in India", *CNN*, 5 March 2019, https://edition.cnn.com/2019/03/04/health/most-polluted-cities-india-china-intl/index.html.

25 Covenant of Mayors for Climate & Energy, "Signatories", https://www.covenantofmayors.eu/about/covenant-community/signatories/key-actions.html, viewed 14 October 2019.

26 Rome from REN21, *Renewables 2019 Global Status Report* (Paris: June 2019), p. 58, https://www.ren21.net/gsr-2019/, and from Kristine Lofgren, "Rome is banning all oil-burning cars by 2024", *Inhabitat*, 3 January 2018, https://inhabitat.com/rome-is-banning-all-oil-burning-cars-by-2024; Madrid from REN21, op. cit. this note, p. 58, and from Feargus O'Sullivan, "Madrid takes its car ban to the next level", CityLab, 24 May 2018, https://www.citylab.com/transportation/2018/05/madrid-spain-car-ban-city-center/561155/; Eltis, "Lisbon introduces car restrictions (Portugal)", 30 January 2015, http://www.eltis.org/discover/news/lisbon-introduces-car-restrictions-portugal-0; Oslo Kommune, "Climate and Energy Strategy for Oslo", 22 June 2016, https://www.oslo.kommune.no/getfile.php/13166797-1480690482/Content/English/Politics%20and%20administration/Green%20

Oslo/Plans%20and%20programmes/Climate%20and%20 Energy%20Strategy%20Oslo.pdf; Athens from REN21, op. cit. this note, p. 58.

27 REN21, op. cit. note 43, p. 185.

28 C40 Cities, "Scores of cities commit to bold climate action to deliver on the highest ambition of Paris Agreement", press release (San Francisco, CA: 14 September 2018), https://www.c40.org/press_releases/scores-of-cities-commit-to-bold-climate-action-to-deliver-on-the-highest-ambition-of-paris-agreement.

29 Kirk Caldwell and Dawn Lippert, "Hawaii's mayors just committed to 100% renewable transportation by 2045", *Fast Company*, 21 December 2017, https://www.fastcompany.com/40511006/why-hawaicabbis-mayors-just-committed-to-100-renewable-transportation-by-2045.

30 WHO, *Burning Opportunity: Clean Household Energy for Health, Sustainable Development and Wellbeing of Women and Children* (Geneva: 2016), https://www.who.int/airpollution/publications/burning-opportunities/en/.

31 Toby D. Couture and David Jacobs, *Beyond Fire: How to Achieve Electric Cooking?* (Hamburg, Germany: Hivos, World Future Council, 2019), https://greeninclusiveenergy.org/publication/beyond-fire-how-to-achieve-electric-cooking/.

32 Kumlachew Geremew et al., "Current level and correlates of traditional cooking energy sources utilization in urban settings in the context of climate change and health, northwest Ethiopia: A case of Debre Markos town", *BioMed Research International* (2014), p. 572473, https://www.hindawi.com/journals/bmri/2014/572473/.

33 Karen C. Seto et al., "Human settlements, infrastructure and spatial planning", in Ottmar Edenhofer et al., eds., *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK and New York, NY: Cambridge University Press, 2014), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter12.pdf; United Nations Department of Economic and Social Affairs (UN DESA), *The World's Cities in 2018* (New York: 2018), p. 1, https://www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in_2018_data_booklet.pdf; Coalition for Urban Transitions, *Climate Emergency, Urban Opportunity: How National Governments Can Secure Economic Prosperity and Avert Climate Catastrophe by Transforming Cities* (New York: 2019), https://urbantransitions.global/wp-content/uploads/2019/09/Climate-Emergency-Urban-Opportunity-report.pdf.

34 Daniel Moran et al., "Carbon footprints of 13 000 cities", *Environmental Research Letters*, vol. 13, no. 6 (2018), p. 64041, https://doi.org/10.1088/1748-9326/aac72a.

35 UN Environment Programme, "Cities and climate change", https://www.unenvironment.org/explore-topics/resource-efficiency/what-we-do/cities/cities-and-climate-change, viewed 3 May 2019.

36 C40 Cities, "Why Cities?" https://www.c40.org/ending-climate-change-begins-in-the-city, viewed 14 October 2019; UN-Habitat, "Climate change", https://unhabitat.org/urban-themes/climate-change/, viewed 3 May 2019.

37 UN-Habitat, op. cit. note 36.

38 C40 Cities, C40 *Cities Annual Report 2017* (New York and London: 2017), https://c40-production-images.s3.amazonaws.com/other_uploads/images/2056_C40_ANNUAL_REPORT_2017.original.pdf.

39 Climate Emergency Declaration, "Climate emergency declaration in 1,120 jurisdictions and local governments cover 285 million citizens", 13 October 2019, https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/; James Ellsmoor, "Climate emergency declarations: How cities are leading the charge", 20 July 2019, *Forbes*, https://www.forbes.com/sites/jamesellsmoor/2019/07/20/climate-emergency-declarations-how-cities-are-leading-the-charge/.

40 Cedamia, "Climate Emergency Declarations", https://www.cedamia.org/global/, viewed 14 October 2019.

41 UNEP, op. cit. note 35.

42 World Resources Institute (WRI), "4 ways local solar projects can benefit cities & The Renewables Accelerator", CleanTechnica, 28 March 2019, https://cleantechnica.com/2019/03/28/4-ways-local-solar-projects-can-benefit-cities-the-renewables-accelerator/; 100 Resilient Cities, "Mayor Emanuel releases 'Resilient Chicago,' Chicago's resilience strategy, in partnership with 100RC", press release (Chicago: 14 February 2019), https://www.100resilientcities.org/mayor-emanuel-releases-resilient-chicago-in-partnership-with-100rc/.

43 Berlin Senate Department for the Environment, Transport and Climate Protection, "Climate Protection in Berlin", https://www.berlin.de/senuvk/klimaschutz/bek_berlin/index_en.shtml, viewed 10 October 2019; Berlin Senate Department for the Environment, Transport and Climate Protection, "Masterplan Solar City", https://www.berlin.de/sen/energie/energie/erneuerbare-energien/masterplan-solarcity/, viewed 10 October 2019.

44 Helsingin kaupungin ympäristökeskus, *Helsinki's Climate Roadmap* (Helsinki, Finland: 2015), https://issuu.com/helsinginymparistokeskus/docs/helsinki_climate_roadmap_20150427; 100% Renewable Energy Atlas, "Malmö, Sweden", https://www.100-percent.org/malmo-sweden/, viewed 17 October 2019.

45 100% Renewable Energy Atlas, "Stockholm, Sweden", https://www.100-percent.org/stockholm-sweden/, viewed 17 October 2019; *100% Renewable Energy Atlas*, Oslo, Norway, https://www.100-percent.org/oslo-norway/, viewed 17 October 2019

46 Ayyoob Sharifi and Yoshiki Yamagata, "Principles and criteria for assessing urban energy resilience: A literature review", *Renewable and Sustainable Energy Reviews*, vol. 60 (2016), pp. 1654-77, https://www.sciencedirect.com/science/article/pii/S136403211600263X.

47 Emma Foehringer Merchant, "Sandy 5 years later: Is the Northeast closer to grid resilience?" Greentech Media, 20 October 2017, https://www.greentechmedia.com/articles/read/five-years-after-sandy-is-the-northeast-closer-to-resilience; IRENA, *Innovation Outlook: Renewable Mini-Grids* (Abu Dhabi: 2016), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Innovation_Outlook_Minigrids_2016.pdf.

48 NY Prize, "Powering a new generation of community energy", https://www.nyserda.ny.gov/All-Programs/Programs/NY-Prize, viewed 6 August 2019.

49 Merchant, op. cit. note 47.

50 WRI, op. cit. note 42.

51 Kashiwa No-Ha, "Smart City Tour", https://www.kashiwanoha-smartcity.com/en/tour/pc/, viewed 14 October 2019.

52 Ibid.

53 IRENA, *Renewable Energy in Cities* (Abu Dhabi: 2016), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf; Environmental Entrepreneurs (E2), "Clean Jobs Cities 2018" (San Francisco and Washington, DC: 2018), https://www.e2.org/wp-content/uploads/2018/09/E2-Clean-Job-Cities-2018.pdf; Angelina Davydova, "Ukraine cities gear up to run on local clean energy by 2050", *Reuters*, 14 December 2018, https://www.reuters.com/article/us-climatechange-ukraine-renewables/ukraine-cities-gear-up-to-run-on-local-clean-energy-by-2050-idUSKBN1OD1CA.

54 Jan Corfee-Morlot, Michael I. Westphal and Rachel Spiegel, "4 ways to shift from fossil fuels to clean energy", WRI blog, 15 January 2019, https://www.wri.org/blog/2019/01/4-ways-shift-fossil-fuels-clean-energy.

55 IRENA, *Renewable Power Generation Costs in 2018*, op. cit. note 2.

56 90% from Ibid.; REN21, op. cit. note 26.

57 Sophie Vorrath, "Kiribati leads by example on solar, slashes dependence on diesel fuel", One Step Off the Grid, 26 September 2016, https://onestepoffthegrid.com.au/kiribati-leads-example-solar-slashes-dependence-diesel-fuel/.

58 Henner Busch and Kes McCormick, "Local power: Exploring the motivations of mayors and key success factors for local municipalities to go 100% renewable energy", *Energy, Sustainability, and Society*, vol. 4, no. 5 (2014), p. 5. https://doi.org/10.1186/2192-0567-4-5.

59 100% Renewable Energy, "East Hampton, New York, USA", https://www.100-percent.org/east-hampton-ny-usa/, viewed 3 May 2019.

60 Perry Stein, "City deal will increase D.C. government's solar energy capacity by 70 percent", *Washington Post*, 2 December 2015, https://www.washingtonpost.com/news/local/wp/2015/12/02/city-deal-will-increase-d-c-governments-solar-energy-capacity-by-70-percent/.

61 Joshue S. Hill, "100% renewable energy bill passes in Washington, DC", CleanTechnica, 28 December 2018, https://cleantechnica.

com/2018/12/28/100-renewable-energy-bill-passes-in-washington-dc/.

62 Dan Lieberman and Siobhan Doherty, *Renewable Energy as a Hedge Against Fuel Price Fluctuation: How to Capture the Benefits* (Montreal, Canada: Commission for Environmental Cooperation, 2008), http://www.cec.org/islandora/en/item/2360-renewable-energy-hedge-against-fuel-price-fluctuation-en.pdf.

63 City of Melbourne, "Melbourne Renewable Energy Project: A new generation of energy", https://www.melbourne.vic.gov.au/business/sustainable-business/mrep/Pages/melbourne-renewable-energy-project.aspx, viewed 14 October 2019.

64 Calgary Transit, "Ride the wind – a success story", http://library.tac-atc.ca/proceedings/2002/calgary.pdf, viewed 14 October 2019.

65 Daniel M. Kammen and Deborah A. Sunter, "City-integrated renewable energy for urban sustainability", Science, vol. 352, no. 6288 (20 May 2016), pp. 922-28, https://science.sciencemag.org/content/352/6288/922; Walid El-Khattam and Magdy M.A. Salama, "Distributed generation technologies, definitions and benefits", *Electric Power Systems Research*, vol. 71, no. 2 (2004), pp. 119-128, https://www.sciencedirect.com/science/article/abs/pii/S0378779604000240; Guido Pepermans et al., "Distributed generation: definition, benefits and issues", *Energy Policy*, vol. 33, no. 6 (2005), pp. 787-98, https://www.researchgate.net/publication/222561651_Distributed_generation_definition_benefits_and_issues

66 C40 Cities, "Barcelona's Solar Hot Water Ordinance", 3 November 2011, https://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance.

67 Ibid.; European Solar Thermal Industry Association, "Solar ordinances", http://www.estif.org/policies/solar_ordinances/ http://www.estif.org/policies/solar_ordinances/.

68 Kelsie Defrancia, "Moving towards 100% renewable energy: Drivers behind city policies and pledges", State of the Planet, Columbia University Earth Institute, 24 April 2018, https://blogs.ei.columbia.edu/2018/04/24/moving-towards-100-renewable-energy-drivers-behind-city-policies-pledges/; Katharina Heinbach, Bernd Hirschl and Steven Salecki, "Value-added and employment effects of renewable energies and the energy-efficiency refurbishment of existing housing – Case study: Berlin, Germany", in Peter Droege, ed., *Urban Energy Transition: Renewable Strategies for Cities and Regions* (Amsterdam: Elsevier, 2018), pp. 457-66, https://www.sciencedirect.com/science/article/pii/B978008102074600036X.

69 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.

70 The Solar Foundation, *National Solar Jobs Census 2018* (Washington, DC: 2018), https://www.thesolarfoundation.org/national/.

71 Mark Muro, Jonathan Rothwell and Devashree Saha, *Sizing the Clean Economy: A National and Regional Green Jobs Assessment* (Washington, DC: Brookings Institution, 2011), https://www.brookings.edu/research/sizing-the-clean-economy-a-national-and-regional-green-jobs-assessment/.

72 Energy Transition, "Energy transition and youth employment in Spain and Greece", 10 December 2018, https://energytransition.org/2018/12/energy-transition-and-youth-employment/.

73 Deutsche Welle, "Dezhou: China's 'Solar Valley'", video, 17 March 2017, https://www.dw.com/en/dezhou-chinas-solar-valley/av-37980019.

74 E2, op. cit. note 53.

75 Arthur Beesley, "Climate change and the end of Ireland's peat bogs", *Financial Times*, 24 July 2019, https://www.ft.com/content/7b46d01a-ada6-11e9-8030-530adfa879c2.

76 Scottish Development International, "Learning Journey to Heerlen Minewater District Heating System: Report", 23 May 2016, https://www.gov.scot/publications/learning-journey-to-heerlen-minewater-district-heating-system-report/.

77 Julia Pyper, "San Diego moves ahead with 100% Clean Energy Community Choice Program", Greentech Media, 25 October 2018, https://www.greentechmedia.com/articles/read/san-diego-moves-ahead-with-100-clean-energy-community-choice-program; Clean Power SF, "Clean energy starts with you", https://www.cleanpowersf.org/, viewed 15 July 2019; Solana Energy Alliance, "SEA Choice", https://solanaenergyalliance.org/your-options/sea-choice/, viewed 13 June 2019.

78 Google, "Breaking ground for Google's first data center in Denmark", 20 November 2018, https://www.blog.google/inside-google/infrastructure/breaking-ground-googles-first-data-center-denmark/.

79 Stockholm Data Parks, "Green computing redefined", https://stockholmdataparks.com/benefits-of-green-computing-in-stockholm/, viewed 9 May 2019.

80 Henner Busch and Stefan Anderberg, "Green attraction – Transnational municipal climate networks and green city branding", *Journal of Management and Sustainability*, vol. 5, no. 4 (2015), p. 1, http://www.ccsenet.org/journal/index.php/jms/article/view/52101/29650; Ida Andersson, *Geographies of Place Branding – Researching Through Small and Medium Sized Cities* (Stockholm: Stockholm University, 2015), https://www.diva-portal.org/smash/get/diva2:798832/FULLTEXT01.pdf.

81 The EcoTipping Points Project, "Germany – Freiburg – Green city", January 2011, http://www.ecotippingpoints.org/our-stories/indepth/germany-freiburg-sustainability-transportation-energy-green-economy.html; SMILE, "Samsø, Denmark", https://www.h2020smile.eu/the-islands/samso-denmark/, viewed 29 March 2019; Andersson, op. cit. note 80.

82 Genevalive, "Green Geneva", https://www.geneve.com/en/topicblocks/green-geneva/, viewed 14 October 2019.

83 City of Vancouver, "Greenest City – Action Plan", https://vancouver.ca/files/cov/Greenest-city-action-plan.pdf, viewed 14 October 2019.

84 Alix Bolle, Energy Cities, personal communication with REN21, 5 April 2019.

85 Kashiwa No-Há Smart City, https://www.kashiwanoha-smartcity.com/en/, viewed 17 October 2019.

86 IRENA, *A New World: The Geopolitics of the Energy Transformation* (Abu Dhabi: 2019), http://geopoliticsofrenewables.org/assets/geopolitics/Reports/wp-content/uploads/2019/01/Global_commission_renewable_energy_2019.pdf.

87 International Finance Corporation (IFC), *Climate Investment Opportunities in Cities* (Washington, DC: 2018), https://www.ifc.org/wps/wcm/connect/bffd2386-ff4c-454d-8366-8d801bf3b9c5/201811-CIOC-IFC-Analysis.pdf?MOD=AJPERES.

88 100 Resilient Cities, *Resilient Cities, Resilient Lives: Learning from the 100RC Network* (London: July 2019), http://100resilientcities.org/wp-content/uploads/2019/07/100RC-Report-Capstone-PDF.pdf.

89 Fossil Free, "City in Ukraine announces commitment to 100% renewable energy by 2050", 25 June 2018, https://gofossilfree.org/press-release/ukraine-city-announces-commitment-to-100-renewable-energy-by-2050/; Angelina Davydova, "Ukraine cities gear up to run on local clean energy by 2050", *Reuters*, 14 December 2018, https://www.reuters.com/article/us-climatechange-ukraine-renewables/ukraine-cities-gear-up-to-run-on-local-clean-energy-by-2050-idUSKBN1OD1CA.

90 Fossil Free, op. cit. note 89; P.E. Kalle, "Understanding Municipal Climate Action – From Transnational to Local" (Lund, Sweden: Lund University Department of Human Geography, 2019), https://www.cambridge.org/core/books/urban-climate-politics/transnational-municipal-networks-and-cities-in-climate-governance/7D9FB46F1B6C8CC64A7CC6B2D1871EE2.

91 IRENA, *Scaling Up Renewables in Cities: Opportunities for Municipal Governments* (Abu Dhabi: 2018), https://www.irena.org/publications/2018/Dec/Scaling-up-Renewables-in-Cities

92 WWF, "Tshwane waste to energy" 11 November 2015, http://wwf.panda.org/?256140/Tshwane-waste-to-energy.

93 eThekwini Municipality, "Renewable energy development hub one step closer", http://www.durban.gov.za/Resource_Centre/Press_Releases/Pages/Renewable-Energy-Development-Hub-one-step-closer.aspx, viewed 16 July 2019.

94 Ingo Stadler and Michael Sterner, "Urban energy storage and sector coupling", in Droege, op. cit. note 68; Luc Van Nuffel et al., *Sector Coupling: How Can It Be Enhanced in the EU to Foster Grid Stability and Decarbonise?* (Brussels: 2018), https://op.europa.eu/en/publication-detail/-/publication/858d789d-f132-11e8-9982-01aa75ed71a1/language-en.

95 KTC, "Skive bygger Europas storste power to gas-anlaeg", 20 April 2016, https://www.ktc.dk/artikel/skive-bygger-europas-stoerste-power-gas-anlaeg.

96 Vattenfall, "Salt as energy storage: Vattenfall launch pilot project at heat plant in Berlin", press release (Stockholm: 11 March 2019), https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2019/

salt-as-energy-storage-vattenfall-launch-pilot-project-at-heat-plant-in-berlin.

97 Nice Smart Valley, "Nice Smart Valley, Demonstrator of the European Interflex project in the Alpes – Maritimes", http://nice-smartvalley.com/gb/interflex-demonstration/, viewed 16 July 2019.

98 C. Ewbank et al., "A systematic review of oil tanker truck disasters: Identifying prevention targets", *Burns* vol. 45, no. 4 (2019), pp. 905-13, https://www.ncbi.nlm.nih.gov/pubmed/30808527.

99 Jessica Murphy, "Lac-Megantic: The runaway train that destroyed a town", *BBC*, 19 January 2018, https://www.bbc.com/news/world-us-canada-42548824.

100 Matthew Bremner, "A gas heist gone wrong, an explosion, and 137 deaths in Mexico", *Bloomberg Business Week*, 26 June 2019, https://www.bloomberg.com/news/features/2019-06-26/a-gas-heist-gone-wrong-an-explosion-and-137-deaths-in-mexico.

101 Jeff D. Colgan, "Fueling the fire: Pathways from oil to war", *International Security*, vol. 38, no. 2 (2013), pp. 147-80, https://www.mitpressjournals.org/doi/10.1162/ISEC_a_00135; Indra Overland, "The geopolitics of renewable energy: Debunking four emerging myths", *Energy Research & Social Science*, vol. 49 (March 2019), pp. 36-40, https://www.sciencedirect.com/science/article/pii/S2214629618308636.

102 André Månsson, "A resource curse for renewables? Conflict and cooperation in the renewable energy sector", *Energy Research & Social Science*, vol. 10 (November 2015), pp. 1-9, https://www.sciencedirect.com/science/article/pii/S2214629615000791.

103 Ibid.; Clare Church and Alec Crawford, *Green Conflict Minerals: The Fuels of Conflict in the Transition to a Low-carbon Economy* (Winnipeg, Manitoba, Canada: International Institute for Sustainable Development (IISD), 2018), https://www.iisd.org/sites/default/files/publications/green-conflict-minerals.pdf.

104 Natalie Ralph, "Ensuring renewable energy doesn't fuel conflict", Australian Institute of International Affairs, 13 March 2018, http://www.internationalaffairs.org.au/australianoutlook/potential-renewable-energy-fuel-conflict/.

105 IRENA, *City in Focus: Austin, US – Stimulating Renewable Energy Through Public and Private Procurement* (Abu Dhabi: 2013), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/Jan/IRENA-cities-case-4-Austin.pdf.

106 World Bank, "Access to electricity, urban (% of urban population)", https://data.worldbank.org/indicator/EG.ELC.ACCS.UR.ZS, viewed 3 May 2019

107 Ibid.

108 Ibid.; Power for All, "Campaign Update: May 2018", 25 May 2018, https://www.powerforall.org/news-media/campaign-updates/campaign-updates-may-2018; Michael I. Westphal, Sarah Martin and David Satterthwaite, "Powering cities in the Global South: How energy access for all benefits the economy and the environment", WRI blog, 7 September 2017, https://www.wri.org/blog/2017/09/powering-cities-global-south-how-energy-access-all-benefits-economy-and-environment; World Bank, "More people have access to electricity than ever before, but world is falling short of sustainable energy goals", press release (Washington, DC: 22 May 2019), https://www.worldbank.org/en/news/press-release/2019/05/22/tracking-sdg7-the-energy-progress-report-2019.

109 A2EI data, personal communication, with REN21, 25 September 2019. See also https://a2ei.org/data.

110 Westphal, Martin and Satterthwaite, op. cit. note 108.

111 Abdoulaye Fall et al., "Modern energy access in peri-urban areas of West Africa: The case of Dakar, Senegal", *Energy for Sustainable Development*, vol. 12, no. 4 (2008), pp. 22-37, https://www.sciencedirect.com/science/article/pii/S0973082609600053; C.A. Kennedy et al., "Energy and material flows of megacities", *Proceedings of the National Academy of Sciences*, vol. 112, no. 19 (2015), pp. 5985-90, https://www.pnas.org/content/112/19/5985.

112 El Cordillerano, "Bariloche exporta al pais experiencia y capitacion con el programa sustentabilizar hogares", 25 September 2018, https://www.elcordillerano.com.ar/noticias/2019/09/25/83093-bariloche-exporta-al-pais-experiencia-y-capacitacion-con-el-programa-sustentabilizar-hogares; Fovisee, "Sustentabilizar Hogares", https://www.fovisee.org/proyecto/sustentabilizar-hogares/, viewed 14 October 2019

113 REN21, op. cit. note 26, p. 133.

114 "Ugandan mayor: My district will be 100% renewable by 2020", *The Guardian* (UK), 20 October 2015, https://www.theguardian.com/global-development-professionals-network/2015/oct/20/ugandan-mayor-my-district-will-be-100-renewable-by-2020.

115 Werner Weiss, AEE INTEC, Gleisdorf, Austria, personal communication with REN21, 26 April 2019

116 Ministry of Energy and Mines of the Republic of Burundi and Japan International Cooperation Agency, *Final Report of the Preparatory Survey on the Project for Introduction of Clean Energy by Solar Electricity Generation System in the Republic of Burundi* (Bujumbura, Burundi: August 2010), p. 2-1, http://open_jicareport.jica.go.jp/pdf/12003851.pdf.

117 Ines Mayer et al., "The two faces of energy poverty: A case study of households' energy burden in the residential and mobility sectors at the city level", *Transportation Research Procedia*, vol. 4 (2014), pp. 228-240, https://www.sciencedirect.com/science/article/pii/S2352146514003019.

118 World Bank, *Expenditure of Low-income Households on Energy* (Washington, DC: 2010) http://siteresources.worldbank.org/EXTOGMC/Resources/336929-1266963339030/eifd16_expenditure.pdf, viewed 14 October 2019.

119 H. Thomson, S. Bouzarovski and C. Snell, "Rethinking the measurement of energy poverty in Europe: A critical analysis of indicators and data, *Indoor and Built Environment*, vol. 26 (2017), pp. 879-901, https://journals.sagepub.com/doi/full/10.1177/1420326X17699260; European Commission, "Energy poverty", https://ec.europa.eu/energy/en/eu-buildings-factsheets-topics-tree/energy-poverty#Tackling-Fuel-Poverty, viewed 14 August 2019.

120 Edo Omic, *Energy Poverty in Europe: How Energy Efficiency and Renewables* (Paris: Council of Europe Development Bank, 2019) , p. 1, https://coebank.org/media/documents/CEB_Study_Energy_Poverty_in_Europe.pdf.

121 Covenant of Mayors for Climate & Energy, "Rainha Dona Leonor Renovation", https://www.covenantofmayors.eu/IMG/pdf/Porto.pdf, viewed 14 October 2019.

122 CapaCITIES, "Quick win projects in Rajkot", https://capacitiesindia.org/projects-rajkot/, viewed 14 October 2019.

123 Arnulf Grubler et al., "Urban energy systems", in T.B. Johansson et al., eds., *Global Energy Assessment: Toward a Sustainable Future* (Cambridge, UK, New York, NY and Laxenburg, Austria: Cambridge University Press and International Institute for Applied Systems Analysis, 2012),

124 Jimenez Mori et al., *Understanding the Drivers of Household Energy Spending: Micro Evidence for Latin America* (Washington, DC: Inter-American Development Bank: 2017), https://publications.iadb.org/en/understanding-drivers-household-energy-spending-micro-evidence-latin-america

125 Westphal, Martin and Satterthwaite, op. cit. note 108.

126 Grubler et al., op. cit. note 123.

127 Ibid.

128 C40 Cities, "New solar project expected to provide power to critical public sectors across Lagos", 14 October 2015, https://www.c40.org/blog_posts/new-solar-project-expected-to-provide-power-to-critical-public-sectors-across-lagos.

129 Kyra Appleby, "Cities are harnessing the power of renewable energy: Here's how", CDP, 27 February 2018, https://www.cdp.net/en/articles/cities/cities-are-harnessing-the-power-of-renewable-energy.

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1 David Jacobs et al., *RE-TRANSITION: Transitioning to Policy Frameworks for Cost-competitive Renewables* (Paris: International Energy Agency Technology Collaboration Programme for Renewable Energy Technology Deployment (IEA-RETD), 2016), http://iea-retd.org/wp-content/uploads/2016/03/IEA-RETD_RE-TRANSITION.pdf.

2 Renewable Energy Policy Network for the 21st Century (REN21), *Renewables 2018 Global Status Report* (Paris: 2018), https://www.ren21.net/gsr-2019/; International Renewable Energy Agency (IRENA), *Renewable Energy in Cities* (Abu Dhabi: 2016), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf; Sierra Club, "100% commitments in cities, counties and states", https://www.sierraclub.org/ready-for-100/commitments, viewed 10 November 2019; Covenant of Mayors for Climate & Energy, "Plans and actions", https://www.covenantofmayors.eu/plans-and-actions/action-plans.html, viewed 10 November 2019.

3 Ibid., all references.

4 Ghislaine Kieffer and Toby Couture, *Renewable Energy Target Setting* (Abu Dhabi: IRENA, 2015), https://www.irena.org/documentdownloads/publications/irena_re_target_setting_2015.pdf.

5 Seattle City Light, "The nation's greenest utility", https://www.seattle.gov/light/greenest/cleanhydro.asp, viewed 13 November 2019; Ministry of Energy and Natural Resources, Government of Quebec, "Hydroelectric dams in Quebec", https://mern.gouv.qc.ca/en/energy/hydroelectricity/hydroelectric-dams-quebec/, viewed 13 November 2019.

6 Patricia McCarney et al., "Cities and climate change: The challenges for governance", in William D. Solecki, Stephen A. Hammer and Cynthia E. Rosenzweig, eds., *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network* (Cambridge, UK: Cambridge University Press, 2011), pp. 249-69, http://uccrn.org/files/2014/02/ARC3-Chapter-9.pdf.

7 United Nations Framework Convention on Climate Change, "Essential background – Durban outcomes", https://unfccc.int/process/conferences/the-big-picture/milestones/outcomes-of-the-durban-conference, viewed 15 October 2019; Urban Pathways; "Pilot city: Kigali", https://www.urban-pathways.org/kigali.html, viewed 12 November 2019; Asian Development Bank, *50 Climate Solutions from Cities in the People's Republic of China* (Beijing: 2018), https://www.adb.org/sites/default/files/publication/469536/50-climate-solutions-prc-cities.pdf.

8 Coalition for Urban Transitions, *Climate Emergency, Urban Opportunity: How National Governments Can Secure Economic Prosperity and Avert Climate Catastrophe by Transforming Cities* (Washington, DC: 2019), https://urbantransitions.global/wp-content/uploads/2019/09/Climate-Emergency-Urban-Opportunity-report.pdf.

9 Alexandra Aznar et al., *City-Level Energy Decision Making: Data Use in Energy Planning, Implementation, and Evaluation in U.S. Cities* (Golden, CO: National Renewable Energy Laboratory (NREL), 2015), https://www.nrel.gov/docs/fy15osti/64128.pdf.

10 Coalition for Urban Transitions, op. cit. note 8.

11 Ibid.

12 Organisation for Economic Co-operation and Development (OECD) and United Cities and Local Governments (UCLG), *Subnational Governments Around the World: Structure and Finance* (Paris: 2016), https://www.oecd.org/regional/regional-policy/Subnational-Governments-Around-the-World-%20Part-I.pdf; OECD and UCLG, 2019 Report of the World Observatory on Subnational Government Finance and Investment (Paris: 2019), https://www.oecd.org/about/secretary-general/launch-of-2019-report-on-world-observatory-paris-june-2019.htm.

13 Coalition for Urban Transitions, op. cit. note 8.

14 **Figure 7** from Ibid.

15 OECD/IEA, "Energy subsidies", https://www.iea.org/weo/energysubsidies/, viewed 27 March 2019.

16 Post-tax subsidies are the difference between the average end-use prices actually paid by consumers for the fuel and the amount that consumers would pay if prices reflected both the cost of supplying the fuel and the taxes necessary to reflect environmental costs (such as local air pollution, effects of climate change, congestion, etc.) and revenue requirements. The international debate typically focuses on the narrower pre-tax approach to estimating subsidies. Some of the methodologies and assumptions to estimate post-tax subsidies remain controversial and uncertain, but this allows for an estimation of the ultimate cost paid for fossil fuel consumption and its associated externalities. Fossil fuel subsidies estimate based on the following calculations: more than USD 302.4 billion in 2017, an increase from USD 270 billion in 2016, based on 41 countries, from OECD/IEA, op. cit. note 15; USD 295.9 billion, based on 115 countries, from International Monetary Fund (IMF), "How large are global energy subsidies? Country-level subsidy estimates", 3 October 2018, https://www.imf.org/~/media/Files/Topics/Environment/energy-subsidies/subsidies-database-2018.ashx; David Coady et al., *Global Fossil Fuel Subsidies Remain Large: An Update Based on Country Level Estimates* (Washington, DC: IMF, 2019), https://www.imf.org/en/Publications/WP/Issues/2019/05/02/Global-Fossil-Fuel-Subsidies-Remain-LargeAn-Update-Based-on-Country-Level-Estimates-46509.

17 Ibid., all sources.

18 OECD, *Global State of National Urban Policy* (Paris: 2018), http://www.oecd.org/regional/global-state-of-national-urban-policy-9789264290747-en.htm.

19 Ibid.

20 Ibid.

21 Ibid.

22 Coalition for Urban Transitions, op. cit. note 8.

23 UN-Habitat, *Sustainable Urbanization in the Paris Agreement* (Nairobi: 2017) https://urban-leds.org/wp-content/uploads/2019/resources/guidance_and_tools/Integrated_climate_action/Sustainable%20Urbanization%20in%20the%20Paris%20Agreement%20-%20Comparative%20Review%20of%20NDC%20-%20July%202018.pdf.

24 **Sidebar 2** based on the following sources: OECD, "Achieving the SDGs in cities and regions", http://www.oecd.org/about/impact/achievingthesdgsincitiesandregions.htm, viewed 16 August 2019; Sustainable Development Solutions Network (SDSN), *Getting Started with the SDGs in Cities: A Guide for Local Stakeholders* (New York: 2016), https://sdgcities.guide/; C40 Cities, "Towards the localization of SDGs: 10 recommendations to tackle the climate crisis and inequality in cities", 18 July 2019, https://www.c40.org/blog_posts/towards-the-localization-of-sdgs-10-recommendations-to-tackle-the-climate-crisis-and-inequality-in-cities; Michael Woodbridge, "Cities and the Sustainable Development Goals" (Bonn: ICLEI–Local Governments for Sustainability, undated), https://www.localizingthesdgs.org/library/232/ICLEI-Briefing-Sheets-02-Cities-and-the-Sustainable-Development-Goals.pdf; *New Climate Institute et al., Global Climate Action from Cities, Regions and Businesses* (Cologne and Berlin: 2019), pp. 7 and 47, https://newclimate.org/wp-content/uploads/2019/09/Report-Global-Climate-Action-from-Cities-Regions-and-Businesses_2019.pdf; SDG Tracker, "Measuring progress towards the Sustainable Development Goals", https://sdg-tracker.org/, viewed 24 September 2019; SDG Tracker, "Sustainable Development Goal 11: Make cities inclusive, safe, resilient and sustainable", https://sdg-tracker.org/cities, viewed 16 August 2019; SDG Tracker, "Sustainable Development Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all", https://sdg-tracker.org/energy, viewed 16 August 2019; United Nations Environment Programme (UNEP) and International Resource Panel, *The Weight of Cities: Resource Requirements of Future Urbanization* (Nairobi: 2018), https://www.resourcepanel.org/file/954/download?token=Z5MMHSMi; SDSN, *Mapping the Renewable Energy Sector to the Sustainable Development Goals: An Atlas* (New York: 2019), https://www.business-humanrights.org/sites/default/files/Renewables%20Atlas%20Final.pdf; Renewable Cities, "Renewable energy in cities: State of the movement", 10 January 2018, https://www.renewablecities.ca/articles/renewable-energy-in-cities-state-of-the-movement; 10,000 cities from Global Covenant of Mayors for Climate & Energy, *Implementing Climate Ambition: Global Covenant of Mayors 2018 Global Aggregation Report* (Brussels: 2018), https://www.globalcovenantofmayors.org/wp-content/uploads/2018/09/2018_GCOM_report_web.pdf; Global Covenant of Mayors for Climate & Energy, "About", https://www.globalcovenantofmayors.org/about/, viewed 16 May 2019; ICLEI, "Our network", https://iclei.org/en/our_network.html, viewed 6 May 2019; CDP, "Guidance for cities", https://www.cdp.net/en/guidance/guidance-for-cities, viewed 6 May 2019; C40 Cities, "Climate Action Planning Resource Centre", https://resourcecentre.c40.org/, viewed 3 October 2019; CDP, "2018 – City-wide emissions reduction targets", dataset,

https://data.cdp.net/Emissions/2018-City-wide-Emissions-Reduction-Targets/65hr-r9az, updated 6 June 2019; Albana Kona et al., "Covenant of Mayors signatories leading the way towards 1.5 degree global warming pathway", *Sustainable Cities and Society*, vol. 41 (August 2018), pp. 568-75, https://www.sciencedirect.com/science/article/pii/S2210670717314762; WWF, "One Planet City Challenge", http://wwf.panda.org/our_work/projects/one_planet_cities/one_planet_city_challenge/, viewed 3 October 2019; "'We Are Still In' Declaration", https://www.wearestillin.com/we-are-still-declaration, viewed 9 May 2019; US Conference of Mayors, "2017 Adopted Resolutions", http://legacy.usmayors.org/resolutions/85th_Conference/proposedcommittee.asp?committee=Energy, viewed 6 May 2019; ICLEI, "158 Japanese organizations adopt the Japan Climate Action Summit Declaration", 13 October 2018, https://iclei.org/en/media/158-japanese-organizations-adopt-the-japan-climate-action-summit-declaration; Local Renewables, "The Nagano Declaration", 8 September 2017, http://local-renewables-conference.org/fileadmin/repository/LR_Nagano/LR2017-Nagano-Declaration-JP-EN.pdf.

25 IRENA, op. cit. note 2; Kieffer and Couture, op. cit. note 4.

26 Ibid., both sources.

27 Ibid., both sources.

28 Stephen Abbott, "What good are city clean-energy targets?" Rocky Mountain Institute (RMI), 12 August 2019, https://rmi.org/what-good-are-city-clean-energy-targets/; IRENA, op. cit. note 2.

29 Kinesis, *City of Sydney Decentralised Energy Master Plan Trigeneration 2010-2030* (Sydney, Australia: City of Sydney, 2013), https://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0007/193057/Trigeneration-Master-Plan-Kinesis.pdf.

30 Ibid.

31 Simone Grassi, "Bristol to generate as much solar energy as an average nuclear power station", Bristol Is Open, 17 November 2015, https://www.bristolisopen.com/bristol-to-generate-as-much-solar-energy-as-an-average-nuclear-power-station-2/.

32 Kieffer and Couture, op. cit. note 4.

33 Ibid.

34 Ibid.

35 Ibid.

36 Tatjana Veith, Local Energy and Climate Roadmaps: 5 City Visions for 2050 (Brussels: Energy Cities, 2018), https://energy-cities.eu/wp-content/uploads/2019/02/local_energy_climate_roadmaps_final-1.pdf.

37 Ibid.

38 American Council for an Energy-Efficient Economy (ACEEE), *Local Government Energy Management Goals: Best Practices and Platforms* (Washington, DC: 2014), https://aceee.org/local-government-energy-management-goals-best-practices-and-platforms.

39 Global 100% Renewable Energy Platform with material provided by a variety of stakeholders, including CDP, Climate Action Network (CAN), C40 Cities, ICLEI, IRENA, The Sierra Club and Renewable Cities.

40 City of Sydney, "Getting ready to go 100% renewable", 17 October 2019, https://news.cityofsydney.nsw.gov.au/articles/getting-ready-to-go-100-renewable; Joshua S. Hill, "City of Sydney announces 100% renewable energy target", CleanTechnica, 2 April 2019, https://cleantechnica.com/2019/04/02/city-of-sydney-announces-100-renewable-energy-target/; City of Sydney, *Environmental Action 2016-2021: Strategy and Action Plan* (Sydney, Australia: March 2017), https://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0007/284749/Environmental-Action-strategy-and-action-plan.pdf.

41 Thousands of cities based on databases of the Global Covenant of Mayors for Climate & Energy, CDP and ICLEI.

42 Global Covenant of Mayors for Climate & Energy, *Implementing Climate Ambition*, op. cit. note 24.

43 Covenant of Mayors for Climate & Energy, "Plans and actions", https://www.covenantofmayors.eu/plans-and-actions/action-plans.html, viewed 10 November 2019.

44 CDP, "Cities Renewable Energy Targets", https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data, viewed 10 November 2019.

45 Carbonn Center, "Reporting entities", https://carbonn.org/entities, viewed 10 November 2019.

46 **Sidebar 3** based on the following sources: More than 240 cities from Global 100% Renewable Energy Platform, "100% Renewable energy is reality today", http://www.go100re.net/, viewed 6 May 2019. Germany from the following: Agentur für Erneuerbare Energien, "Energie-Kommunen", http://www.kommunal-erneuerbar.de/energie-kommunen/energie-kommunen/auflistung-aller-energie-kommunen.html, viewed 10 October 2019; Miriam Eisermann and Sylvie Lacassagne, *Cities Heading Towards 100% Renewable Energy by Controlling Their Consumption: Food for Thought and Action* (Brussels: Energy Cities, 2016), p. 8, http://www.energy-cities.eu/IMG/pdf/publi_100pourcent_final-web_en.pdf; REN21, op. cit. note 2; Go100%RE, "Munich, Germany", http://www.go100re.net/properties/munich/, viewed 26 June 2015. United States from the following: Christian Roselund, "The 100% renewable energy movement is unstoppable", pv magazine, 6 December 2018, https://pv-magazine-usa.com/2018/12/06/the-100-renewable-energy-movement-is-unstoppable/; 100% Renewable Energy Atlas, "Grand Rapids, Michigan", https://www.100-percent.org/grand-rapids-michigan-usa/, viewed 12 November 2019; Sam Schaust, "Minneapolis moves towards sustainability with 100 percent renewable electricity plan", Twin Cities Business, 18 April 2018, http://tcbmag.com/news/articles/2018/april/minneapolis-moves-towards-sustainability-with-100. Other cities from the following sources: Global 100% Renewable Energy Platform, with material provided by a variety of stakeholders, including CDP, CAN, C40 Cities, ICLEI, IRENA, The Sierra Club and Renewable Cities; Latin America from Elle Hunt, "More than 100 cities now mostly powered by renewable energy, data shows", *The Guardian* (UK), 27 February 2018, https://www.theguardian.com/cities/2018/feb/27/cities-powered-clean-energy-renewable, and from CDP, "Over 100 global cities get majority of electricity from renewables", 27 February 2018, https://www.cdp.net/en/articles/cities/over-100-global-cities-get-majority-of-electricity-from-renewables; Norbert Zösch, Stadtwerk Haßfurt, "EE-Ausbaustrategien in Haßfurt: Stadtwerk Haßfurt GmbH", presentation, 2012, https://www.duh.de/fileadmin/user_upload/download/Projektinformation/Kommunaler_Umweltschutz/Stadtwerke-Wettbewerb/Downloads/Vortr%C3%A4ge_WS-I_Schw%C3%A4bisch_Hall/WS-I_Vorreiter_Energiewende_Zoesch.pdf; Ted Sickinger, "Portland, Multnomah County set 100% renewable energy goal", OregonLive, 2 June 2017, https://www.oregonlive.com/portland/2017/06/portland_multnomah_county_set.html; Nicholas Caleb, "The Portland Model for Climate and Energy Action", Center for Sustainable Economy, 8 November 2018, https://sustainable-economy.org/the-portland-model-for-climate-and-energy-action/. Estimates of 50 cities and 110 cities from Global 100% RE Platform, op. cit. this note. More than 70 cities from Global 100% RE Platform, op. cit. this note; additional examples from Reference Tables for this report, and from the following: Bex Bastable, "Brighton and Hove Buses wins millions in funding for eco-friendly vehicles – in Crawley", *Brighton & Hove Independent*, 6 February 2019, https://www.brightonandhoveindependent.co.uk/news/traffic-and-travel/brighton-and-hove-buses-wins-millions-in-funding-for-eco-friendly-vehicles-in-crawley-1-8799206; 100% Renewable Energy Atlas, "Oslo, Norway", https://www.100-percent.org/oslo-norway/, viewed 20 October 2019; Meister Consultants Group, *Pennsylvania Electric Vehicle Roadmap*, prepared for the Pennsylvania Department of Environmental Protection (Harrisburg, PA: February 2019), http://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf; Leak Willingham, "Concord passes resolution to work toward 100 percent renewable energy", *Concord Monitor*, 10 July 2018, https://www.concordmonitor.com/Concord-city-council-passes-goal-of-100-percent-renewable-energy-18738362; Kirk Caldwell and Dawn Lippert, "Hawaii's mayors just committed to 100% renewable transportation by 2045", *Fast Company*, 21 December 2017, https://www.fastcompany.com/40511006/why-hawaicabbis-mayors-just-committed-to-100-renewable-transportation-by-2045; Go 100% Renewable Energy, "Region of Ulm/Neu-Ulm", http://www.go100percent.org/cms/index.php?id=70&tx_ttnews[tt_news]=71, viewed 15 October 2019; Ann Dale, "Växjö, Sweden: The Greenest City in Europe" (Växjö, Sweden: Community Research Connections, 7 March 2011), https://www.crcresearch.org/community-research-connections/climate-change-adaptation-and-mitigation/v%C3%A4xj%C3%B6-sweden-greenest-city-e. **Figure 9** compiled by the Global 100% Renewable Energy Platform with material provided by a variety of stakeholders, including CDP, CAN, C40 Cities, ICLEI, IRENA, The Sierra Club and Renewable Cities.

47 Jenny Heeter, Bethany Speer and Mark B. Glick, *International Best Practices for Implementing and Designing Renewable Portfolio Standard (RPS) Policies* (Golden, CO: NREL, April 2019), https://www.nrel.gov/docs/fy19osti/72798.pdf.

48 IEA/IRENA Joint Policies and Measures database, "China 13th Renewable Energy Development Five Year Plan (2016-2020)", June 2018, https://www.iea.org/policiesandmeasures/pams/china/name-161254-en.php; Beijing Development and Reform Commission, "Beijing Municipality 13 Five Year Plan RE Targets", 6 September 2016, http://www.beijing.gov.cn/zfxxgk/110002/zzqgh33/2016-10/21/content_742180.shtml; Shenzhen Development and Reform Commission, "Shenzhen 13th Five-Year-Plan Power Development", 1 August 2017, http://www.sz.gov.cn/szfgw/xxgk/ghjh/zxgh/201612/t20161227_5773598.htm; China National Energy Administration, "Opinions on the Notice on the Implementation of the Renewable Energy Electricity Quota System", 15 November 2018, http://www.nea.gov.cn/2018-11/15/c_137607356.htm; International Solar PV Network, "Tianjin City 13 Five Year Plan Renewable Energy Targets", 21 December 2016, http://solar.in-en.com/html/solar-2282220.shtml; REN21, *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf.

49 REN21, op. cit. note 2; Opendatasoft, "Renewable targets by cities", https://data.opendatasoft.com/explore/dataset/world-city-level-examples-renewable-targets-2015-2050%40kapsarc/table/?disjunctive.country&disjunctive.city&disjunctive.indicator&sort=capacity_mw, viewed 14 October 2019; Kang Seung-woo, "Seoul to generate 1GW of energy from solar by 2022", *Korea Times*, 27 November 2018, https://www.koreatimes.co.kr/www/nation/2018/11/281_259295.html.

50 Global 100% Renewable Energy Platform, op. cit. note 46; data compiled by Global 100% Renewable Energy Platform with material provided by a variety of stakeholders, including CDP, CAN, C40, ICLEI, IRENA, The Sierra Club and Renewable Cities.

51 Carbonn Center, www.carbonn.org, viewed 13 November 2019.

52 Beijing Development and Reform Commission, op. cit. note 48; REN21, op. cit. note 48.

53 European Bioenergy Day, "Helsinki transport goes renewable by 2020", http://www.europeanbioenergyday.eu/helsinki-transport-goes-renewable-by-2020/, viewed 7 November 2019; Janne Suokas, "Wood-based solutions for sustainable transport", UPM Biofore, 10 August 2019, https://www.upm.com/news-and-stories/articles/2019/08/wood-based-solutions-for-sustainable-transport/.

54 Bex Bastable, "Brighton and Hove Buses wins millions in funding for eco-friendly vehicles – in Crawley", Brighton & Hove Independent, 6 February 2019, https://www.brightonandhoveindependent.co.uk/news/traffic-and-travel/brighton-and-hove-buses-wins-millions-in-funding-for-eco-friendly-vehicles-in-crawley-1-8799206; **Oslo** from; Meister Consultants Group, *Pennsylvania Electric Vehicle Roadmap* (Harrisburg, PA: Penssylvania Department of Environmental Protection, 2019), http://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf.

55 **Figure 9** from sources in Reference Table R6.

56 Auckland Council, "Low Carbon Strategic Action Plan: The Way We Travel", https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/docslowcarbonaim/low-carbon-strategic-action-plan-travel.pdf, viewed 23 October 2019.

57 Veith, op. cit. note 36.

58 C40 Cities, "Green and Healthy Streets: Fossil-Fuel-Free Streets Declaration" (London: 2017), https://www.c40.org/other/green-and-healthy-streets.

59 Matthew Keegan, "Shenzhen's silent revolution: World's first fully electric bus fleet quietens Chinese megacity", **The Guardian** (UK), 12 December 2018, https://www.theguardian.com/cities/2018/dec/12/silence-shenzhen-world-first-electric-bus-fleet; Wuhan City Government, "Wuhan City 13th Five-Year-Plan Power Development", *Huanbao Magazine*, 13 November 2017, http://huanbao.bjx.com.cn/news/20171113/861215.shtml.

60 Partnership on Sustainable Low Carbon Transport (SLoCaT), *E-Mobility Trends and Targets* (Shanghai: July 2019), http://slocat.net/sites/default/files/e-mobility_overview.pdf.

61 **Table 1** based on following sources: data for "more than 10,000 cities" are gathered by CDP (also reported by C40 Cities), the Global Covenant of Mayors for Climate & Energy and ICLEI; CDP, "2017 – Cities emissions reduction targets, map", https://data.cdp.net/Emissions/2017-Cities-Emissions-Reduction-Targets-Map/j5zb-bfpp, viewed 30 September 2019; Global Covenant of Mayors for Climate & Energy, "The impact cities can make on climate", https://www.globalcovenantofmayors.org/impact2018/, viewed 30 September 2019; ICLEI, "The carbonn Center", https://iclei.org/en/cCR.html, viewed 30 September 2019.

62 ACEEE, op. cit. note 38.

63 STEP UP, "Riga publishes 'Riga Smart City Sustainable Energy Action Plan for 2014-2020'", 6 August 2014, https://www.stepupsmartcities.eu/ViewNews/tabid/3242/articleType/ArticleView/articleId/4018/Riga-publishes-Riga-Smart-City-Sustainable-Energy-Action-Plan-for-2014-2020.aspx.

64 CDP, op. cit. note 61.

65 Victor Olgyay, "Designing a climate-positive future with zero-energy districts", RMI, 23 September 2019, https://rmi.org/designing-a-climate-positive-future-with-zero-energy-districts/; C40 Cities, "The Net Zero Carbon Buildings Declaration", https://www.c40.org/other/net-zero-carbon-buildings-declaration, viewed 2 October 2019; World Green Building Council, "What is net zero?" https://www.worldgbc.org/advancing-net-zero/what-net-zero, viewed 18 June 2019; The Energy Mix, "19 cities, combined population 130 million, pledge net-zero carbon buildings by 2030", 26 August 2018, https://theenergymix.com/2018/08/26/19-cities-combined-population-130-million-pledge-net-zero-carbon-buildings-by-2030/; World Green Building Council (WGBC), "Commitment Signatories", https://www.worldgbc.org/commitment-signatories?cat=all, viewed 18 June 2019; WGBC, "The Net Zero Carbon Buildings Commitment", https://www.worldgbc.org/thecommitment, viewed 18 June 2019; Ana Maria Lebada, "Leaders launch initiative to decarbonize buildings by 2050", International Institute for Sustainable Development (IISD) SDG Knowledge Hub, 1 October 2019, http://sdg.iisd.org/news/leaders-launch-initiative-to-decarbonize-buildings-by-2050/; Better Buildings Initiative, "Zero energy districts", https://betterbuildingsinitiative.energy.gov/accelerators/zero-energy-district, viewed 24 June 2019; Victor Olgyay and Iain Campbell, "An integrative business model for net-zero energy districts", in Peter Droege, ed., *Urban Energy Transition: Renewable Strategies for Cities and Regions* (Amsterdam, The Netherlands: Elsevier, 2018), pp. 445-56, https://www.elsevier.com/books/urban-energy-transition/droege/978-0-08-102074-6; Molly Miller, "New zero-energy districts: A mile high and growing", GreenBiz, 4 January 2017, https://www.greenbiz.com/article/new-zero-energy-districts-mile-high-and-growing; Matt Jungclaus, "Driving industrial revitalisation with net-zero energy", RMI, 16 April 2018, https://rmi.org/driving-industrial-revitalization-with-net-zero-energy/; Seth Coan, "Designing the city of the future and the pursuit of happiness", RMI, 16 September 2019, https://rmi.org/designing-the-city-of-the-future-and-the-pursuit-of-happiness/.

66 Energy & Climate Intelligence Unit, "Net zero: The scorecard", https://eciu.net/briefings/net-zero/net-zero-the-scorecard, viewed 25 October 2019.

67 Elena Kosolapova, "77 countries, 100+ cities commit to net zero carbon emissions by 2050 at Climate Summit", IISD SDG Knowledge Hub, 24 September 2019, https://sdg.iisd.org/news/77-countries-100-cities-commit-to-net-zero-carbon-emissions-by-2050-at-climate-summit/.

68 Carbon Neutral Adelaide, https://www.carbonneutraladelaide.com.au/about, viewed 21 November 2019; Siemens, *Copenhagen's Big Incentive* (Munich, Germany: October 2015), https://assets.new.siemens.com/siemens/assets/public.1541966559.148321fc2ebebca2aad295c247932ce220e076e1.summary-copenhagen-cypt-report-oct-2015.pdf.

69 Zero Emissions Byron, "About", https://zerobyron.org/about/, viewed 1 February 2019; City of Boston, "Reducing emissions", 8 October 2019, https://www.boston.gov/departments/environment/carbon-free-boston; Heidelberg City, "Ziel: Klimaneutrale Kommune", https://www.heidelberg.de/hd/HD/Leben/Ziel_+Klimaneutrale+Kommune.html, viewed 13 November 2019; "Foundations, C40 Cities to help Montreal deliver on 2050 carbon neutral target", The Energy Mix, 14 December 2018, https://theenergymix.com/2018/12/14/foundations-c40-cities-to-help-montreal-deliver-on-2050-carbon-neutral-target/; European Commission (EC), "Oslo starts its year as European Green Capital 2019", press release (Brussels: 4 January 2019), https://ec.europa.eu/info/news/

oslo-starts-its-year-european-green-capital-2019-2019-jan-04_en.

70 Robin Whitlock, "ENGIE partners with Greater Springfield, Australia, to develop zero net energy city of the future", Renewable Energy Magazine, 6 December 2018, https://www.renewableenergymagazine.com/panorama/engie-partners-with-greater-springfield-australia-to-20181206.

71 Ibid.

72 Veith, op. cit. note 36, p. 30.

73 Ibid.

74 CDP, op. cit. note 61.

75 City of Cape Town and C40, *Strategic Climate Action Planning Appraisal Report* (Cape Town, South Africa: November 2018); City of Cape Town, "Cape Town Energy 2040" (Cape Town, South Africa: 2015), https://savingelectricity.org.za/wp-content/uploads/2018/01/2040_energy_vision_cct_brochure.pdf.

76 C40 Cities, "35 cities unite to clean the air their citizens breathe, protecting the health of millions", press release (Copenhagen: 11 October 2019), https://www.c40.org/press_releases/35-cities-unite-to-clean-the-air-their-citizens-breathe-protecting-the-health-of-millions.

77 Ibid.

78 IQ Air, AirVisual, "World most polluted cities 2018 ($PM_{2.5}$)", https://www.airvisual.com/world-most-polluted-cities, viewed 21 November 2019. **Figure 11** from sources in Reference Table R7.

79 Based on information and sources provided throughout this section.

80 **Sidebar 4** based on the following sources: Peter Droege, *The Renewable City: The Future of Low-carbon Living* (Sydney, Australia: Cooperative Research Centre for Low Carbon Living, 2018), http://www.lowcarbonlivingcrc.com.au/sites/all/files/droege_renewable_city_30102018_1.pdf; GO 200%, "Burlington, VT – 100% renewable public power", http://www.go100percent.org/cms/index.php?id=77&tx_ttnews%5Btt_news%5D=257&cHash=70c73ba3cc8f2fb3d258c736a9ee7ff6, viewed 18 November 2018; Burlington Electric Department: "Charge your EV at home and save", https://www.burlingtonelectric.com/evrate, viewed 18 November 2018; Burlington Electric Department, "Burlington Electric Department tariff sheet: Residential electric vehicle rate", https://www.burlingtonelectric.com/sites/default/files/inline-files/Residential%20EV%20Rate%20Tariff.pdf, viewed 18 November 2018; Burlington Electric Department, "Electric vehicles", https://www.burlingtonelectric.com/ev, viewed 13 November 2019; Burlington City Council, "Resolution relating to obtaining Public Utility Commission rulings and approving continued development of district energy system" (Burlington, VT: 26 April 2018), https://www.boarddocs.com/vt/burlingtonvt/Board.nsf/files/AY7QC6601275/%24file/BED%20-%20District%20Energy%20System%20-%20Obtaining%20Public%20Utility%20Commission%20Rulings%20%26%20Approving%20Continued%20Development.pdf; Kelsey Neubauer, "Burlington moves ahead with plan to use heat from power plant", VT Digger, 2 May 2018, https://vtdigger.org/2018/05/02/burlington-moves-ahead-plan-use-heat-power-plant/; Sustainable Energy Africa, *Green Power Purchase Agreements* (PPA) (Cape Town, South Africa: 2016), http://www.sustainable.org.za/userfiles/final%20gov%20green%20PPA.pdf; IRENA and ICLEI, *Mitigating Climate Change Through Renewable Energy Development: Cape Town*, South Africa (Abu Dhabi: 2018), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Dec/IRENA_Cities_2018b_Cape-Town.pdf?la=en&hash=DA85B0E4CCB76529FC4DBC6F0409822F38956477; Sustainable Energy Africa, City of Cape Town Electric Vehicle Tariff (Briefing Note) (Cape Town, South Africa: July 2018), http://www.cityenergy.org.za/uploads/resource_471.pdf; NEW 4.0: "Die Modellregion", https://www.new4-0.de/die-modellregion/, viewed 14 October 2019; Gunhild Nasner, "First power-to-heat plant in Hamburg to convert wind energy into heat", press release (Stockholm: Vattenfall, 15 February 2019), https://group.vattenfall.com/press-and-media/news--press-releases/newsroom/2019/first-power-to-heat-plant-in-hamburg-to-convert-wind-energy-into-heat; NEW 4.0: "Norddeutsches Reallabor will Sektorkopplung voranbringen", press release (Hamburg: 18 July 2019), https://www.new4-0.de/wp-content/uploads/2019/07/PM_Norddeutsches-Reallabor_20190718.pdf; NEW 4.0, "Energiewende: Entdecke das Energiesystem der Zukunft!" July 2019, https://www.new4-0.de/energiewende/; Seoul Metropolitan Government, "Seoul launches 'Seoul Energy Corporation'", 3 March 2017, http://english.seoul.go.kr/seoul-launches-seoul-energy-corporation/; Walter Foreman, "A most ambitious energy transition", Siemens, 14 February 2018, https://new.siemens.com/global/en/company/stories/infrastructure/seoul-shift-toward-energy-sustainability.html; "KIREC SEOUL 2019: The 8th International Energy Conference", http://www.kirec2019.kr/sub01/about.html, viewed 13 November 2019; City of Sydney, "Getting ready to go 100% renewable", https://news.cityofsydney.nsw.gov.au/articles/getting-ready-to-go-100-renewable, updated 17 October 2019; Edify Energy, "Australia's largest integrated battery with a solar farm ready for summer", press release (Sydney, Australia: 16 November 2018), http://edifyenergy.com/australias-largest-integrated-battery-with-a-solar-farm-ready-for-summer/; Uppsala Kommun, *Energy Programme 2050* (Uppsala, Sweden: 2018), https://www.uppsala.se/contentassets/8c70693a41a74dd1a7ca4662f63fcd82/energy-programme-2050; Uppsala Kommun, "Uppsala – award winning climate city", https://www.uppsala.se/climatecity, updated 12 September 2018; Internationales Verkehrwensen, "New gasification technique: Turn forestry waste into bioenergy", 21 January 2019, https://www.internationales-verkehrswesen.de/new-gasification-technique/;.

81 Jacobs et al., op. cit. note 1.

82 The New Climate Economy, "Cities", in *Unlocking the Inclusive Growth Story of the 21st Century: Accelerating Climate Action in Urgent Times* (Washington, DC: World Resources Institute, 2018), https://newclimateeconomy.report/2018/cities/; Droege, ed., op. cit. note 65.

83 The New Climate Economy, op. cit. note 82.

84 Furman Center for Real Estate and Urban Policy, "New York City's multi-family rental housing and the market downturn", in *State of New York City's Housing & Neighborhoods 2010* (New York: 2010), https://furmancenter.org/files/sotc/Multifamily_Rental_Housing_2010.pdf; Statistics Canada, "Census in Brief: Dwellings in Canada", 3 May 2017, https://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016005/98-200-x2016005-eng.cfm.

85 Meister Consultants Group, *Pathways to 100: An Energy Supply Transformation Primer for U.S. Cities* (Boston: 2017), https://www.sierraclub.org/sites/www.sierraclub.org/files/sce/southeastern-pennsylvania-group/Paula/MCG-Pathways-to-100-Energy-Supply-Transformation-Primer-for-Cities%281%29.pdf.

86 **Table 3** based on American Public Power Association, "Benefits of public power", in *Public Power for Your Community* (Arlington, VA: 2016), https://www.publicpower.org/system/files/documents/municipalization-benefits_of_public_power.pdf.

87 Ibid.

88 Apolitical, "Japan's municipalities set up their own clean, local energy companies", 11 April 2017, https://apolitical.co/solution_article/japans-municipalities-set-clean-local-energy-companies/; Olongapo Electricity Distribution Corporation, Inc., http://www.oedc.com.ph/, viewed 18 November 2019; Association of Municipal Electricity Utilities, "About", http://www.ameu.co.za/, viewed 14 November 2019; Vivien Foster et al., *Charting the Diffusion of Power Sector Reforms Across the Developing World* (Washington, DC: World Bank, 2017), https://openknowledge.worldbank.org/bitstream/handle/10986/28853/WPS8235.pdf.

89 Power Africa, *Development of Kenya's Power Sector 2015-2020* (Nairobi: 2016) https://www.usaid.gov/sites/default/files/documents/1860/Kenya_Power_Sector_report.pdf; Export.gov, "Tunisia Electrical Power Systems and Renewable Energy", 14 July 2019, https://www.export.gov/article?id=Tunisia-Electrical-Power-Systems-and-Renewable-Energy.

90 US Department of Energy (DOE), Transforming the Nation's Electricity System: The Second Installment of the QER (Washington, DC: 2017), https://www.energy.gov/sites/prod/files/2017/02/f34/Appendix--Electricity%20System%20Overview.pdf.

91 European Federation of Local Energy Companies (CEDEC), "About us", http://www.cedec.com/en/about-us, viewed 2 November 2019.

92 Robin Hood Energy, "About", https://robinhoodenergy.co.uk/.

93 Energia Barcelona, "Barcelona Energia", http://energia.barcelona/en/, viewed 21 October 2019.

94 Lori Valigra, "Maine's case for a public utility", *Bangor Daily News*, 22 May 2019, https://bangordailynews.com/2019/05/22/business/maines-case-for-a-public-utility/; Catherine Morehouse, "Chicago introduces order to study municipalizing ComEd",

Smart Cities Dive, 24 July 2019, https://www.smartcitiesdive.com/news/chicago-introduces-order-to-study-municipalizing-comed/559523/; Alexander Sammon, "San Francisco makes a charge toward public power", The American Prospect, 10 September 2019, https://prospect.org/environment/san-francisco-makes-charge-toward-public-power/.

95 Steve Dubb, "In Europe, nonprofit and local public utilities are seen as key to green future", Nonprofit Quarterly, 9 May 2018, https://nonprofitquarterly.org/europe-nonprofit-local-public-utilities-seen-key-green-future/.

96 Utility Connection, "251 Publicly Owned Electric & Gas Utilities (US)", http://www.utilityconnection.com/page2e.asp#muni_util, viewed 1 October 2019.

97 Richard F. Hirsh, Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System (Cambridge, MA: MIT Press, 2002), https://mitpress.mit.edu/books/power-loss.

98 **Box 2** based on the following sources: Bekezela Phakathi , "Cape Town pushing to buy energy directly from IPPs", Business Day, 26 February 2019, https://www.businesslive.co.za/bd/national/2019-02-26-cape-town-pushing-to-buy-energy-directly-from-ipps/; Congressional Budget Office, *Causes and Lessons of the California Electricity Crisis* (Washington, DC: 2001), https://www.cbo.gov/sites/default/files/107th-congress-2001-2002/reports/californiaenergy.pdf; Thomas Mlynarski, "Electricity deregulation: California and Australia", Journal of Undergraduate Research, vol. 5, no. 1 (2015), https://journals.uic.edu/ojs/index.php/JUR/article/viewFile/7543/6036; Vivien Foster and Rana Anshul, *Rethinking Power Sector Reform in the Developing World* (Washington, DC: World Bank, 2019), https://openknowledge.worldbank.org/handle/10986/32335.

99 Richard Farmer and Gail Cohen, *Causes and Lessons of the California Electricity Crisis* (Washington, DC: Congressional Budget Office, 2001), https://www.cbo.gov/sites/default/files/107th-congress-2001-2002/reports/californiaenergy.pdf; Mlynarski, op. cit. note 98. Edward A. Holt and Jeffrey M. Fang, *The New Hampshire Retail Competition Pilot Program and the Role of Green Marketing* (Golden, CO: NREL,1997), https://www.nrel.gov/docs/legosti/old/23446.pdf.

100 Foster et al., op. cit. note 88.

101 World Business Council for Sustainable Development, *Innovation in Power Purchase Agreements* (Geneva: 2018), https://www.wbcsd.org/contentwbc/download/4468/60118; Foster and Anshul, op. cit. note 98.

102 Nitin Kabeer, "SDMC earns ₹0.96 million selling surplus rooftop solar power", Mercom India, 28 May 2018, https://mercomindia.com/sdmc-selling-rooftop-solar-power/; Saumy Prateek, "South Delhi corporation to develop 27.5MW of solar projects across two sites", Mercom India, 26 December 2018, https://mercomindia.com/sdmc-27-5-mw-solar-projects-two-sites/.

103 "Delhi: South corporation to focus on solar panels, e-charging points", *Times of India*, 15 April 2019, https://timesofindia.indiatimes.com/city/delhi/s-corpn-to-focus-on-solar-panels-e-charging-points/articleshow/68896938.cms.

104 Anjana Parikh, "Delhi Police goes green: Sign pact with SECI for 3-4 MW of rooftop solar installations", Mercom India, 5 July 2019, https://mercomindia.com/delhi-police-rooftop-solar/.

105 Nitin Kabeer, "Greater Chennai Corporation's 662 buildings to get solar panels under smart city program", Mercom India, 29 November 2018, https://mercomindia.com/greater-chennai-corporation-solar-smart-city/.

106 Anjana Parikh, "Karnataka's Tumakuru Smart City floats tender for 1.86 MW of rooftop solar projects", Mercom India, 16 October 2019, https://mercomindia.com/tumakuru-smart-city-floats-tender-rooftop-solar/.

107 Dubai Electricity and Water Authority, "DEWA signs MoU with Dubai Future Foundation to produce renewable energy at Museum of the Future", press release (Dubai, UAE: 9 March 2019), https://www.dewa.gov.ae/en/about-us/media-publications/latest-news/2019/03/dewa-signs-mou-with-dubai-future-foundation-to-produce-renewable-energy-at-museum-of-the-future.

108 Pavlos Trichakis et al., *Enabling the UAE's Energy Transition: Top Ten Priority Areas for Renewable Energy Policymakers* (Abu Dhabi: UAE Ministry of Energy and Industry and Emirates Wildlife Society in association with WWF, 2018), https://www.emiratesnaturewwf.ae/sites/default/files/doc-2018-09/Enabling%20the%20UAE%E2%80%99s%20energy%20transition_%20F4_EWSWWF_WEB.pdf.

109 Tatira Zwinoira, "HCC eyes 25% in renewable energy by 2025", Newsday, 7 June 2017, https://www.newsday.co.zw/2017/06/hcc-eyes-25-renewable-energy-2025/.

110 City of Cincinnati, "New deal brings 100% green energy to most city facilities", 4 December 2017, https://www.cincinnati-oh.gov/oes/news/new-deal-brings-100-green-energy-to-most-city-facilities/; Jessica Leung and Amy Bailey, *How Cities Benefit from Power Purchase Agreements* (Arlington, VA: C2ES, September 2018), https://www.c2es.org/site/assets/uploads/2018/09/how-cities-benefit-from-ppas.pdf.

111 Leung and Bailey, op. cit. note 110.

112 Evan Pappas, "City signs up for all-wind power", *Snoqualmie Valley Record*, 1 May 2017, http://www.valleyrecord.com/news/city-signs-up-for-all-wind-power/.

113 City of Melbourne, "Melbourne Renewable Energy Project: A new generation of energy", https://www.melbourne.vic.gov.au/business/sustainable-business/mrep/Pages/melbourne-renewable-energy-project.aspx, viewed 16 May 2019.

114 Moreland City Council, "Melbourne Renewable Energy Project – MREP", https://www.moreland.vic.gov.au/about-us/projects/environmental-projects/melbourne-renewable-energy-project---mrep/, viewed 15 October 2019.

115 Beyond Zero Emissions, ICLEI Oceania and Ironbark Sustainability, *Australian Local Government Climate Review 2018* (Melbourne: 2018), http://media.bze.org.au/ZCC/Australian%20Local%20Government%20Climate%20Review%20FINAL.pdf.

116 Green Cape, *Utility-scale Renewable Energy: 2019 Market Intelligence Report* (Cape Town, South Africa: 2019) https://www.investcapetown.com/wp-content/uploads/2019/04/GreenCape_Market-Intelligence-Report_-Renewable-Energy-2019-1.pdf.

117 "Cape Town to petition to allow electricity purchases from IPPs", IOL News, 26 February 2019, https://www.iol.co.za/news/politics/cape-town-to-petition-to-allow-electricity-purchases-from-ipps-19519550; Tom Head, "Then VS Now: How much Eskom's electricity prices have increased since 1970", *The South African*, 1 April 2019, https://www.thesouthafrican.com/news/eskom-electricity-prices-for-april-from-1970/.

118 Solar Energy Industries Association, *Principles for the Evolution of Net Energy Metering and Rate Design* (Washington, DC: May 2017), https://www.seia.org/sites/default/files/NEM%20Future%20Principles_Final_6-7-17.pdf; Toby Couture et al., *The New Generation of Renewable Electricity Policy: How Rapid Change Is Breaking Down Conventional Policy Categories* (Golden, CO: NREL, February 2015), https://www.nrel.gov/docs/fy15osti/63149.pdf.

119 Wolf von Fabeck, "Historisches zur kostendeckenden Vergütung bis zu ihrer Aufnahme in das EEG vom 1. Aug. 2004 mit Folien zum Aachener Modell", Solarenergie Förderverein Deutschland, updated July 2014, http://www.sfv.de/lokal/mails/wvf/kostendeckende_Verguetung_bis_hin_zum_EEG_2004.htm.

120 Ibid.

121 Alvaro Queiroz, Fazil T. Najafi and Pegeen Hanrahan, "Case study: Implementation and results of solar feed-in tariff in Gainesville, Florida", *Journal of Energy Engineering*, vol. 143, no. 1 (February 2017), https://ascelibrary.org/doi/10.1061/%28ASCE%29EY.1943-7897.0000373; A. Miller, "Fort Collins solar feed-in-tariff planned", Clean Energy Authority, 14 January 2011, https://www.cleanenergyauthority.com/solar-energy-news/fort-collins-solar-feed-in-tarriff-planned-011411; Christian Roselund, "Los Angeles still has a feed-in tariff. And it's growing.", pv magazine, 27 September 2019, https://pv-magazine-usa.com/2019/09/27/los-angeles-still-has-a-feed-in-tariff-and-its-growing/.

122 Los Angeles Department of Water and Power (LADWP), "Feed-in tariff (FIT) program", https://www.ladwp.com/ladwp/faces/ladwp/commercial/c-gogreen/c-gg-localrenewableenergyprogram; LADWP, "Solar programs", https://www.ladwp.com/ladwp/faces/ladwp/residential/r-gogreen/r-gg-ressolar, viewed 15 November 2019.

123 LADWP, "Renewable energy program", https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-renewableenergy/a-p-re-renewableenergypolicy, viewed 15 November 2019.

124 REN21, op. cit. note 2.

125 South African Local Government Association, *Status of Small Scale Embedded Generation (SSEG) in South African Municipalities* (Pretoria, South Africa: October 2017), https://

www.salga.org.za/SALGA%20Energy%20Summit%202018/Energy%20Summit%20Web/Document/Status%20of%20Small%20Scale%20Embedded%20Generation.pdf; City of Cape Town, Solar PV Info Sheet #1: SSEG Tariff (Cape Town, South Africa: July 2018), https://www.westerncape.gov.za/energy-security-game-changer/files/atoms/files/PV%20info%20sheet%20on%20tariffs_final.pdf; Ethekwini Municipality, "19/20 Tariff Booklet (Ethekwini electricity unit)" (Ethekwini, South Africa: July 2019), http://www.durban.gov.za/City_Services/electricity/Tariffs/Current%20Tariffs/Tarrif%20Booklet%202019-20.pdf; City Power, "Schedule of Approved Electricity Tariffs for FY 2019/20" (Johannesburg, South Africa: 2019), https://www.citypower.co.za/Reports%20and%20Documents/Schedule%20of%20Approved%20Tariffs%201920.pdf.

126 AREP Energy, *South Africa Solar PV Update 2019* (Cape Town, South Africa: January 2019), https://arepenergy.co.za/south-africa-solar-pv-update-2019/.

127 Norton Rose Fulbright, "Jordan turbocharges distributed solar", 18 October 2016, https://www.projectfinance.law/publications/2016/October/jordan-turbocharges-distributed-solar; Lexology, "Approval of wheeling regulations for Pakistan", June 2016, https://www.lexology.com/library/detail.aspx?g=e28ab9d7-7b99-4d82-87f7-dee1321cde40; California Public Utilities Commission, "Virtual net metering", https://www.cpuc.ca.gov/General.aspx?id=5408, viewed 24 November 2019.

128 Solar Roof Top India, "Delhi Solar Rooftop Portal", https://solarrooftop.gov.in/delhi/learn-more, viewed 13 November 2019; Vikram Solar, "Delhi's new virtual net metering policy: A guideline for rooftop solar India should adopt nationally", 21 February 2019, https://www.vikramsolar.com/delhis-new-virtual-net-metering-policy-a-guideline-for-rooftop-solar-india-should-adopt-nationally/.

129 Roland Devenyi and Irina Mladenova, *International Markets for Renewables Energy Certificates* (RECs) (Cambridge, MA: Sustainability Roundtable Inc., 2012), http://sustainround.com/library/sites/default/files/SRER_Member%20Briefing_International%20Markets%20for%20Renewable%20Energy%20Certificates_2012-07-16.pdf.

130 US Environmental Protection Agency, "Renewable Energy Certificates (RECs)", https://www.epa.gov/greenpower/renewable-energy-certificates-recs, updated 13 May 2019.

131 Meister Consultants Group, op. cit. note 85.

132 Burlington Energy Department, "Our energy portfolio", https://www.burlingtonelectric.com/our-energy-portfolio, viewed 11 May 2019.

133 IRENA, *City in Focus: Austin, US – Stimulating Renewable Energy Through Public and Private Procurement* (Abu Dhabi: 2013), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/Jan/IRENA-cities-case-4-Austin.pdf.

134 Jon Pierre, "Multilevel governance as a strategy to build capacity in cities: Evidence from Sweden", *Journal of Urban Affairs*, vol. 41, no. 1 (2019), pp. 103-116, https://www.tandfonline.com/doi/full/10.1080/07352166.2017.1310532; Håvard Haarstad, "Where are urban energy transitions governed? Conceptualizing the complex governance arrangements for low-carbon mobility in Europe", *Cities*, vol. 54 (May 2016), pp. 4-10, https://www.sciencedirect.com/science/article/pii/S0264275115001663.

135 National Conference of State Legislatures (NCSL), "Community choice aggregation policies", 1 December 2015, http://www.ncsl.org/research/energy/community-choice-aggregation.aspx.

136 Mass Power Choice, "Cambridge Community Electricity Program", http://masspowerchoice.com/cambridge, viewed 19 November 2019.

137 Ibid.

138 Lean Energy US, "CCA by state", https://leanenergyus.org/cca-by-state/, viewed September 2019.

139 NCSL, op. cit. note 135.

140 Vlada Bdbih, "R Srpska snabdijevajući Brčko Distrikt električnom energijom donirala Brčkom preko 30 miliona KM", Brcanski Forum, 1 February 2019, http://brcanskiforum.com/index.php/politika/2473-r-srpska-snabdijevajuci-brcko-distrikt-elektricnom-energijom-donirala-brckom-preko-30-miliona-km.

141 David Ribiero, "US cities adopt stricter building energy codes", ACEEE, 9 September 2019, http://www.aceee.org/blog/2019/09/us-cities-adopt-stricter-building.

142 Meredydd Evans and al., *Building Energy Code Compliance in Developing Countries: The Potential Role of Outcomes-based Codes in India* (Denver, CO: ACEEE Summer Study on Energy Efficiency in Buildings, 2014), https://aceee.org/files/proceedings/2014/data/papers/8-283.pdf.

143 Madeleine Cuff, "San Francisco adopts law requiring solar panels on all new buildings", *The Guardian* (UK), 21 April 2016, https://www.theguardian.com/environment/2016/apr/21/san-francisco-adopts-law-requiring-solar-panels-on-all-new-buildings; Christian Roselund, "Santa Monica mandates solar PV on new buildings", pv magazine, 4 May 2016, https://www.pv-magazine.com/2016/05/04/santa-monica-mandates-solar-pv-on-new-buildings_100024445/.

144 Rachel Kaufman, "California will require solar panels on all new homes", Next City, 11 December 2018, https://nextcity.org/daily/entry/california-will-require-solar-panels-on-all-new-homes; Jack Flemming, "Starting in 2020, all new homes in California must come with solar panels – Builders are getting ready", *Los Angeles Times*, 14 December 2018, https://www.latimes.com/business/realestate/hot-property/la-fi-solar-mandate-20181214-story.html; California Energy Commission, 'Local ordinances, exceeding the 2016 building energy efficiency standards", https://ww2.energy.ca.gov/title24/2016standards/ordinances/, viewed 13 November 2019.

145 Sandra Enkhardt, "Tübingen führt Photovoltaik-Pflicht ein", pv magazine, 5 July 2018, https://www.pv-magazine.de/2018/07/05/tuebingen-fuehrt-photovoltaik-pflicht-ein/; Frank Fortino, "New York City mandates green roof systems for new buildings, major alterations", Metropolis Group, 29 July 2019, https://metropolisny.com/2019/07/new-york-city-mandates-green-roof-systems-for-new-buildings-major-alterations/.

146 Jeffrey Cook and al., *Clean Energy in City Codes: A Baseline Analysis of Municipal Codification Across the United States* (Golden, CO: NREL, December 2016), https://www.nrel.gov/docs/fy17osti/66120.pdf.

147 Building and Construction Authority of Singapore, *GM SLE: Green Mark for Super Low Energy Buildings* (Singapore: 2018), https://www.bca.gov.sg/GreenMark/others/GM_SLE.pdf.

148 Ibid.

149 Stephen Cirell, "The Merton rule and the need for local authorities to push the envelope", Current News, 5 July 2017, https://www.current-news.co.uk/blogs/the-merton-rule-and-the-need-for-local-authorities-to-push-the-envelope.

150 Lucy Woods, "Merton rule to be retained after renewables industry petition", Solar Power Portal, 14 March 2014, https://www.solarpowerportal.co.uk/news/merton_rule_to_be_retained_after_solar_industry_petition.

151 A. Kona et al., Covenant of Mayors in Figures: 8-year Assessment (Ispra, Italy: European Commission Joint Research Centre (EC JRC), 2017), https://ec.europa.eu/commission/sites/beta-political/files/covenant-mayors-8-year-assessment_en.pdf; Covenant of Mayors for Climate & Energy, "About", https://www.covenantofmayors.eu/support/faq.html, viewed 13 November 2019.

152 RENAISSANCE Project, *Innovative Buildings for Low-Energy Cities*, 2012, p. 10, http://www.renaissance-project.eu/IMG/pdf/RENAISSANCE_Innovative_Buildings_Final_Publication.pdf.

153 Ibid.

154 Carbonn Climate Registry, www.carbonn.org, viewed 1 November 2019.

155 Ibid.

156 Municipality of Medellín, Agreement 066 (Medellín, Colombia: 2017), pp. 80-81, https://www.medellin.gov.co/irj/go/km/docs/pccdesign/medellin/Temas/Hacienda/Normas/Shared%20Content/Documentos/2017/Acuerdo066de2017-Medellin.pdf.

157 Energy Matters, "Darebin council leads the way with Solar Saver scheme", https://www.energymatters.com.au/darebin-council-solar-saver-scheme/, viewed 16 May 2019.

158 Ibid.

159 Darebin City council is also exploring allowing larger systems to participate. See Ibid.

160 NC Clean Energy Technology Center, Database of State Incentives for Renewables & Efficiency (DSIRE), "Programs", https://programs.dsireusa.org/system/program, viewed 12 November 2019.

161 David Gabrielson, Executive Director, PACENation, "PACE: Property Assessed Clean Energy. Energy efficiency in buildings: How to accelerate investments?" presentation, Paris, 12 November 2017, https://ec.europa.eu/energy/sites/ener/files/documents/007_1a_david_gabrielson_seif_paris_11-12-17.pdf; US DOE, "Property assessed clean energy programs", https://www.

energy.gov/eere/slsc/property-assessed-clean-energy-programs, viewed 23 October 2019.

162 US DOE, op. cit. note 161, viewed 13 November 2019.

163 Ibid.; EuroPace, "About", https://www.europace2020.eu/, viewed 19 November 2019; PACE Canada, "About", https://www.paceab.ca/, viewed 15 November 2019

164 Evans et al., op. cit. note 142.

165 H.M. Jens et al., *Experiences from Middelgrunden 40 MW Offshore Wind Farm* (Copenhagen: Copenhagen Offshore Wind, October 2005), http://www.spok.dk/consult/reports/Copenhagen%20Offshore%20Middelgrunden.pdf.

166 City of Chicago, *Solar Zoning Policy* (Chicago, IL: Chicago Department of Planning and Development, 2015), https://www.chicago.gov/content/dam/city/depts/zlup/Sustainable_Development/Publications/City_of_Chicago_Solar_Zoning_Policy_Updated.pdf.

167 IEA Solar Heating and Cooling Programme, *Country Report* (Switzerland) (Paris: 2019), https://www.iea-shc.org/country-report-switzerland.

168 Fracesco Meneguzzo, Mario Pecoraino and Mario Pagliaro, "Combine historic preservation with efficient generation of solar", PV Europe, 3 June 2018, https://www.pveurope.eu/News/Solar-Generator/Combine-historic-preservation-with-efficient-generation-of-solar.

169 Kerry Boyd Anderson, "Renewable energy on the rise in the Middle East", Arab News, 6 February 2019, http://www.arabnews.com/node/1448021; "Can Qatar's low carbon city show a greener Middle East future?" *Reuters*, 1 March 2019, https://af.reuters.com/article/commoditiesNews/idAFL5N1VX5BH; Msheireb Properties, "About Msheireb Downtown Doha", https://www.msheireb.com/msheireb-downtown-doha/about-msheireb-downtown-doha/, viewed 18 April 2019.

170 Megan Day, "Best practices in zoning for solar", NREL, 21 April 2017, https://www.nrel.gov/state-local-tribal/blog/posts/best-practices-in-zoning-for-solar.html.

171 US DOE, *Installing Solar Panels on Historic Buildings: Survey of the Regulatory Environment* (Washington, DC: August 2012), https://www.solsmart.org/media/installing-solar-panels-on-historic-buildings_0812.pdf.

172 Zafrir Rinat, "Israeli cities take the lead in recycling and renewable energy", Haaretz, 9 March 2018, https://www.haaretz.com/israel-news/israeli-cities-take-the-lead-in-recycling-and-renewable-energy-1.5867242.

173 Kristen Ardani et al., *Cost Reduction Roadmap for Residential Solar Photovoltaics 2017-2030* (Golden, CO: NREL, January 2018), https://www.nrel.gov/docs/fy18osti/70748.pdf.

174 Linda Irvine, Alexandra Sawyer and Jennifer Grove, *The Solarize Guidebook* (Golden, CO: NREL, 2012), https://www.nrel.gov/docs/fy12osti/54738.pdf.

175 Ibid.

176 Solar Crowd Source, "Solarize Athens", https://www.solarcrowdsource.com/campaign/athens-ga-2/; Solar Crowd Source, "Solarize Newto-Morgan", https://www.solarcrowdsource.com/campaign/newton-morgan/; Solar Crowd Source, "Solarize Middle-Georgia", https://www.solarcrowdsource.com/campaign/middle-georgia/; Solar Crowd Source, "Solarize Roswell", https://www.solarcrowdsource.com/campaign/solarize-roswell/. All viewed 13 November 2019.

177 Energy Matters, "Darebin City council solar power bulk buy", https://www.energymatters.com.au/darebin-city-council-solar-power-bulk-buy-directory/, viewed 24 November 2019; Sunshine Coast Community Solar Association, "Residential solar panel bulk buy", https://suncoastcommsolar.weebly.com/bulk-buy.html, viewed 21 November 2019; Australian Energy Foundation, "City of Stonnington and the Australian Energy Foundation", https://aef.com.au/councils/stonnington/, viewed 21 November 2019, Shire of Strathbogie, "Bogie Bulk Buy", https://www.strathbogie.vic.gov.au/environment-heading/environment-sub/bogie-bulk-buy, viewed 21 November 2019.

178 Energy Matters, op. cit. note 177.

179 Ibid.

180 OECD/IEA, "Renewable heat: Tracking clean energy progress", https://www.iea.org/tracking/tcep2018/energyintegration/renewableheat/, updated 25 January 2019; Frauke Urban, Sam Geall and Yu Wang, "Solar PV and solar water heaters in China: Different pathways to low carbon energy", *Renewable and Sustainable Energy Reviews*, vol. 64 (October 2016), pp. 531-42, https://www.sciencedirect.com/science/article/pii/S1364032116302416; IEA/RETD, *Waking the Sleeping Giant: Next Generation Policy Instruments for Renewable Heating & Cooling in Commercial Buildings* (RES-H-NEXT) (Paris: 2015), http://iea-retd.org/wp-content/uploads/2015/02/RES-H-NEXT.pdf; Allan Miller et al., *Chilling Prospects: Providing Sustainable Cooling for All* (New York: Sustainable Energy for All, 2018), https://www.seforall.org/sites/default/files/gather-content/SEforALL_CoolingForAll-Report.pdf; EUROPA SETIS, "Heating and Cooling Technologies" (Brussels: European Commission, 2015), https://setis.ec.europa.eu/system/files/Technology_Information_Sheet_Heating_and_Cooling.pdf.

181 OECD/IEA, *The Future of Cooling* (Paris: 2018) p. 11, https://www.iea.org/futureofcooling/; UN Secretary General (UNSG) Summit: Cool Coalition, "Cities Action on Efficient, Climate-friendly Cooling" (New York: September 2019), https://www.k-cep.org/wp-content/uploads/2019/08/Guidance-Note-Cities_Cool-Coalition.pdf.

182 EUROPA SETIS, op. cit. note 180; IEA RETD, *Waking the Sleeping Giant*, op. cit. note 180.

183 Ibid., both sources.

184 Alice Springs Town Council, "Alice Solar City", http://www.alicesprings.nt.gov.au/living/environment/alice-solar-city, viewed 24 November 2019; Australian Government Solar Cities, *Alice Solar Energy Champions* (Alice Springs, Australia: 2013), http://www.alicesprings.nt.gov.au/sites/default/files/Alice%20Springs%20Hospital%20Energy%20Efficiency%20Project%20Report.pdf.

185 UNEP, *Solar Water Heating: A Strategic Planning Guide for Cities in Developing Countries* (Nairobi: 2015), http://www.estif.org/fileadmin/estif/content/publications/downloads/UNEP_2015/unep_report_cities_lr.pdf.

186 Noisun, "Noise barriers with sun energy, production for district heating systems", https://docplayer.se/128265467-Noisun-bullerskydd-som-producerar-solenergi-till-fjarrvarmenat-noise-barriers-with-sun-energy-production-for-district-heating-systems.html, viewed 24 November 2019.

187 "Lepoglava: First Croatian green prison", Balkan Green Energy News, 7 December 2017, https://balkangreenenergynews.com/lepoglava-first-croatian-green-prison/.

188 Oesterreichs Energie, "Electricity generation: Energy efficiency in thermal power plants through cogeneration", https://oesterreichsenergie.at/the-world-of-electricity/electricity-generation/energy-efficiency-through-cogeneration.html, viewed 24 November 2019.

189 Anders Haaker, "Biomass and the city", Bioenergy international, 1 February 2016, https://bioenergyinternational.com/heat-power/biomass-and-the-city; Fortum, "Värtaverket CHP Plant", https://www.fortum.com/about-us/our-company/our-energy-production/our-power-plants/vartaverket-chp-plant, viewed 17 November 2019.

190 Vattenfall, "Vattenfall invests for fossil free district heating in Amsterdam", press release (Stockholm: 21 March 2019), https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2019/vattenfall-invests-for-fossil-free-district-heating-in-amsterdam.

191 IRENA, *Renewable Energy Market Analysis: GCC 2019* (Abu Dhabi: 2019), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_Market_Analysis_GCC_2019.pdf.

192 S. Tredinnick and G. Phetteplace, "District cooling, current status and future trends", in Robin Wiltshire, ed., *Advanced District Heating and Cooling (DHC) Systems* (Amsterdam, The Netherlands: Elsevier, 2016), https://www.sciencedirect.com/science/article/pii/B9781782423744000082; H. Gadd and S. Werner, "Thermal energy storage systems for district heating and cooling", in Luisa F. Cabeza, ed., *Advances in Thermal Energy Storage Systems* (Amsterdam, The Netherlands: Elsevier, 2015), https://www.sciencedirect.com/science/article/pii/B9781782420880500183.

193 IRENA, *Renewable Energy in District Heating and Cooling: A Roadmap for REmap* (Abu Dhabi: 2017), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_REmap_DHC_Report_2017.pdf.

194 District Energy in Cities Initiative, "Cooling smart cities, Rajkot leads the way", press release (Rajkot, India: 7 February 2019), http://www.districtenergyinitiative.org/cooling-smart-cities-rajkot-leads-way.

195 UNSG Summit: Cool Coalition, op. cit. note 181.

196 Ibid.; Andrez Kimos, "Toronto's deep lake water cooling system", Buildipedia.com, 27 October 2011, http://buildipedia.com/aec-pros/engineering-news/torontos-deep-lake-water-cooling-system.

197 Barcelona and Lisbon from European Commission, *Possibilities for more district cooling in Europe*, (Brussels: 2006), https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ecoheatcool_more_district_cooling_in_europe.pdf; A. di Cecca and al., "Energy storage: The Parisian district cooling system", *UNEP Energy Learning* (Paris: 2010), https://www.energy-learning.com/index.php/archive/94-energy-storage-the-parisian-district-cooling-system.

198 REN21, *Renewables 2017 Global Status Report* (Paris: 2017), http://www.ren21.net/gsr-2017/.

199 IRENA and ICLEI, *City in Focus: Sao Paulo, Brazil – Local Governments Regulation Ordinances and Laws to Promote Renewable Energy* (Abu Dhabi: 2012), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/Jan/IRENA-cities-case-6-Sao-Paulo.pdf.

200 European Solar Thermal Industry Association (ESTIF), "Solar ordinances", http://www.estif.org/policies/solar_ordinances/, viewed 15 July 2019; C40 Cities, "Case study: Barcelona's Solar Hot Water Ordinance", 3 November 2011, https://www.c40.org/case_studies/barcelonas-solar-hot-water-ordinance.

201 Ibid.

202 Ibid.

203 Ibid.

204 IRENA and ICLEI, op. cit. note 199; IRENA, IEA and REN21, *Renewable Energy Policies in a Time of Transition* (Abu Dhabi: 2018), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_IEA_REN21_Policies_2018.pdf.

205 Montevideo Universidad de la República de Uruguay, "Decree No. 34,151", 2011, https://eva.fing.edu.uy/mod/resource/view.php?id=25145; IRENA and ICLEI, *Promoting Solar Water Heaters for Urban Homes and Businesses: Rosario, Argentina* (Abu Dhabi: 2018), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Dec/IRENA_Cities_2018c_Rosario.pdf.

206 ACEEE, "Energy code stringency", https://database.aceee.org/city/energy-code-stringency, viewed 14 October 2019.

207 Bärbel Epp, "Successful solar energy bylaw in Bengaluru, India", Solarthermalworld.org, 17 August 2018, https://www.solarthermalworld.org/content/successful-solar-energy-bylaw-bengaluru-india; Beirut from UNEP, *Solar Water Heaters' Market Evaluation: Case Study of Lebanon 2015* (Nairobi: 2015), https://www.solarthermalworld.org/sites/gstec/files/story/2015-11-27/swh_case_study_report_uptd_25nov._web.pdf; Loures and Vienna from REN21, op. cit. note 2; IRENA, *Renewable Energy Market Analysis: Latin America* (Abu Dhabi: 2016), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Market_Analysis_Latin_America_2016.pdf; Vellmar from ESTIF, op. cit. note 200.

208 Michael Shank, "Adopting a zero-emissions standard for new buildings", Carbon Neutral Cities Alliance, 29 November 2018, https://carbonneutralcities.org/adopting-a-zero-emissions-standard-for-new-buildings/.

209 Ibid.

210 City of Santa Monica, "Santa Monica City Council votes in the world's first zero-net energy building requirement; implementation begins in 2017", press release (Santa Monica, CA: October 2016), https://www.santamonica.gov/press/2016/10/27/santa-monica-city-council-votes-in-the-world-s-first-zero-net-energy-building-requirement-implementation-begins-in-2017.

211 EC, "Nearly zero-energy buildings", https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/nearly-zero-energy-buildings, updated 20 August 2019;

212 C40 Cities, *Net Zero Carbon Buildings Declaration: Planned Actions to Deliver Committments* (Paris: 2018), https://c40-production-images.s3.amazonaws.com/other_uploads/images/1928_Brochure_building.original.pdf.

213 Natural Resources Canada, *Solar Ready Guidelines for Solar Domestic, Hot Water and Photovoltaic Systems* (Gatineau, Québec: 2013), https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/SolarReadyGuidelines_en.pdf.

214 Mid-America Regional Council, "Five area cities recognized as Solar Ready Communities", press release (Kansas City, MO: 23 June 2015), https://www.marc.org/News-Releases/Archive/June-2015/Five-area-cities-recognized-as-Solar-Ready-Communi.html; Lunning Wende Associates, Inc., *Solar Ready Building Design Guidelines, prepared for the Minneapolis Saint Paul Solar Cities Program* (St. Paul, MN: 2010), http://mn.gov/commerce-stat/pdfs/solar-ready-building.pdf.

215 International Finance Corporation, *Climate Investment Opportunities* (Washington, DC: 2018), https://www.ifc.org/wps/wcm/connect/875afb8f-de49-460e-a66a-dd2664452840/201811-CIOC-IFC-Analysis.pdf?MOD=AJPERES&CVID=mthPzYg.

216 Raimond Tamm, "From Hrustsovkas to Smartkovskas", SmartEnCity, https://smartencity.eu/about/lighthouse-cities/tartu-estonia/, viewed 24 November 2019.

217 Ibid.

218 RES Legal, "RES-H building obligations", http://www.res-legal.eu/search-by-country/germany/single/s/res-hc/t/policy/aid/res-h-building-obligations-quota/lastp/135/, updated 14 January 2019.

219 REN21, op. cit. note 2.

220 Carbonn Center, www.carbonn.org, viewed 18 November 2019.

221 City of Boulder, "City and County promote renewable way to heat and cool homes", press release (Boulder, CO: 26 April 2018), https://bouldercolorado.gov/newsroom/city-and-county-promote-renewable-way-to-heat-and-cool-homes.

222 City of Boulder, "Energy future", https://bouldercolorado.gov/energy-future, viewed 16 May 2019.

223 EC, "CONCERTO projects demonstrate the potential of solar energy", https://cordis.europa.eu/news/rcn/131050/en, viewed 24 April 2019.

224 Municipality of the District of Shelburne, *PACE Pilot Program* (Shelburne, Nova Scotia, Canada: 2015), https://municipalityofshelburne.ca/sustainability/296-pace-brochure/file.html.

225 Jana Cicmanova, *Financing Schemes Increasing Energy Efficiency and Renewable Energy Use in Public and Private Buildings: Comparative Study* (Brussels: Energy Cities, 2014), http://www.energy-cities.eu/IMG/pdf/infinite_solutions_comparative_analysis_web.pdf; BWP, "BAFA-Förderung für Wärmepumpen", https://www.waermepumpe.de/waermepumpe/foerderung/bafa-foerderung-fuer-waermepumpen/, viewed 6 May 2019.

226 Veith, op. cit. note 36; Grenobles-Alpes Metropole, "Fonds Chaleur Territorial: Passez à l'action" (Grenoble, France: 2016), http://planairclimat.lametro.fr/Media/Files/Flyer-fonds-chaleur-territorial.

227 NC Clean Energy Technology Center, DSIRE, "Solar Energy System and Cogeneration Systems Personal Property Tax Credit", http://programs.dsireusa.org/system/program/detail/5245, updated 19 June 2019.

228 Uutiset, "Helsinki mayor pledges €1m for idea to replace coal-fired energy plants", 4 April 2019, https://yle.fi/uutiset/osasto/news/helsinki_mayor_pledges_1m_for_idea_to_replace_coal-fired_energy_plants/10722507.

229 Marina Galindo Fernández et al., *Efficient District Heating and Cooling Systems in the EU* (Vienna: EC JRC, 2016), https://www.euroheat.org/wp-content/uploads/2017/01/study-on-efficient-dhc-systems-in-the-eu-dec2016_final-public-report6.pdf.

230 Ibid.

231 City of Cape Town Energy Directorate, "Get a solar water heater today!" https://savingelectricity.org.za/solar-water-heaters/, viewed 24 November 2019.

232 Energy Matters, op. cit. note 177; Australian Energy Foundation, op. cit. note 177; Jonathan Prendergast, "Hot water heat pump bulk buy", Sunny Shire, May 2018, http://sunnyshire.org.au/hot-water-heat-pump-bulk-buy/; Healesville Core, "Community solar hot water & heat pumps bulk buy", https://www.healesvillecore.org.au/solar-hot-water-heat-pumps-info/, viewed 13 September 2019.

233 Piotr Lyczko, "Ban on the use of solid fuels in Krakow from September 2019", Malopolska, 15 January 2016, https://powietrze.malopolska.pl/en/news/ban-on-the-use-of-solid-fuels-in-krakow-from-september-2019/.

234 Oiwan Lam, "In the fight against smog, China bans coal in 28 cities", Hong Kong Free Press, 14 October 2017, https://www.hongkongfp.com/2017/10/14/fight-smog-china-bans-coal-28-cities/.

235 Uutiset, op. cit. note 228.

236 David Blackman, "Fossil fuel heating in new builds to be phased out in 2020s", *Network*, 13 October 2017, https://networks.online/gphsn/news/1000738/fossil-fuel-heating-builds-phased-2020s.

237 Emilie Raguso, "Berkeley first city in California to ban natural

gas in new buildings", Berkeleyside, 17 July 2019, https://www.berkeleyside.com/2019/07/17/natural-gas-pipes-now-banned-in-new-berkeley-buildings-with-some-exceptions.

238 Nichola Groom, "San Jose moves to ban natural gas in new residential buildings", *Reuters*, 17 September 2019, https://www.reuters.com/article/us-usa-naturalgas-sanjose/san-jose-moves-to-ban-natural-gas-in-new-residential-buildings-idUSKBN1W302J.

239 IRIS Smart Cities, "City of Gothenburg (GOT), Sweden", https://irissmartcities.eu/content/city-gothenburg-got-sweden, viewed 6 May 2019.

240 Based on information and sources provided throughout this section.

241 Peter Fraser, "Commentary: More of good things – is surplus renewable electricity an opportunity for early decarbonisation", OECD/IEA, 9 October 2019, https://www.iea.org/newsroom/news/2019/october/more-of-a-good-thing--is-surplus-renewable-electricity-an-opportunity-for-early-.html; IRENA, *Solutions to Integrate High Shares of Variable Renewable Energy* (Abu Dhabi: 2019), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jun/IRENA_G20_grid_integration_2019.pdf.

242 Malin Aldenius and Jamil Khan, "Strategic use of green public procurement in the bus sector: Challenges and opportunities", *Journal of Cleaner Production*, vol. 164 (2017), pp. 250-57, https://www.sciencedirect.com/science/article/pii/S0959652617313665.

243 Ibid.

244 IRENA, *Biogas for Road Vehicles: Technology Brief* (Abu Dhabi: 2018), p. 47, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_Biogas_for_Road_Vehicles_2017.pdf.

245 Juliane Große et al., *Urban Energy Planning in Tartu* (Tartu, Estonia: PLEEC, 2015), http://pleecproject.eu/downloads/Reports/Work%20Package%204/D4.2%20%20Case%20Study%20Reports/d4.2_tartu_2015-01-14_final.pdf.

246 Samuele Nannoni, "From waste to reclaimed water and biomethane for transport: Life Methamorphosis project", *BE Sustainable*, 2 May 2019, http://www.besustainablemagazine.com/cms2/from-waste-to-reclaimed-water-and-biomethane-for-transport-life-methamorphosis-project/; Vilasana from European Commission, *Assessment of a Co-digestion Plant Hypothetically Situated in Pla d'Urgell, Catalonia, Spain* (Barcelona: 2007), https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/probiogas_national_report_spain.pdf.

247 Sohini Dey, "Fuel made from cow dung is powering India's cheapest bus service", *The Better India*, 1 April 2017, https://www.thebetterindia.com/93954/biogas-bus-cowdung-fuel-kolkata/.

248 Motiva, "Biogas bus purchase of city of Vaasa creates markets for clean technology", https://www.motiva.fi/en/public_sector/sustainable_public_procurements/examples_of_the_procurements/biogas_bus_purchase_of_city_of_vaasa_creates_markets_for_clean_technology, updated 1 August 2019.

249 Robert Brears, "Revealed: Top 5 green public transport projects globally", Impact4All, 15 May 2018, http://zooxel.com/impact4all/revealed-top-5-renewable-public-transport-systems/; Bay Area Rapid Transit, "BART commits to a future powered by wind and solar power", 7 December 2017, https://www.bart.gov/news/articles/2017/news20171207-1.

250 Dubai is also focusing on providing innovative mobility solutions, including increasing use of public transport, testing autonomous vehicles and decreasing the need for motorised transport altogether. See Smart Dubai 2021, "Smart mobility", https://2021.smartdubai.ae/smart-mobility, viewed 14 November 2019; Intelligent Transport, "Dubai's RTA pushes green mobility to lower its carbon footprint", 30 July 2019, https://www.intelligenttransport.com/transport-news/85461/dubais-rta-pushes-green-mobility-to-lower-its-carbon-footprint/.

251 Wellington City Council, *Wellington Resilience Strategy* (Wellington, New Zealand: 2017), https://wellington.govt.nz/~/media/about-wellington/resilient-wellington/files/strategy/reslience-strategyj001767-100-web.pdf?la=en.

252 Ibid.

253 Dunedin City, *Integrated Transport Strategy* (Dunedin, New Zealand: 2013), https://www.dunedin.govt.nz/__data/assets/pdf_file/0004/349735/Transport-Strategy-as-PDF.pdf; Dunedin City, *The Energy Plan 1.0* (Dunedin, New Zealand: 2015), https://www.dunedin.govt.nz/__data/assets/pdf_file/0019/518131/Energy-Plan-March-2017.pdf.

254 Green Car Congress, "Climate mayors EV purchasing collaborative: More than 140 cities have committed to purchasing over 2,100 EVs by 2020", 28 June 2019, https://www.greencarcongress.com/2019/06/20190628-cmev.html. At the regional level, the Australia Capital Territory is launching an EV bulk buying programme aimed at making its vehicle fleets totally electric, from Tony Bosworth, "ACT urges local governments to join bulk-buy for electric vehicle fleets", The Driven, 22 October 2018, https://thedriven.io/2018/10/22/act-proposes-local-governments-join-bulk-buy-for-electric-vehicle-fleets/.

255 Green Car Congress, op. cit. note 254.

256 Ibid.

257 REN21, op. cit. note 2.

258 Ibid.

259 BSR, "Unsere gruene Fahrzeugflotte: sparsam, sauber, leide", https://www.bsr.de/innovative-fahrzeugtechnik-22319.php, viewed 21 November 2019.

260 Ibid.

261 Sustainable Transport in China, "New era of urban freight in China: Workshop with 22 pilot cities on green urban delivery in Chengdu", 7 January 2019, http://www.sustainabletransport.org/archives/6575.

262 Municipality of Loja, *Ordenanza que Crea y Regula el Servicio de Taxi Ecológico – Eléctrico en el Cantón Loja* (Loja, Ecuador: 8 April 2018), pp. 1-6, https://www.loja.gob.ec/files/documentos/2016-06/ord_taxi_electrico_loja_uno.pdf.

263 Ibid.

264 Andy Koen, "Commission requires Colorado car dealers to carry more electric cars", KOAA News5, 19 August 2019, https://www.koaa.com/stories/cover-stories/commission-requires-colorado-car-dealers-to-carry-more-electric-cars; Ministry of the Environment and the Fight Against Climate Change, "The zero-emission vehicle (ZEV) standard, Quebec", http://www.environnement.gouv.qc.ca/changementsclimatiques/vze/index-en.htm, viewed 21 November 2019.

265 Several US cities – including Boston (5%), Salt Lake City (4%) and San Francisco (20%) – have introduced mandates for a specific share of new and existing parking areas to install EV charging stations, from ACEEE, op. cit. note 206. At the regional level, the Australian Capital Territory, as part of its plan to scale-up zero-emissions transport, requires all new multi-unit and mixed-use developments in the region to install charging infrastructure for EVs, from ACT Government, *The ACT's Transition to Zero Emission Vehicles* (Action Plan 2018-21) (Canberra: Australian Capital Territory, 2018), https://www.environment.act.gov.au/__data/assets/pdf_file/0012/1188498/2018-21-ACTs-transition-to-zero-emissions-vehicles-Action-Plan-ACCESS.pdf.

266 In April 2019, the Seattle City Council (Washington) approved requirements that every home with private parking must have an EV-ready space; multi-unit residential buildings must offer at least 20% of their parking spaces as EV ready, and non-residential parking facilities need to provide a minimum of 10% EV-ready spaces, from SmartCitiesWorld, "Seattle's new buildings primed to be EV-ready", 30 April 2019, https://www.smartcitiesworld.net/energy/energy/seattles-new-buildings-primed-to-be-ev-ready. Other efforts to make US cities "EV ready" have been launched in Long Beach, Pasadena, Palo Alto, Sacramento, San Francisco (California) and in Boston (Massachusetts), Denver (Colorado) and Hartford (Connecticut), from ACEEE, op. cit. note 206; California Air Resources Board, *Electric Vehicle Charging Infrastructure: Multifamily Building Standards* (Sacramento, CA: April 2018), https://ww3.arb.ca.gov/cc/greenbuildings/pdf/tcac2018.pdf; City of Sacramento, *Planning and Design Commission Report* (Sacramento, CA: June 2019), https://sacramento.granicus.com/MetaViewer.php?view_id=21&clip_id=4421&meta_id=557883.

267 Hui He et al., *Assessment of Electric Car Promotion Policies in Chinese Cities* (Beijing/Washington: International Council on Clean Transportation (ICCT), 2018), https://theicct.org/sites/default/files/publications/China_city_NEV_assessment_20181018.pdf; Sustainable Transportation in China, "Shared mobility services and car sharing in China", 25 April 2018, https://www.sustainabletransport.org/archives/5934. The Australian Capital Territory, which includes the country's capital Canberra, has introduced zero-emission vehicle licence plates to enable easy identification, to help smooth the monitoring of EV use, and to reduce enforcement costs for local officials, from

ACT Government, *The ACT's Transition to Zero Emissions Action Plan 2018-2021* (Canberra: ACT, 2018), https://www.environment.act.gov.au/__data/assets/pdf_file/0012/1188498/2018-21-ACTs-transition-to-zero-emissions-vehicles-Action-Plan-ACCESS.pdf. **Figure 12** based on the following sources: REN21, op. cit., note 2; REN21, op. cit. note 48; Feargus O'Sullivan, "Madrid takes its car ban to the next level", CityLab, 24 May 2018, https://www.citylab.com/transportation/2018/05/madrid-spain-car-ban-city-center/561155/; Theo Leggett, "Polluted Paris steps up war on diesel", *BBC*, 30 May 2018, https://www.bbc.com/news/business-43925712; Kristine Lofgren, "Rome is banning all oil-burning cars by 2024", Inhabitat, 3 January 2018, https://inhabitat.com/rome-is-banning-all-oil-burning-cars-by-2024/; Aria Bendix, "15 major cities around the world that are starting to ban cars", Business Insider, 12 January 2019, https://www.businessinsider.es/cities-going-car-free-ban-2018-12; SLoCaT, *Transport and Climate Change Global Status Report 2018* (Shanghai: 2018), http://slocat.net/sites/default/files/slocat_transport-and-climate-change-2018-web.pdf; Tim Wenger, "7 cities that are banning cars from their city centers", Matador Network, 3 April 2019, https://matadornetwork.com/read/cities-banning-cars-city-centers/; Leanna Garfield, "13 cities that are starting to ban cars", Business Insider, 8 June 2018, https://www.businessinsider.es/cities-going-car-free-ban-2017-8?r=US&IR=T; Megan Barber, "15 cities tackling pollution by curbing cars", Curbed, 14 August 2018, https://www.curbed.com/2017/4/10/15207926/car-ban-cities-pollution-traffic-paris-london-mexico-city; Patrick Ploetz et al., "Designing car bans for sustainable transportation", *Nature Sustainability*, vol. 2 (2019), pp. 534-36; Dearman, "Global shift towards diesel bans continues", 30 July 2018, https://dearman.co.uk/global-shift-towards-diesel-bans-continues; Andrea Pinto, "Delhi won't be the first city to ban private cars", *Condé Nest Traveller*, 31 October 2018, https://www.cntraveller.in/story/delhi-wont-first-city-ban-private-cars/.

268 Increased interest in biogas and biomethane, for example in the UK, from Kate Dickinson, "Waitrose to run HGV fleet on biomethane", Resource, 30 July 2018, https://resource.co/article/waitrose-run-hgv-fleet-biomethane-12768; Alan Sherrard, "Biomethane reaches 91% share in expansive Swedish vehicle gas market", *Bioenergy International*, 22 February 2019, https://bioenergyinternational.com/markets-finance/biomethane-reaches-91-share-in-expansive-swedish-vehicle-gas-market; Raffaella Ocone, "Does the 2040 ban on new petrol and diesel cars mean the death of biofuels?" *The Conversation*, 30 July 2017, https://theconversation.com/does-the-2040-ban-on-new-petrol-and-diesel-cars-mean-the-death-of-biofuels-81765.

269 REN21, op. cit. note 2, p. 38. For example, hybrid vehicles are still allowed to enter the city centre of Madrid (Spain), which has put in place bans on petrol and diesel cars registered before 2000 and 2006, respectively, from Jon Porter, "Madrid's ban on polluting vehicles cuts traffic by nearly 32 percent in some areas", The Verge, 3 December 2018, https://www.theverge.com/2018/12/3/18123561/vehicle-emissions-pollution-ban-madrid-spain-traffic-decrease.

270 For example, in Athens (Greece), Brussels (Belgium), Lisbon (Portugal), Madrid (Spain), Mexico City (Mexico), Paris (France) and Rome (Italy). These city targets and policies are in addition to the at least 19 countries that aim to replace or phase out ICE vehicles and "non zero-emission vehicles" to stimulate EV uptake. See sources for Figure 12, op. cit. note 267.

271 O'Sullivan, op. cit. note 267; Rome from SLoCaT, op. cit. note 60.

272 "China starts implementing tougher vehicle emission standards", *China Daily*, 2 July 2019, http://www.chinadaily.com.cn/a/201907/02/WS5d1ac566a3103dbf1432b6d2.html.

273 Including Beijing, Guangdong, Hebei, Shanghai and Tianjin. See Ibid.

274 Lulu Xue, "Hainan bans all fossil fuel vehicles. What does it mean for clean transport in China?" The City Fix, 11 September 2019, https://thecityfix.com/blog/hainan-bans-fossil-fuel-vehicles-mean-clean-transport-china-lulu-xue/.

275 IRENA, op. cit. note 244, p. 48.

276 GRDF, "Découvrir les unités d'injection", https://www.grdf.fr/institutionnel/actualite/dossiers/biomethane-biogaz/unites-injection-gaz-vert, viewed 24 November 2019; Paul Molga, "Le gaz vert enflamme les acteurs de la transition énergétique", Les Echos, 24 September 2019, https://www.lesechos.fr/thema/energie-stockage/le-gaz-vert-enflamme-les-acteurs-de-la-transition-energetique-1134201; ENEA, *Overview of the Biomethane Sector in France* (Paris: 2017), p. 4, http://www.enea-consulting.com/wp-content/uploads/2018/04/ENEA-2017-10-biomethane-france-2017-en.pdf.

277 Gaz Mobilité, "Les stations BioGNV & biogas en France", https://www.gaz-mobilite.fr/stations-gnv-france/type/biognv-biogaz/, viewed 24 November 2019.

278 Sébastian Compagnon, "409 bus au gaz naturel vont circuler en Ile-de-France à partir de 2020", *Le Parisien*, 1 October 2019, http://www.leparisien.fr/info-paris-ile-de-france-oise/transports/409-bus-au-gaz-naturel-vont-circuler-en-ile-de-france-a-partir-de-2020-01-10-2019-8163816.php.

279 Axel Ensslen et al., "Incentivizing smart charging: Modeling charging tariffs for electric vehicles in German and French electricity markets", *Energy Research and Social Science*, vol. 42 (August 2018), pp. 112-26, https://www.sciencedirect.com/science/article/pii/S2214629618301865.

280 Cabell Hodge, *Aligning PEV Charging Times with Electricity Supply and Demand* (Golden, CO: NREL, 2017), https://www.nrel.gov/docs/fy17osti/68623.pdf.

281 Steffen Limmer, "Dynamic pricing for electric vehicle charging – A literature review", *Energies*, vol. 12, no. 18 (2019), p. 3574, https://www.researchgate.net/publication/335919327_Dynamic_Pricing_for_Electric_Vehicle_Charging-A_Literature_Review.

282 UNIDO, *Biogas to Biomethane* (Vienna: September 2017), p. 22, https://www.biogas-to-biomethane.com/Download/BTB.pdf; Sabine Strauch and Joachim Krassowski, *Overview of Biomethane Markets and Regulations in Partner Countries* (Oberhausen, Germany: GreenGasGrids Project, 2012), p. 43, https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/greengasgrids_overview_of_biomethane_markets.pdf.

283 Ibid., both sources.

284 For example, in Hefei, Nanchang, Shenzhen, Xi'an and Yichun in China. Audrey Quicke, *Driving Norse: Electric Vehicle Policies in Norway* (Canberra: The Australia Institute / Nordic Policy Centre, 2019), https://d3n8a8pro7vhmx.cloudfront.net/theausinstitute/pages/2985/attachments/original/1555050708/P718_NPC_Driving_Norse_-_EV_Policy.pdf; He et al., op. cit. note 267.

285 Sebastian Ibold, "Shared mobility services and car-sharing in China", Sustainable Transportation in China, 25 April 2018, https://www.sustainabletransport.org/archives/5934.

286 ACT Government, op. cit. note 267.

287 ICCT, *Electric Vehicle Capitals: Accelerating the Global Transition to Electric Drive* (Washington and Beijing: 2018), https://theicct.org/sites/default/files/publications/EV_Capitals_2018_final_20181029.pdf.

288 Municipality of Buenos Aires, Ministry of Transport, "Plan de Movilidad Limpia", presentation, 2018, https://www.itba.edu.ar/intranet/ols/wp-content/uploads/sites/4/2018/09/PML-CABA-NACION_300518.pdf.

289 Aghaddir Ali, "No registration fees for electrical vehicles in RAK", Gulf News UAE, 30 September 2018, https://gulfnews.com/uae/transport/no-registration-fees-for-electrical-vehicles-in-rak-1.2284605.

290 IRENA, op. cit. note 244, p. 48.

291 Peter Slowik and Nic Lutsey, *The Surge of Electric Vehicles in United States Cities* (San Francisco, CA: ICCT, 2018), https://theicct.org/publications/surge-Evs-US-cities-2019.

292 CALeVIP, "Sacramento county incentive project", https://calevip.org/incentive-project/sacramento-county-incentive-project, viewed 16 November 2019; CALeVIP, "Fresno County incentive project", https://calevip.org/incentive-project/fresno, viewed 16 November 2019.

293 Richmond City Council, "18 December 2017: Minutes" (Richmond, CA: 2017), https://www.richmond.ca/cityhall/council/agendas/hearings/2017/121817_minutes.htm.

294 Aparna Menon, Zifei Yang and Anup Bandivadekar, *Electric Vehicle Guidebook for Indian States* (Washington, DC: ICCT, 2019), https://theicct.org/sites/default/files/publications/India_EV_State_Guidebook_20191007.pdf.

295 Magdalena Rogulska, Pawel Bukrejewski and Ewa Krasuska, "Biomethane as transport fuel", in Krzysztof Biernat, ed., *Biofuels: State of Development* (IntectOpen, 2018), https://www.intechopen.com/books/biofuels-state-of-development/biomethane-as-transport-fuel.

296 Intelligent Energy Europe, "Urban waste for biomethane grid injection and transport in urban areas (URBANBIOGAS)",

https://ec.europa.eu/energy/intelligent/projects/en/projects/urbanbiogas#results, viewed 15 November 2019.

297 Nils Fearnley et al., *E-vehicle Policies and Incentives: Assessment and Recommendations* (Oslo: Norwegian Centre for Transport Research, 2015), https://www.toi.no/getfile.php?mmfileid=41187. It is estimated that 4 kW of solar PV in a jurisdiction with solar resource comparable to Austria's would be sufficient to drive some 26,000 kilometres. See Klima Energie Fonds, *Model Regions of Electric Mobility in Austria* (Vienna: 2015), https://www.klimafonds.gv.at/wp-content/uploads/sites/6/MODELREGIONSofelectricmobilityinAustria.pdf.

298 Ibid.

299 City of Berlin, "Low-emission zone", https://www.berlin.de/senuvk/umwelt/luftqualitaet/umweltzone/en/gebiet.shtml, viewed 17 May 2019; Stuttgart City, "Stuttgart is a low emission zone", https://www.stuttgart.de/en/item/show/573353, viewed 17 November 2019; Jon Hughes, "Paris places record order for biogas buses", World Biogas Association, 23 October 2019, https://www.worldbiogasassociation.org/paris-places-record-order-for-biogas-buses/.

300 Collins Dictionary, "Definition of congestion charge", https://www.collinsdictionary.com/dictionary/english/congestion-charge, viewed 14 May 2019; REN21, op. cit. note 2, pp. 230-35.

301 Sarah Shaath, "New York City congestion charge: What can it learn from London", *BBC*, 18 April 2019, https://www.bbc.com/news/world-us-canada-47874725.

302 Gareth Roberts, "Changes proposed to London's congestion charge", Fleet News, 7 September 2018, https://www.fleetnews.co.uk/news/environment/2018/07/09/changes-proposed-to-london-s-congestion-charge.

303 Peter Campbell, "London clean air rules accelerate slump in diesel cars demand", *Financial Times*, 1 July 2019, https://www.ft.com/content/6378f18a-8dc5-11e9-a1c1-51bf8f989972.

304 Katie Coyne, "Waste food firm runs biogas vehicles to meet new emissions rule", MRW, 8 April 2019, https://www.mrw.co.uk/latest/waste-food-firm-runs-biogas-vehicles-to-meet-new-emissions-rule/10041819.article; Campbell, op. cit. note 303.

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1 Peter Droege, *Urban Energy Transition: Renewable Strategies for Cities and Regions* (Amsterdam, The Netherlands: Elsevier, 2018), https://www.elsevier.com/books/urban-energy-transition/droege/978-0-08-102074-6.

2 Ibid.

3 Based on examples and sources cited throughout this chapter.

4 Renewable Energy Policy Network for the 21st Century (REN21), *Renewables 2018 Global Status Report* (Paris: 2018), https://www.ren21.net/gsr-2019/; International Renewable Energy Agency (IRENA), *Renewable Energy in Cities* (Abu Dhabi: 2016), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf; Sierra Club, "100% commitments in cities, counties and states", https://www.sierraclub.org/ready-for-100/commitments, viewed 10 November 2019; Covenant of Mayors for Climate & Energy, "Plans and actions", https://www.covenantofmayors.eu/plans-and-actions/action-plans.html, viewed 10 November 2019.

5 Droege, op. cit. note 1.

6 REN21, *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/gsr-2019/.

7 **Sidebar 5** based on the following sources: Global Methane Initiative, *Landfill Methane: Reducing Emissions, Advancing Recovery and Use Opportunities* (Washington, DC: 2011), https://www.globalmethane.org/documents/landfill_fs_eng.pdf; World Bank, "Solid waste management", http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management, updated 1 April 2019; World Bank, *What a Waste: A Global Review of Solid Waste Management* (Washington, DC: 2012), https://openknowledge.worldbank.org/handle/10986/17388; UNESCO, "Is wastewater the new black gold?" press release (Durban, South Africa: 22 March 2017), https://en.unesco.org/news/wastewater-new-black-gold; International Water Association, *The Reuse Opportunity* (London: 2018), p. 2, http://www.iwa-network.org/wp-content/uploads/2018/02/OFID-Wastewater-report-2018.pdf; International Energy Agency (IEA) Bioenergy, *Municipal Solid Waste and Its Role in Sustainability* (Paris: 2003), https://www.ieabioenergy.com/wp-content/uploads/2013/10/40_IEAPositionPaperMSW.pdf; "Asja inaugurate third landfill gas to energy plant in Brazil", Bioenergy international, 16 September 2017, https://bioenergyinternational.com/biogas/asja-inaugurate-third-landfill-gas-to-energy-plant-in-brazil; "Construction underway for Asja's largest landfill gas project in Brazil", Bioenergy International, 9 August 2018, https://bioenergyinternational.com/biogas/construction-underway-for-asjas-largest-landfill-gas-project-in-brazil; European Biogas Association (EBA), *Statistical Report 2018* (Brussels: 2018), https://uabio.org/en/materials/analytics/4018-eba-statistical-report-2018; "Map of over 500 European biomethane facilities released", Bioenergy Insight, 13 February 2018, https://www.bioenergy-news.com/display_news/13428/map_of_over_500_european_biomethane_facilities_released/1/; EBA, "Open market for digestate from anaerobic digestion – Uppsala, Sweden" (Brussels: 2016), https://www.europeanbiogas.eu/wp-content/uploads/2016/03/Urban-Biowaste-AD-Success-Stories-FINAL.pdf; IEA Bioenergy, "Task 37 (Biogas) Country Reports", http://task37.ieabioenergy.com/country_reports.html; "Public buses to run on biogas in Karachi", Bioenergy Insight, 3 January 2019, https://www.bioenergy-news.com/display_news/14251/public_buses_to_run_on_biogas_in_karachi/1/; Meghan Sapp, "India looks to build 5,000 bio-CNG plants producing 15 million tons by 2023", Biofuels Digest, 17 December 2018, https://www.biofuelsdigest.com/bdigest/2018/12/17/india-looks-to-build5000-bio-cng-plants-producing-15-million-tons-by-2023/; Bioenergy Europe, *Biomass Supply: Statistical Report 2019* (Brussels: 2019), http://staging.bioenergyeuropenew.web-005.karakas.prvw.eu/index.php?option=com_content&view=article&id=178; Waste Management World, "Waste to energy: China drives an Asian awakening", 6 June 2019, https://waste-management-world.com/a/in-depth-waste-to-energy-china-drives-an-asian-awakening.

8 Greenhouse Gas Protocol, "GHG Protocol for Cities – An Accounting and Reporting Standard for Cities", https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities, viewed June 2019.

9 Ibid.

10 Droege, op. cit. note 1

11 **Figure 12** from CDP, "Over 100 global cities get majority of electricity from renewables", 27 February 2018, https://www.cdp.net/en/articles/cities/over-100-global-cities-get-majority-of-electricity-fromrenewables.

12 Ibid.

13 Ibid.

14 Ibid.

15 Ibid.

16 Ibid.

17 Miguel-Angel Perea-Moreno, Quetzalcoatl Hernandez-Escobedo and Alberto-Jesus Perea-Moreno, "Renewable energy in urban areas: Worldwide research trends", *Energies*, vol. 11, no. 3 (2018), p. 577, https://www.mdpi.com/1996-1073/11/3/57; REN21, op. cit. note 6.

18 REN21, op. cit. note 6; IRENA, *Renewable Power Generation Costs in 2018* (Abu Dhabi: 2019), https://www.irena.org/publications/2019/May/Renewable-power-generation-costs-in-2018; IEA Photovoltaic Power Systems Programme (IEA PVPS), *Trends 2018 in Photovoltaic Applications* (Paris: 2018), http://www.iea-pvps.org/fileadmin/dam/public/report/statistics/2018_iea-pvps_report_2018.pdf.

19 Organisation for Economic Co-operation and Development (OECD) / IEA, *Renewables 2019* (Paris: 2019), https://www.iea.org/renewables2019/.

20 Ibid.

21 Emiliano Bellini, "Rooftop PV has reached grid parity in main EU market", pv magazine, 16 August 2019, https://www.pv-magazine.com/2019/08/16/rooftop-pv-has-reached-grid-parity-in-main-eu-markets; Powermode, "Rooftop solar PV nears grid parity – without subsidies", https://powermode.co.za/rooftop-solar-pv-nears-grid-parity-without-subsidies/, viewed 15 October 2019; José Rojo Martín, "IRENA: Global solar months away from sweeping grid parity", PV Tech, 30 May 2019, https://www.pv-tech.org/news/irena-global-solar-months-away-from-sweeping-grid-parity; Deloitte Center for Energy Solutions, *Journey to Grid Parity: Three Converging Forces Provide a Tailwind for US Renewable Power* (Washington, DC: 2015), https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-pu-journey-to-grid-parity-report.pdf.

22 Heymi Bahar, "Tracking clean energy progress: Solar PV", OECD/IEA, https://www.iea.org/tcep/power/renewables/solarpv/, updated 24 May 2019.

23 Ibid.

24 Environment America and Frontier Group, *Shining Cities 2019: The Top U.S. Cities for Solar Energy* (Washington, DC: April 2019), https://environmentamerica.org/sites/environment/files/reports/WEB_AME_Shining-Cities_2019_040919-v1.pdf.

25 "Guerilla-Photovoltaik ist legalisert", Enbausa.de, 12 November 2019, https://www.enbausa.de/solarenergie/aktuelles/artikel/guerilla-photovoltaik-ist-legalisiert-5908.html.

26 Environment America and Frontier Group, op. cit. note 24.

27 US Department of Energy, Energy Efficiency & Renewable Energy, *Solar Powering Your Community: A Guide for Local Governments* (Washington, DC: 2011), https://www.nrel.gov/docs/fy11osti/47692.pdf.

28 Kelsey Misbrener, "8 Minute Solar Energy approved to build 400-MW solar+storage project for City of Los Angeles", Solar Power World, 10 September 2019, https://www.solarpowerworldonline.com/2019/09/8minute-solar-energy-los-angeles-solar-storage/; Los Angeles Department of Water and Power (LADWP), "Renewable Energy Program", https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-renewableenergy/a-p-re-renewableenergypolicy, viewed 15 September 2019; LADWP, "Facts & figures", https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-factandfigures, viewed 15 September 2019.

29 Environment America and Frontier Group, op. cit. note 24.

30 Ibid.

31 Mario Osava, "Energy habits are changing in Latin America's cities", *Inter Press Service*, 24 August 2017, http://www.ipsnews.net/2017/08/energy-habits-changing-latin-americas-cities/.

32 Zafrir Rinat, "Israeli cities take the lead in recycling and renewable energy", Haaretz, 9 March 2018, https://www.haaretz.com/israel-news/israeli-cities-take-the-lead-in-recycling-and-renewable-energy-1.5867242; Eilat-Eilot, "About Eilat-Eilot", http://www.eilatenergy.org/about/, viewed 15 October 2019.

33 Sophie Vorrath, "WA Council to install 200kw solar system at aquatic centre, save USD73k a year", One Step Off the Grid, 15 September 2017, https://onestepoffthegrid.com.au/wa-council-install-200kw-solar-system-aquatic-centre/.

34 Kyle Greene, Town of Vulcan, "Vulcan Solar Park" (2015); David Dodge and Dylan Thompson, "Episode 153. Vulcan builds Canada's first solar park," Green Energy Futures, 5 September 2016, http://www.greenenergyfutures.ca/episode/vulcan-solar-park.

35 IRENA and ICLEI–Local Governments for Sustainability, *City in Focus: Dezhou, China – Green Economic Development with Renewable Energy Industries* (Abu Dhabi: 2013), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/Jan/IRENA-cities-case-1-Dezhou.pdf.

36 **Box 2** based on the following sources: REN21, op. cit. note 6; RE100, *RE100 Progress and Insights Annual Report, November 2018* (London, New Delhi and New York: 2018), http://media.virbcdn.com/files/fd/868ace70d5d2f590-RE100ProgressandInsightsAnnualReportNovember2018.pdf; RE100, "Companies", http://there100.org/companies, viewed 10 October 2019; City of Chicago, "Chicago Renewable Energy Challenge", https://www.chicago.gov/city/en/progs/env/chicago-renewable-energy-challenge-program.html, viewed 9 October 2019.

37 Droege, op. cit. note 1; Adele Peters, "Ikea just invested in two giant solar farms", *Fast Company*, 16 September 2019, https://www.fastcompany.com/90404732/ikea-just-invested-in-two-giant-solar-farms.

38 Apple, "Apple now globally powered by 100 percent renewable energy", press release (Cupertino, CA: 9 April 2018), https://www.apple.com/newsroom/2018/04/apple-now-globally-powered-by-100-percent-renewable-energy/.

39 Ibid.

40 Target, *Future at Heart: 2019 Corporate Responsibility Report* (Minneapolis, MN: 2019), https://corporate.target.com/_media/TargetCorp/csr/pdf/2019_corporate_responsibility_report.pdf.

41 Sophie Vorrath, "Shopping center solar roll-out claims biggest PV array, biggest battery", RenewEconomy, 4 May 2018, https://reneweconomy.com.au/shopping-centre-solar-roll-claims-biggest-pv-array-biggest-battery-57305/.

42 "R16 million solar farm installed on top of Joburg shopping centre", Business Tech, 4 October 2017, https://businesstech.co.za/news/energy/202792/r16-million-solar-farm-installed-on-top-of-joburg-shopping-centre/; Jean Marie Takouleu, "Namibia: Coca-Cola sets up off-grid on rooftop at Windhoek plant", Afrik 21, 30 September 2019, https://www.afrik21.africa/en/namibia-coca-cola-sets-up-off-grid-on-rooftop-at-windhoek-plant/; "Property fund boosts energy savings with solar farm at mall", Green Business News Africa, 2 October 2017, http://www.greenbusinessnewsafrica.com/property-fund-boosts-energy-savings-solar-farm-mall/.

43 Takouleu, op. cit. note 42.

44 Timon Singh, "Vatican City crowned the 'Greenest State in the World'", Blue Channel 24, 12 May 2013, https://bluechannel24web.wordpress.com/2013/05/12/vatican-city-crowned-the-greenest-state-in-the-world/.

45 Marcelo M. Pedalino, "Diocese Maasin uses sun's energy to power churches", Philippine Information Agency, 12 February 2018, https://pia.gov.ph/news/articles/1004948.

46 Adela Suliman, "With green mosques and schools Amman pushes for net-zero emissions", *Reuters*, 30 October 2018, https://www.reuters.com/article/jordan-climatechange-solar/feature-with-green-mosques-and-schools-amman-pushes-for-zero-emissions-idUSL8N1WP5RA.

47 Emiliano Bellini, "Jordan's plan to have solar on all mosques moves forward", pv magazine, 12 July 2019, https://www.pv-magazine.com/2019/07/12/jordans-plan-to-have-solar-on-all-mosques-moves-forward/; Adela Suliman, "Feature: With green mosques and schools, Amman pushes for zero emissions", *Reuters*, 30 October 2018, https://www.reuters.com/article/jordan-climatechange-solar/feature-with-green-mosques-and-schools-amman-pushes-for-zero-emissions-idUSL8N1WP5RA; "Temple Beth El's solar roof paying dividends", *Stamford Advocate*, 27 June 2014, https://www.stamfordadvocate.com/business/article/Temple-Beth-El-s-solar-roof-paying-dividends-5568612.php.

48 Louise Osborne, "Solar panels make Morocco's mosques a model for green energy", Deutsche Welle, 20 February 2017, https://www.dw.com/en/solar-panels-make-moroccos-mosques-a-model-for-green-energy/a-37583670; Jewish Climate Action Network, "Solar synagogues", https://www.jewishclimate.org/solar-for-synagogues, viewed 19 October 2019; Power Generation Advancement, "Temple Aliyah partners with Solect Energy and PowerOptions to install 81 kW rooftop solar array", https://www.powergenadvancement.com/news/temple-aliyah-partners-with-solect-energy-and-poweroptions-to-install-81-kw-rooftop-solar-array/, viewed 15 September 2019; Lisa Webber, "Congregation Har HaShem completes 50 kW solar PV project", Boulder Jewish News, 5 December 2017, https://boulderjewishnews.org/2017/congregation-har-hashem-completes-50-kw-solar-pv-project/; Energy Sage, "Solar panels for churches: How congregations benefit from solar", https://news.energysage.com/solar-panels-for-churches/, viewed 12 September 2019.

49 Energy Sector Management Assistance Program, *Proven Delivery Models for LED Public Lighting: Synthesis of Six Case Studies* (Washington, DC: World Bank, 2017), https://openknowledge.worldbank.org/handle/10986/25336.

50 Ibid.

51 SunMaster, "The advantages and disadvantages of solar street lights", https://www.solarlightsmanufacturer.com/the-advantages-and-disadvantages-of-solar-street-lights/, viewed 19 October 2019.

52 Covenant of Mayors for Climate & Energy, op. cit. note 4.

53 Savings are referring to the United for Efficiency (U4E) Minimum Ambition Scenario and to the 156 targeted countries of U4E. See U4E, "Savings and Policy Assessments", https://united4efficiency.org/countries/country-assessments/, viewed 19 November 2019, and United Nations Environment Programme (UNEP), Global Environment Facility (GEF) and U4E, *Accelerating the Global Adoption of Energy-Efficient Lighting* (Nairobi: 2017), https://united4efficiency.org/wp-content/uploads/2017/04/U4E-LightingGuide-201703-Final.pdf.

54 UNEP, GEF and U4E, *Accelerating the Global Adoption of Energy-Efficient Lighting*, op. cit. note 52.

55 Ankit Gupta and Aditya Singh Bais, *Solar Street Lighting Market Size by Product (Standalone, Grid Connected), By Luminaries (LED, CFL), by Application (Residential, Commercial, Industrial), by Analysis Report, Regional Outlook, Growth Potential, Price Trends, Competitive Market Share & Forecast, 2018-2024* (Selbyville, DE: Global Market Insights, 2018), https://www.gminsights.com/industry-analysis/solar-street-lighting-market.

56 Ibid.

57 Ibid.

58 Ibid.

59 Enkonn, "20w integrated solar street light installed in the resident area of Beijing China", https://enkonn-solar.com/20w-integrated-solar-street-light-installed-resident-area-beijing-china/, viewed 10 November 2019; "Sin City going green: Las Vegas to use solar and pedestrian power for street lights", New Atlas, 10 March 2016, https://newatlas.com/engoplanet-solar-kinetic-street-light/42249/; Digitalgov, "Barcelona switches to smart lighting", 2 May 2015, https://digitalgov.com.au/barcelona-switches-to-smart-lighting/; Amsterdam Smart City, "Smart Solar Street Lights", https://amsterdamsmartcity.com/products/smart-solar-street-lights, viewed 10 November 2019.

60 Ross Gillard et al., *Sustainable Urban Infrastructure for All: Lessons on Solar-powered Street Lights from Kampala and Jinja, Uganda* (Washington, DC: Coalition for Urban Transitions, 2019), http://newclimateeconomy.net/sites/default/files/cut19_frontrunners_streetlighting_final.pdf.

61 Ibid.

62 Gigawatt Global, "Solar street lights illuminate Bujumbura, Burundi", press release (Bujumbura, Burundi: 19 July 2017), https://www.globenewswire.com/news-release/2017/07/19/1054218/0/en/Solar-Street-Lights-Illuminate-Bujumbura-Burundi.html; Fonroche Lighting, "Fonroche Lighting wins world's largest solar streetlamp project, covering 30% of Senegal", press release (Dakar, Senegal: 2 February 2018), https://www.fonroche-lighting.com/fichier_article/files/CP-fonroche-eclairage_senegal-02fev18_EN.pdf; Sauli Giliard, "Solar powered street lights boost Lindi women's businesses", All Africa, 24 April 2019, https://allafrica.com/stories/201904240725.html; Fonroche Lighting, "Off grid solar street lighting for local authorities and businesses – Fonroche solar lamps light up the

Ouagadougou-Lomé highway", 15 September 2017, https://www.fonroche-lighting.com/n-installation%20of%20%20off-grid%20solar%20street%20lighting%20in%20Burkina-99.html; "Germany and Kenya launch project to install 1 million solar streetlight", Coastweek, 5 April 2014, http://www.coastweek.com/3714-latest-news-Germany-Kenya-launch-solar-streetlight-project.htm.

63 **Sidebar 6** based on the following sources: Victor Olgyay, "Designing a climate-positive future with zero-energy districts", Rocky Mountain Institute (RMI), 23 September 2019, https://rmi.org/designing-a-climate-positive-future-with-zero-energy-districts/; C40 Cities, "The Net Zero Carbon Buildings Declaration", https://www.c40.org/other/net-zero-carbon-buildings-declaration, viewed 2 October 2019; World Green Building Council, "What is net zero?" https://www.worldgbc.org/advancing-net-zero/what-net-zero, viewed 18 June 2019; The Energy Mix, "19 cities, combined population 130 million, pledge net-zero carbon buildings by 2030", 26 August 2018, https://theenergymix.com/2018/08/26/19-cities-combined-population-130-million-pledge-net-zero-carbon-buildings-by-2030/; World Green Building Council (WGBC), "Commitment signatories", https://www.worldgbc.org/commitment-signatories?cat=all, viewed 18 June 2019; WGBC, "The Net Zero Carbon Buildings Commitment", https://www.worldgbc.org/thecommitment, viewed 18 June 2019; International Institute for Sustainable Development SDG Knowledge Hub, "Leaders launch initiative to decarbonise buildings by 2050", 1 October 2019, http://sdg.iisd.org/news/leaders-launch-initiative-to-decarbonize-buildings-by-2050/; Better Buildings Initiative, "Zero energy districts", https://betterbuildingsinitiative.energy.gov/accelerators/zero-energy-district, viewed 24 June 2019; Victor Olgyay and Iain Campbell, "An integrative business model for net-zero energy districts", in Droege, op. cit. note 1, pp. 445-456; Molly Miller, "New zero-energy districts: A mile high and growing", GreenBiz, 4 January 2017, https://www.greenbiz.com/article/new-zero-energy-districts-mile-high-and-growing; Matt Jungclaus, "Driving industrial revitalisation with net-zero energy", RMI, 16 April 2018, https://rmi.org/driving-industrial-revitalization-with-net-zero-energy/; Seth Coan, "Designing the city of the future and the pursuit of happiness", RMI, 16 September 2019, https://rmi.org/designing-the-city-of-the-future-and-the-pursuit-of-happiness/.

64 REN21, op. cit. note 6.

65 Mireya Navarro, "City issues rule to ban dirtiest oils at buildings", *New York Times*, 21 April 2019, https://www.nytimes.com/2011/04/22/nyregion/new-york-city-bans-dirtiest-heating-oils-at-buildings.html; Ian Willoughby, "Prague plans ban on coal heating using outmoded stoves and boilers", Radio Prague International, 9 September 2019, https://www.radio.cz/en/section/business/prague-plans-ban-on-coal-heating-using-outmoded-stoves-and-boilers; Krystina Shveda, "Poland air pollution: Why Krakow's domestic coal ban is a big deal", Unearthed, 21 January 2016, https://unearthed.greenpeace.org/2016/01/21/poland-air-pollution-krakow-coal-ban/.

66 Ibid., all references.

67 Werner Weiss and Monika Spörk-Dür, *Solar Heat Worldwide. Global Market Development and Trends in 2018, Detailed Market Figures 2017* (Gleisdorf, Austria: IEA Solar Heating and Cooling Programme (SHC), 2019), https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2019.pdf; REN21, op. cit. note 6.

68 Center for Clean Air Policy, *Solar Thermal Ordinance for Efficient Water Heating in Barcelona* (Washington, DC: 2012), http://ccap.org/assets/CCAP-Booklet_Spain.pdf.

69 Bärbel Epp and Eugene Gerden, "Solar retrofit of Kiev's childcare facilities", Solarthermalworld.org, 18 December 2018, https://www.solarthermalworld.org/news/solar-retrofit-kievs-childcare-facilities.

70 Leticia Sother, "Sun provides 70% of hot water in blocks of flats", Solarthermalworld.org, 13 December 2017, https://www.solarthermalworld.org/news/sun-provides-70-hot-water-blocks-flats. The system at the sports club in Belo Horizonte is planned to meet 70% of the water heating demand for five pools, including an Olympic-sized pool and three large changing rooms, from Leticia Sother, "3,300 m^2 for sports club in Brazil", Solarthermalworld.org, 8 August 2018, https://www.solarthermalworld.org/content/3300-m2-sports-club-brazil.

71 Marisol Oropeza, "Big solar plans in Mexico City", Solarthermalworld.org, 24 June 2019, https://www.solarthermalworld.org/news/big-solar-plans-mexico-city.

72 Mexico City also is providing direct incentives to businesses that install solar water heaters, from Marisol Oropeza, "Solar heat in 10 Mexico city hospitals", Solarthermalworld.org, 27 August 2018, https://www.solarthermalworld.org/news/solar-heat-10-mexico-city-hospitals.

73 Bärbel Epp, "Promoting solar heat in Panama", Solarthermalworld.org, 20 June 2019, https://www.solarthermalworld.org/news/promoting-solar-heat-panama.

74 Bärbel Epp, "Successful solar energy bylaw in Bengaluru, India", Solarthemalworld.org, 17 August, 2018, https://www.solarthermalworld.org/news/successful-solar-energy-bylaw-bengaluru-india.

75 Weiss and Spörk-Dür, op. cit. note 67.

76 Ibid.

77 Jen Anesi-Brombach, "Arizona high school utilizes solar cooling", *Plumbing & Mechanical*, 25 November 2016, https://www.pmmag.com/articles/100246-arizona-high-school-utilizes-solar-cooling; Fahrenheit, "First adsorption solar cooling project in Saudi Arabia", 13 May 2018, https://fahrenheit.cool/en/first-adsorption-solar-cooling-project-in-saudi-arabia/; Bärbel Epp and Eugene Gerden, "IKEA stores begin to switch over to solar heating and cooling", Solarthermalworld.org, 13 February 2018, https://www.solarthermalworld.org/news/ikea-stores-begin-switch-over-solar-heating-and-cooling; Jaideep Malaviya, "First cooling installation on Indian government building", 10 April 2018, Solarthermalworld.org, https://www.solarthermalworld.org/news/first-cooling-installation-indian-government-building; Colin Jeffrey, "Solar-powered air-com uses heat to cool shopping center", New Atlas, 20 June 2016, https://newatlas.com/solar-thermal-energy-cooling-csiro/43908/.

78 C40 Cities and UNEP, *Good Practice Guide: District Energy* (Paris: 2016), http://www.districtenergyinitiative.org/sites/default/files/publications/1c40gpgdeoriginal-21092017534.pdf.

79 Euroheat & Power, *Country by Country 2017* (Brussels: 2018), Executive Summary, https://www.euroheat.org/publications/country-country-2017/; IRENA, *Renewable Energy in District Heating and Cooling: A Sector Roadmap for REmap* (Abu Dhabi: 2017), p. 12, http://www.irena.org/documentdownloads/publications/irena_remap_dhc_report_2017.pdf.

80 IRENA, *op. cit. note 79,* p. 3.

81 Based on examples and sources cited in this section.

82 Euroheat & Power, "Top district heating countries – 2015 survey analysis", Solarthermalworld.org, 1 July 2016, https://www.euroheat.org/news/district-energy-in-the-news/top-district-heating-countries-euroheat-power-2015-survey-analysis/.

83 Dominik Rutz et al., *Upgrading the Performance of District Heating Networks: Technical and Non-technical Approaches* (Munich, Germany: Upgrade DH, 2019), https://www.upgrade-dh.eu/images/Publications%20and%20Reports/D2.5_2019-07-02_Upgrade-DH_Handbook_EN.pdf.

84 Ibid.

85 Sven Werner, "International review of district heating and cooling", *Energy*, vol. 137 (2017), pp. 617-31, https://www.sciencedirect.com/science/article/pii/S036054421730614X; IHK Berlin, *Wettbewerb im Wärmemarkt* (Berlin: 2015), https://www.ihk-berlin.de/blob/bihk24/politische-positionen-und-statistiken_channel/innovation/Politische_Positionen/Download/2677756/88545169b428ef6417b4906411744599/Kurzgutachten-Waermemarkt-data.pdf; SmartEnCity, "Tartu – From Hrustsovkas to Smartkovskas", https://smartencity.eu/about/lighthouse-cities/tartu-estonia/, viewed 12 November 2019.

86 Euroheat & Power, "District energy in Iceland", 1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-iceland/; Euroheat & Power, "District energy in Norway", 1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-norway/.

87 Euroheat & Power, "District energy in Switzerland", 1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-switzerland/; Euroheat & Power, "District energy in France", 1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-france/; Euroheat & Power, "District energy in Lithuania", 1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-lithuania/; Euroheat & Power, "District Energy in Denmark",

1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-denmark/.

88 Bärbel Epp and Eugene Gerden, "In Russia, world's largest DH sector needs upgrading", Solarthermalworld.org, 20 March 2019, https://www.solarthermalworld.org/news/russia-worlds-largest-dh-sector-needs-upgrading.

89 Euroheat & Power, "District energy in China", 1 May 2017, https://www.euroheat.org/knowledge-hub/district-energy-china/.

90 David Benazeraf, "Heating Chinese cities while enhancing air quality", OECD/IEA, 21 December 2017, https://www.iea.org/newsroom/news/2017/december/commentary-heating-chinese-cities-while-enhancing-air-quality.html.

91 Euroheat & Power, op. cit. note 89.

92 US Energy Information Administration (EIA), *U.S. District Energy Services Market Characterization* (Washington, DC: February 2018), https://www.districtenergy.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=44c35916-f1af-6bed-2fed-823299b36bde&forceDialog=0.

93 Ibid. See, for example, City of Boise, "Geothermal", https://www.cityofboise.org/departments/public-works/geothermal/, viewed 5 November 2019, and Ever Green Energy, "District Energy St. Paul", http://www.ever-greenenergy.com/project/district-energy-st-paul/, viewed 5 May 2019.

94 City of Boise, op. cit. note 93.

95 District Energy in Cities Initiative, "District Energy lights up across Chile", 18 October 2019, http://www.districtenergyinitiative.org/district-energy-lights-across-chile-applies-gef.

96 OECD/IEA, *Renewables 2018* (Paris: 2018), p. 137, https://www.iea.org/renewables2018.

97 Ibid., p. 137.

98 AEE Intec, *District Heating in Austria* (Gleisdorf, Austria: 2015), www.aee-intec.net.

99 Karin Jensen, "The path to emisions-free district heating in Denmark", FORESIGHT Climate and Energy, 26 April 2019, https://foresightdk.com/the-path-to-emissions-free-district-heating-in-denmark/.

100 Karin Ericsson and Sven Werner, "The introduction and expansion of biomass use in Swedish district heating systems", *Biomass and Bioenergy*, vol. 94 (November 2016), pp. 57-65, https://www.sciencedirect.com/science/article/pii/S0961953416302793.

101 Euroheat & Power, "District energy in Lithuania", op. cit. note 87.

102 Veolia, "District heating services", https://www.veolia.hu/en/node/296, viewed 14 November 2019.

103 Veolia, "The town of Pécs is heated with straw!" Living Circular, 25 November 2016, https://www.livingcircular.veolia.com/en/industry/town-pecs-hungary-heated-straw.

104 IRENA, op. cit. note 79; KlimaAktiv, *Bioenergy in Austria: A Factor Creating Added Value* (Graz, Austria: 2017), http://www.aebiom.org/wp-content/uploads/2016/10/Folder_Bioenergy_in_Austria_AA-5.pdf.

105 Ever Green Energy, op. cit. note 93.

106 REN21, op. cit. note 6. Heat capacity and output is an extrapolation from five-year growth rates calculated from generation and capacity data for 2009 and 2014, from John W. Lund and Tonya L. Boyd, "Direct utilization of geothermal energy 2015 worldwide review", *Geothermics*, vol. 60 (March 2016), pp. 66-93, http://dx.doi.org/10.1016/j.geothermics.2015.11.004. Capacity and generation for 2018 are extrapolated from 2014 values (from sources, latest available data) by weighted average growth rate across eight categories of geothermal direct use: space heating, bathing and swimming, greenhouse heating, aquaculture, industrial use, snow melting and cooling, agricultural drying and other" (data for 2014).

107 Data are for 2018, from Orkustofnun Data Repository OS-2019-T007-0, 1 October 2019, p. 1, https://orkustofnun.is/gogn/Talnaefni/OS-2019-T007-01.pdf. Most of Iceland's population (92%) is served by district heat networks supplied entirely (or nearly so) by high-temperature geothermal energy, from Euroheat & Power, "District energy in Iceland", op. cit. note 86.

108 PannErgy, "Successful drilling operation on a new concession well around Győr, preparations for the heating season", press release (Budapest, Hungary: 24 September 2018), http://pannergy.com/wp-content/uploads/2018/09/PE_Gyor_BON03_heatingseason_20180924_exe_en.pdf; PannErgy, "Geothermal system of Győr deployed, final test results of the new production well in Bőny", press release (Budapest, Hungary: 29 October 2018), http://pannergy.com/wp-content/uploads/2018/10/PE_gyor_BON03_20181029_en_final.pdf.

109 "Géothermie en profondeur: premiers résultats encourageants pour l'Eurométropole de Strasbourg", France 3, 18 April 2018, https://france3-regions.francetvinfo.fr/grand-est/geothermieprofondeur-premiers-resultats-encourageants-eurometropolestrasbourg-1461229.html; GPC IP, "A second subhorizontal well successfully completed and tested at Cachan (Paris Basin, France)", press release (Paris: undated), http://www.geoproduction.fr/fr/actualite/press-release-subhorizontal-geothermal-wellarchitecture-proven-concept; Dalkia, "Géothermie: premier forage sub-horizontal mondial à Cachan", December 2017, https://www.dalkia.fr/fr/espace-presse/communique-de-presse/geothermie-premier-forage-sub-horizontal-mondial-cachan.

110 Bundesverband Geothermie, "Tiefe Geothermieprojekte in Deutschland" (Berlin: January 2019), https://www.geothermie.de/fileadmin/user_upload/Geothermie/Geothermie_in_Zahlen/Projektliste_Tiefe_Geothermie_Januar_2019.pdf.

111 Stadtwerke München, "Geothermie-Anlage beim Heizkraftwerk Süd", https://www.swm.de/privatkunden/unternehmen/energieerzeugung/geothermie.html, viewed March 2019; Christine Croniger, "Geothermal district heating for Munich", presentation at Baltic Nations Geothermal Symposium, Offenburg, Germany, 13 February 2019, http://iea-gia.org/publications-2/working-group-publications/2019-baltic-nations-symposium-presentations/; Landeshauptstadt München, "Klimaneutralität 2050", https://www.muenchen.de/rathaus/Stadtverwaltung/Referat-fuer-Gesundheit-und-Umwelt/Klimaschutz_und_Energie/Klimaneutralitaet.html, viewed April 2019.

112 REN21, op. cit. note 6.

113 **Figure 13** from Weiss and Spörk-Dür, op. cit. note 67.

114 Ibid., p. 13.

115 PlanEnergi, "Solar district heating in Denmark 1988-2018", http://planenergi.eu/activities/district-heating/solar-district-heating/sdh-in-dk-1988-2018/, viewed 14 November 2019.

116 IEA SHC Task 55, http://task55.iea-shc.org/, viewed 18 November 2019.

117 Bärbel Epp, "Record participation at SDH 2018 in Graz", Solarthermalworld.org, 3 May 2018, https://www.solarthermalworld.org/content/record-participation-sdh-2018-graz; Bärbel Epp, "Five new solar-bioenergy villages in Germany", Solarthermalworld.org, 4 February 2019, https://www.solarthermalworld.org/content/five-new-solar-bioenergyvillages-germany.

118 Alejandro Diego Rosell, "First Spanish solar district heating system for 12,000 families", Solarthermalworld.org, 7 May 2018, https://www.solarthermalworld.org/news/first-spanish-solar-district-heating-system-12000-families.

119 Bärbel Epp, "SDH – a proven technology with a long track record of success", Solarthermalworld.org, 29 January 2019, https://www.solarthermalworld.org/content/sdh-proven-technology-long-track-record-success; Bärbel Epp, "Solar hot water system at Jordanian hospital pays off in 4.4 years", Solarthermalworld.org, 20 November 2019, https://www.solarthermalworld.org/news/solar-hot-water-system-jordanian-hospital-pays-44-years; Sashnee Moodley, Marleny Arnoldi and Natasha Odendaal, "Wits launches first solar district heating system in South Africa", Engineering News, June 2019, https://www.engineeringnews.co.za/article/wits-launches-first-solar-district-heating-system-in-south-africa-2019-06-19.

120 Bärbel Epp, "Solar district heating on the roof of the world", Solarthermalworld.org, 27 February 2018, https://www.solarthermalworld.org/news/solar-district-heating-roof-world; Bärbel Epp, "Sun meets 90 % of district heat demand in Tibet", Solar District Heating, 17 December 2018, https://www.solar-district-heating.eu/sun-meets-90-of-district-heat-demand-in-tibet/; Bärbel Epp, "SDH system under construction in Latvia, soon in Tibet", Solarthermalworld.org, 9 July 2019, https://www.solarthermalworld.org/news/sdh-system-under-construction-latvia-soon-tibet.

121 Bärbel Epp, "Kyrgyzstan's capital sees 0.5 MW SDH plant being built", Solarthermalworld.org, 19 December 2017, https://www.solarthermalworld.org/news/kyrgyzstans-capital-sees-05-mw-sdh-plant-being-built.

122 FILTER SIA, *Solar Thermal District Plan Inauguration* (Salaspils, Latvia: September 2019), https://www.hyxo.ru/images/PRESS/Salaspils_Siltums_Inauguration_Event_Report-12092019-v2.pdf.

123 Bärbel Epp, "Construction starts on Germany's largest SDH plant", Solarthermalworld.org, 2 August 2019, https://www.solarthermalworld.org/news/construction-starts-germanys-largest-sdh-plant.

124 Bärbel Epp, "SDH system under construction in Latvia, soon in Tibet", op. cit. note 120.

125 Engie, *2019 Integrated Report* (Paris: 2018), https://www.engie.com/wp-content/uploads/2019/06/engie_ri_2019_va_v2_12-06-19.pdf.

126 Vattenfall, "Vattenfall invests for fossil free district heating in Amsterdam", press release (Stockholm: 3 April 2019), https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2019/vattenfall-invests-for-fossil-free-district-heating-in-amsterdam.

127 China Petrochemical Corporation (Sinopec), "Sinopec launches green action plan", 11 April 2018, http://www.sinopecgroup.com/group/en/Sinopecnews/20180411/news_20180411_536665179295.shtml.

128 Sinopec, "2018 China Geothermal Energy International Forum held in Shanghai", 30 November 2018, http://www.sinopecgroup.com/group/en/Sinopecnews/20181130/news_20181130_408440241391.shtml; "Geothermal heating helps build 'smokeless cities' in China", SINA, 12 December 2018, http://english.sina.com/china/s/2018-12-12/detail-ihmutuec8358863.shtml; Sinopec, op. cit. note 127.

129 The Berlin project supplies buildings at Potsdamer Platz, from Gunnar Schmidt, "Was passiert in der Berliner Kältezentrale?" Vattenfall, 14 May 2018, https://group.vattenfall.com/de/newsroom/blog-news-presse/blog/2018/mai/was-passiert-in-der-berliner-kaltezentrale. The Hamburg project was originally built in the late 1960s to provide cooling energy to the local office buildings and is being expanded with new cooling units to supply virtually all buildings in the City North district of Hamburg, from Nils Pteresen, "Kälte mit Zukunft für die City Nord", Vattenfall, 22 August 2018, https://group.vattenfall.com/de/newsroom/blog-news-presse/blog/2018/august/fernkalte-fur-die-city-nord. Dubai from Tabreed, "The region's cooling partner of choice", https://www.tabreed.ae/, viewed 15 November 2019; Geneva from Luigi Jorio, "How to get heat from the bottom of a lake", Swiss Info, 7 October 2015, https://www.swissinfo.ch/eng/renewable-energy_how-to-get-heat-from-the-bottom-of-a-lake/41700430; Enwave, "Enwave and Toronto Water tap into innovative energy source", https://www.enwave.com/case-studies/enwave-and-toronto-water-tap-into-innovative-energy-source/, viewed 13 November 2019.

130 Gaurangkumar Patel, "India's first district cooling system at GIFT City", Rehva, January 2018, https://www.rehva.eu/rehva-journal/chapter/indias-first-district-cooling-system-at-gift-city; Engie, "District heating and cooling systems", 2017, https://www.engie.com/en/businesses/district-heating-cooling-systems/; Doris Dumlao-Abadilla, "PH's largest district cooling system plant switched on", Daily Inquirer, 21 September 2017, https://business.inquirer.net/237248/phs-largest-district-cooling-system-dcs-switched.

131 "UAE's Tabreed to build India's first district cooling system in Amaravati", *Times of India*, 14 February 2019, https://timesofindia.indiatimes.com/india/uaes-tabreed-to-build-indias-first-district-cooling-system-in-amaravati/articleshow/67992502.cms; District Energy in Cities Initiative, "Amaravati will be India's first state capital to have district cooling", 6 February 2019, http://www.districtenergyinitiative.org/amaravati-will-be-indias-first-state-capital-have-district-cooling; District Energy in Cities Initiative, "Cooling smart cities, Rajkot leads the way", press release (Rajkot, India: 7 February 2019), http://www.districtenergyinitiative.org/cooling-smart-cities-rajkot-leads-way.

132 Euroheat & Power, "A breakthrough in Singapore's district cooling industry", 6 March 2019, https://www.euroheat.org/news/breakthrough-singapores-district-cooling-industry/.

133 Bärbel Epp, "First district cooling regulation in the MENA region", Solarthermalworld.org, 18 November 2019, https://www.solarthermalworld.org/news/first-district-cooling-regulation-mena-region.

134 Ibid.

135 Based on OECD/IEA, *World Energy Balances and Statistics*, 2018 edition (Paris: 2018), https://www.iea.org/statistics/balances/.

136 OECD / International Transport Forum (ITF), *ITF Transport Outlook 2017* (Paris: 2017), https://www.itf-oecd.org/transport-outlook-2017.

137 OECD/IEA, *A Tale of Renewed Cities* (Paris: 2013), https://www.iea.org/publications/freepublications/publication/Renewed_Cities_WEB.pdf. Calculations based on OECD/ITF, *ITF Transport Outlook 2019* (Paris: 2019), https://read.oecd-ilibrary.org/transport/itf-transport-outlook-2019_transp_outlook-en-2019-en#page30.

138 Sustainable Urban Transport Project, *Urban Transport and Health* (Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2014), https://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB5_Environment%20and%20Health/GIZ_SUTP_SB5g_Urban-Transport-and-Health_EN.pdf.

139 Ibid.

140 C40 Cities and ARUP, *Climate Action in Megacities 3.0* (London: 2015), http://www.cam3.c40.org/images/C40ClimateActionInMegacities3.pdf.

141 Ibid.; Commercial Vehicle Drive to Zero, "Pledge partners", https://globaldrivetozero.org/about/pledge-partners/, viewed 14 November 2019; ICLEI-Local Governments for Sustainability, "Projects: BuyZET", http://iclei-europe.org/projects/?c=search&uid=pAf4DgdT, viewed 14 November 2019.

142 Partnership on Sustainable, Low Carbon Transport (SLoCaT), *Transport and Climate Change 2018 Global Status Report* (Shanghai: 2018), http://slocat.net/sites/default/files/slocat_transport-and-climate-change-2018-web.pdf; Urda Eichhorst, Daniel Bongardt and Victoria Novikova, *Compendium on Greenhouse Gas Baselines and Monitoring: Passenger and Freight Transport,* second edition (Bonn: United Nations Framework Convention on Climate Change and United Nations Development Programme, 2018), https://www.changing-transport.org/wp-content/uploads/2018_Compendium_Passenger_and_Freight_Transport_Volume.pdf; IRENA, op. cit. note 4.

143 Daniel Bongardt et al., Transformative Urban Mobility Initiative, *Sustainable Urban Transport: Avoid – Shift – Improve (A-S-I)* (Bonn and Eshborn, Germany: GIZ, 2019), https://sutp.org/files/contents/documents/resources/L_iNUA/ASI_TUMI_SUTP_iNUA_April%202019.pdf.

144 **Figure 14** from REN21, op. cit. note 6.

145 World Bioenergy Association, *WBA Fact Sheet: Biofuels for Transport* (Stockholm: 2013), https://worldbioenergy.org/uploads/Factsheet%20-%20Biofuels%20for%20transport.pdf.

146 OECD/IEA, "Transport biofuels", https://www.iea.org/tcep/transport/biofuels/, viewed 1 November 2019.

147 OECD/IEA, *Oil 2018: Analysis and Forecasts to 2023* (Paris: 2018), pp. 77, 134, http://www.oecd.org/publications/market-report-series-oil25202707.htm.

148 Calculated from OECD/IEA, op. cit. note 135.

149 OECD/IEA, "Biofuels", https://www.iea.org/tcep/transport/biofuels/, viewed 5 November 2019.

150 David Thorpe, "Dubai is the first city to run its vehicles on waste cooking oil", Business Insider, 9 February 2015, https://www.businessinsider.com/dubai-is-the-first-city-to-run-its-vehicles-on-waste-cooking-oil-2015-2.

151 US Department of Energy, Alternative Fuels Data Center, "Green fuelling station powers fleets in upstate New York", 13 October 2016, https://afdc.energy.gov/case/1082.

152 Natural & Biogas Vehicle Association (NGVA) Europe, *Vehicle Catalogue 2019* (Brussels: 2019), https://www.ngva.eu/wp-content/uploads/2019/08/NGVA-Europe_VehicleCatalogue_2019.pdf.

153 IRENA, *Biogas for Road Vehicles: Technology Brief* (Abu Dhabi: 2017), https://www.irena.org/publications/2017/Mar/Biogas-for-road-vehicles-Technology-brief; NGVA Europe, op. cit. note 152.

154 EBA, *Biomethane in Transport* (Brussels: 2016), https://www.europeanbiogas.eu/wp-content/uploads/2019/07/Biomethane-in-transport.pdf; Cedigaz, "Global biomethane market: Green gas goes global", press release (Rueil Malmaison, France: 20 March 2019), https://www.cedigaz.org/global-biomethane-market-green-gas-goes-global/.

155 Michele Ziosi, "From waste to biomethane: Fostering circular economy solutions in the Euro-Mediterranean Region", *Istituto Affari Internazionali Commentaries*, vol. 19, no. 55 (October 2019), pp. 1-7, https://www.iai.it/en/pubblicazioni/waste-biomethane-fostering-circular-economy-solutions-euro-mediterranean-region.

156 Based on data from US Environmental Protection Agency, "RIN generation and renewable fuel volume production by fuel type from December 2018", https://www.epa.gov/fuels-registration-reporting-and-compliance-help/spreadsheet-rin-generation-and-renewable-fuel-0, updated February 2018.

157 Argonne National Laboratory, "Renewable Natural Gas Database", https://www.anl.gov/es/reference/renewable-natural-gas-database, viewed 14 November 2019.

158 Ibid.

159 OECD/IEA, op. cit. note 96; Gas Infrastructure Europe, "European biomethane map", https://www.gie.eu/index.php/gie-publications/maps-data/bio-map, viewed 1 November 2019; EBA, op. cit. note 154. Based on an analysis of data within the Eurostat SHARES database that includes data to 2017 for biogas use in the transport sector for each EU country. See Eurostat, "SHARES 2017 detailed results", transport tab, https://ec.europa.eu/eurostat/web/energy/data/shares.

160 Nicolae Scarlat, Jean-François Dallemand and Fernando Fahl, "Biogas: Developments and perspectives in Europe", *Renewable Energy*, vol. 129, Part A (2018), pp. 457-72, https://www.sciencedirect.com/science/article/pii/S096014811830301X.

161 IEA Bioenergy, op. cit. note 7.

162 Based on an analysis of data within the Eurostat SHARES database that includes data to 2017 for biogas use in the transport sector for each EU country. See Eurostat, "SHARES 2017 detailed results", op. cit. note 159.

163 Ibid.

164 Liu Zhihua, "Biomethane efforts gaining traction", *China Daily*, 5 June 2019, https://www.chinadaily.com.cn/a/201906/05/WS5cf7252ca31051914270120c.html, viewed 15 November 2019

165 OECD/IEA, "Renewables 2019: Market analysis and forecast from 2019 to 2024: Transport", https://www.iea.org/renewables2019/transport/, viewed 1 November 2019.

166 **Figure 15** from REN21, op. cit. note 6. **Sidebar 7** based on the following sources: IRENA, op. cit. note 4; IRENA, OECD/IEA and REN21, *Renewable Energy Policies in a Time of Transition* (Abu Dhabi: 2018), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_IEA_REN21_Policies_2018.pdf; OECD/IEA, *Global EV Outlook 2019* (Paris: 2019), https://www.iea.org/publications/reports/globalevoutlook2019/; SLoCaT, op. cit. note 142; Oslo and Portland from IRENA, op. cit. note 4; Dubai Electricity and Water Authority, "EV Green Charger FAQ", https://www.dewa.gov.ae/en/consumer/ev-community/ev-green-charger/ev-green-chargers-faq; "UAE's first electric vehicle charging station opens in Dubai", Emirates 24/7, 26 February 2015, https://www.emirates247.com/news/emirates/uae-s-first-electric-vehicle-charging-station-opens-in-dubai-2015-02-26-1.582321; Jean Marie Takouleu, "Egypt: ABB installs first charging station for electric vehicles", Afrik21, 24 November 2018, https://www.afrik21.africa/en/egypt-abb-installs-first-charging-station-for-electric-vehicles/; Dunedin City Council, *The Energy Plan 1.0* (Dunedin, New Zealand: 2017), https://www.dunedin.govt.nz/__data/assets/pdf_file/0019/518131/Energy-Plan-March-2017.pdf; Byron Shire Council and Tweed Shire Council, *Power Up: Northern Rivers Electric Vehicle Strategy* (2017), .

167 OECD/IEA, op. cit. note 166; REN21, op. cit. note 6.

168 Steve Adler, ACCC Meeting, personal communication with World Resources Institute, 10 April 2019.

169 Jean Marie Takouleu, "Morocco: IRESEN tests solar shade for recharging electric vehicles", Afrik21, 2 November 2018, https://www.afrik21.africa/en/morocco-iresen-tests-solar-shade-for-recharging-electric-vehicles/.

170 Smart Solar Charging, "About smart solar charging", https://smartsolarcharging.eu/en/about-smart-solar-charging/, viewed 14 November 2019.

171 Ibid.

172 OECD/IEA, *The Future of Hydrogen* (Paris: 2019), https://www.iea.org/hydrogen2019/.

173 IRENA, *Hydrogen: A Renewable Energy Perspective* (Abu Dhabi: 2019), https://www.irena.org/publications/2019/Sep/Hydrogen-A-renewable-energy-perspective.

174 OECD/IEA, op. cit. note 172.

175 Marc Hudson, "Moreland Council launches hydrogen-powered garbage truck scheme", RenewEconomy, 7 August 2017, https://reneweconomy.com.au/moreland-council-launches-hydrogen-powered-garbage-truck-scheme-35203/.

176 Partners of this Last Mile project include JCDecaux, Galeries Lafayette and other pioneers in zero-emission urban mobility that are committed to transition their fleets to hydrogen vehicles, from Akuo Energy, JCDecaux, Atawey and Galeries Lafayette, "Akuo Energy, Atawey, JCDecaux and Galeries Lafayette are launching hydrogen-powered urban logistics in France", press release (Paris: 10 December 2019), http://www.akuoenergy.com/en/documents/getPdf/cp-last-mile-en.pdf.

177 OECD/IEA, "Transport", https://www.iea.org/tcep/transport/, viewed 1 November 2019.

178 International Association of Public Transport (UITP), *New Urban Rail Infrastructure* (Brussels: 2018), https://www.uitp.org/sites/default/files/cck-focus-papers-files/Statistics%20Brief%20-%20NEW%20URBAN%20RAIL%20INFRASTRUCTURE%202018.pdf.

179 Ibid.

180 OECD/IEA, "Rail", https://www.iea.org/tcep/transport/rail/, viewed 5 November 2019.

181 Eric Vantiegham, "Rail projects around the world run on renewable energy", Midwest Blog, 29 November 2017, https://blog.midwestind.com/rail-projects-around-world-run-renewable-energy/.

182 OECD/IEA, op. cit. note 166.

183 UITP, op. cit. note 178.

184 Ibid.

185 UrbanRail.net, http://www.urbanrail.net/, viewed 15 October 2019.

186 UITP, op. cit. note 178.

187 Mykola Zasiadko, "Melbourne tram network becomes more solar-powered", RailTech.com, 13 August 2019, https://www.railtech.com/policy/2019/08/13/melbourne-tram-network-becomes-more-solar-powered/.

188 "Calgary's wind-powered LRT an incredibly sucessful system: Nenshi", Green Energy Futures, 6 July 2015, http://www.greenenergyfutures.ca/episode/c-train-success-nenshi-calgary.

189 Quintus Vosman, "Amsterdam urban rail switches to renewable energy", *International Railway Journal*, 18 October 2018, https://www.railjournal.com/passenger/light-rail/amsterdam-urban-rail-switches-to-renewable-energy/.

190 Keith Barrow, "Tokyo light rail line to run on renewable energy", *International Railway Journal*, 18 October 2018, https://www.railjournal.com/passenger/light-rail/tokyo-light-rail-line-to-run-on-renewable-energy/.

191 "Qingdao opens fuel cell tram route", Railway Gazette International, 7 March 2016, https://www.railwaygazette.com/qingdao-opens-fuel-cell-tram-route/42177.article.

192 UITP, op. cit. note 178.

193 Ibid.

194 Emiliano Bellini, "SunPower commissions 100 MW solar park in Chile", pv magazine, 11 January 2018, https://www.pv-magazine.com/2018/01/11/sunpower-commissions-100-mw-solar-park-in-chile/.

195 "Delhi Metro trains to now run on solar power too; DMRC gets 27 MW power from Rewa project", *Economic Times*, 18 April 2019, https://economictimes.indiatimes.com/industry/transportation/railways/delhi-metro-trains-to-now-run-on-solar-power-too-dmrc-gets-27-mw-power-from-rewa-project/articleshow/68944024.cms.

196 GIZ, *Renewables in Rail Transport: Approaches and Examples* (Eschborn, Germany: 2014), https://www.sutp.org/files/contents/documents/resources/F_Reading-Lists/GIZ_SUTP_RL_Renewables-in-Rail-Transport_EN.pdf; "El metro, con energía 100% renovable, evita la emisión de 9.359 toneladas de CO2 a la atmósfera en 2017", 20 minutos, 3 February 2018, https://www.20minutos.es/noticia/3252178/0/metro-con-energia-100-renovable-evita-emision-9-359-toneladas-co2-atmosfera-2017/; "Metro de Málaga utilizará energía cien por cien renovable", Energías Renovables, 7 June

2018, https://www.energias-renovables.com/panorama/metro-de-malaga-utilizara-energia-cien-por-20180607.

197 European Commission, "Oslo starts its year as European Green Capital 2019", press release (Brussels: 4 January 2019), https://ec.europa.eu/info/news/oslo-starts-its-year-european-green-capital-2019-2019-jan-04_en.

198 Jean-Paul Rodrigue, "Urban transport challenges", in Jean-Paul Rodrigue, *The Geography of Transport Systems* (New York: Routledge, 2017), https://transportgeography.org/?page_id=4621.

199 Govinda Timilsina and Hari Dulal, "Urban road transportation externalities: Costs and choice of policy instruments", *World Bank Research Observer*, vol. 26, no. 1 (2010), pp. 162-91, http://documents.worldbank.org/curated/en/751701468183286599/pdf/770100JRN0wbro0Box0377291B00PUBLIC0.pdf.

200 Share of 75% from OECD/IEA, op. cit. note 166; more than two-thirds from US EIA, "Transportation sector passenger transport and energy consumption by region and mode", in *International Energy Outlook 2017* (Washington, DC: 2017), https://www.eia.gov/outlooks/aeo/data/browser/#/?id=50-IEO2017&region=0-0&cases=Reference&start=2010&end=2020&f=A&linechart=Reference-d082317.2-50-IEO2017&sourcekey=0.

201 OECD/ITF, op. cit. note 136; OECD/IEA, op. cit. note 135.

202 OECD/IEA, op. cit. note 166.

203 OECD/IEA, *Renewables 2017: Analysis and Forecasts to 2022* (Paris: 2017), www.iea.org/publications/renewables2017/.

204 European Expert Group on Future Transport Fuels, *Future Transport Fuels* (Brussels: 2011), https://ec.europa.eu/transport/sites/transport/files/themes/urban/cts/doc/2011-01-25-future-transport-fuels-report.pdf.

205 Center for Climate and Energy Solutions (C2ES), "Greening city fleets", https://www.c2es.org/2018/11/greening-city-fleets/, viewed 14 November 2019.

206 Ibid.

207 UITP, *The Impact of Electric Buses on Urban Life* (Brussels: 2019), http://www.uitp.org/sites/default/files/cck-focus-papers-files/UITP-policybrief-June2019-V6%20WEB%20-%20OK_0.pdf.

208 UITP, *Global Bus Survey* (Brussels: 2019), http://www.uitp.org/sites/default/files/cck-focus-papers-files/Statistics%20Brief_Global%20bus%20survey%20%28003%29.pdf.

209 Ibid.

210 Aida Abdulah, UITP, "ZeEUS: Bringing e-buses to the heart of public transport", presentation at JASPERS/EIC Workshop, Bucharest, Romania, 24 April 2018, http://www.jaspersnetwork.org/download/attachments/24150588/2.%20Aida%20Abdullah%2C%20UITP.pdf; American Public Transportation Association, *2019 Public Transportation Fact Book* (Washington, DC: 2019), https://www.apta.com/wp-content/uploads/APTA_Fact-Book-2019_FINAL.pdf.

211 "Norwegian city rolls out biogas, biodiesel buses to reduce carbon footprint", Biofuels International, 11 September 2019, https://biofuels-news.com/news/norwegian-city-rolls-out-biogas-biodiesel-buses-to-reduce-carbon-footprint/.

212 Christina Nunez, "Biofuels, explained", *National Geographic*, 15 July 2019, https://www.nationalgeographic.com/environment/global-warming/biofuel/; Mathew Lowry, "Biogas buses are the green solution for cities", EU In My Region, 4 July 2016, https://euinmyregion.blogactiv.eu/2016/07/04/biogas-buses-are-the-green-solution-for-cities/.

213 K T Vinobha, "Mangaluru: Buses run on biofuel made of used cooking oil", *Times of India*, 21 September 2019, https://timesofindia.indiatimes.com/city/mangaluru/mangaluru-buses-run-on-biofuel-made-of-used-cooking-oil/articleshow/71229362.cms.

214 "Public buses to run on biogas in Karachi", Bioenergy News, 3 January 2019, https://www.bioenergy-news.com/display_news/14251/public_buses_to_run_on_biogas_in_karachi/1/; Imran Mukhtar, "Biogas guzzlers: Karachi's public buses to run on cow poo", *Reuters*, 2 January 2019, https://www.reuters.com/article/us-pakistan-transportation-climatechange/biogas-guzzlers-karachis-public-buses-to-run-on-cow-poo-idUSKCN1OW0IW.

215 "First West invests in 77 biomethane buses for Bristol", NGV Global News, 5 July 2019, https://www.ngvglobal.com/blog/first-west-invests-in-77-biomethane-buses-for-bristol-0705.

216 Ziosi, op. cit. note 155.

217 OECD/IEA, op. cit. note 166; Gina Coplon-Newfield and Conner Smith, "For U.S. transit agencies, the future for buses is electric", Sierra Club, 21 February 2019, https://www.sierraclub.org/articles/2019/02/for-us-transit-agencies-future-for-buses-electric; Sustainable Bus, "Electric bus, main fleets and projects around the world", 24 October 2019, https://www.sustainable-bus.com/electric-bus/electric-bus-public-transport-main-fleets-projects-around-world/.

218 OECD/IEA, op. cit. note 166.

219 Brian Eckhouse, "The U.S. has a fleet of 300 electric buses. China has 421,000", *Bloomberg*, 15 May 2019, https://www.bloomberg.com/news/articles/2019-05-15/in-shift-to-electric-bus-it-s-china-ahead-of-u-s-421-000-to-300. **Figure 16** based on data from BloombergNEF, *Electric Vehicle Outlook* (New York: 2019), https://about.bnef.com/electric-vehicle-outlook/, and from China Automotive Information Network, government agencies and news reports.

220 Matthew Keegan, "Shenchen's silent revolution: World's first fully electric bus fleet quietens Chinese megacity", *The Guardian* (UK), 12 December 2018, https://www.theguardian.com/cities/2018/dec/12/silence-shenzhen-world-first-electric-bus-fleet; Michael Coren, "One city in China has more electric buses than all of America's biggest cities have buses", Quartz, 2 January 2018, https://qz.com/1169690/shenzhen-in-china-has-16359-electric-buses-more-than-americas-biggest-citiess-conventional-bus-fleet/.

221 OECD/IEA, op. cit. note 166; C40 Cities, "Case Study: Shenzhen 'New Energy' Vehicle Promotion", 25 July 2018, https://www.c40.org/case_studies/shenzhen-new-energy-vehicle-promotion; Nora Manthey, "1600 new electric car charge points for Berlin," Electrive, 10 January 2019, https://www.electrive.com/2019/01/10/1600-new-electric-car-charge-points-for-berlin/; "Moscow has ordered 100 KAMAZ electric buses", RusAutoNews.com, 27 January 2019, http://rusautonews.com/2019/01/27/moscow-has-ordered-100-kamaz-electric-buses/; "First electric buses have started operating in Moscow in regular transport", RusAutoNews.com, 4 September 2018, http://rusautonews.com/2018/09/04/first-electric-buses-have-started-operating-in-moscow-in-regular-transport/; SLoCaT, op. cit. note 142.

222 Low Carbon Transport South Africa, "UNIDO partners with the City of Tshwane to promote electric vehicles", 9 April 2019, https://www.lctsa.co.za/2019/04/09/unido-partners-with-the-city-of-tshwane-to-promote-electric-vehicles/; Wellington City Council, *Wellington Resilience Strategy 2017* (Wellington, New Zealand: 2017), https://wellington.govt.nz/~/media/about-wellington/resilient-wellington/files/strategy/reslience-strategyj001767-100-web.pdf ; "Abu Dhabi launches Middle East's first electric passenger bus", Arab News, 8 January 2019, http://www.arabnews.com/node/1432361/middle-east.

223 Phil Dzikiy, "Electric buses surging in Latin America, Chile adding to fleet as it aims for all-electric by 2040", Electrek, 24 May 2019, https://electrek.co/2019/05/24/electric-buses-latin-america/.

224 Andrés Bermúdez Liévano, "Latin American cities finally embrace Chinese electric buses", Diálogo Chino, 4 February 2019, https://dialogochino.net/21995-latin-american-cities-finally-embrace-chinese-electric-buses/.

225 SLoCat, "E-mobility trends and targets", http://slocat.net/sites/default/files/e-mobility_overview.pdf, updated 15 March 2019.

226 SLoCat, op. cit. note 142.

227 "First renewable-powered public buses hit US roads", Smart Energy International, 2 May 2019, https://www.smart-energy.com/industry-sectors/electric-vehicles/first-renewable-powered-electric-buses-hit-us-roads-portland/.

228 Sustainable Bus, "Keolis wins a contract for Bergen bus fleet (on renewable energy)", 1 July 2019, https://www.sustainable-bus.com/news/keolis-wins-a-contract-for-bergen-bus-fleet-on-renewable-energy/.

229 OECD/IEA, op. cit. note 172.

230 Chris Randall, "H2Bus consortium is born", Electrive, 4 June 2019, https://www.electrive.com/2019/06/04/h2bus-consortium-brought-into-life/.

231 The Tokyo Metropolitan Government targets 150 hydrogen stations, 6,000 gas fuel vehicles, and 100 gas fuel public buses

by 2020 and 250 station and 100,000 gas fuel vehicles by 2025, from S.K., "Tokyo's surprise for the 2020 Olympics – Hydrogen, the energy for next generation", Harvard Business School, Technology and Operations Management, 15 November 2017, https://digital.hbs.edu/platform-rctom/submission/tokyos-surprise-for-the-2020-olympics-hydrogen-the-energy-for-next-generation/.

232 Calculated based on OECD/ITF, op. cit. note 137.

233 Toni Lindau, "Transport plays a key role in urban air quality", WRI, 3 February 2015, https://www.wri.org/blog/2015/02/transport-plays-key-role-urban-air-quality.

234 Aria Bendix, "15 major cities around the world that are starting to ban cars", Business Insider, 12 January 2019, https://www.businessinsider.es/cities-going-car-free-ban-2018-12?page=5.

235 Ibid.; European Automobile Manufacturers Association (ACEA), "Passenger cars", https://www.acea.be/automobile-industry/passenger-cars, viewed 14 November 2019; ACEA, "Share of alternatively-powered vehicles in the EU fleet", https://www.acea.be/statistics/tag/category/share-of-alternative-fuel-vehicles-per-vehicle-segment, viewed 14 November 2019.

236 Johannes Pagenkopf et al., "Transport transition concepts", in *Achieving the Paris Climate Agreement Goals*, 2019, pp. 131-59, https://link.springer.com/chapter/10.1007/978-3-030-05843-2_6.

237 Mehmet Ilhan Ilhak et al., "Alternative fuels for internal combustion engines", in Antonio Carlucci, *The Future of Internal Combustion Engines* (2019), https://www.intechopen.com/books/the-future-of-internal-combustion-engines/alternative-fuels-for-internal-combustion-engines.

238 Ricardo Energy & Environment, *The Role of Natural Gas and Biomethane in the Transport Sector* (Harwell, UK: 2016), https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf.

239 **Figure 17** from OECD/IEA, op. cit. note 166.

240 Ibid.

241 Ibid.

242 Ibid.

243 Ibid.

244 Zachary Shahan, "Tesla Model 3 = #1 best selling electric car in world, 7% of global EV market in 2018", CleanTechnica, 9 February 2019, https://cleantechnica.com/2019/02/09/tesla-model-3-1-best-selling-electric-car-in-world-7-of-global-ev-market/.

245 Dale Hall, Hongyang Cui and Nic Lutsey, "Electric vehicle capitals of the world: What markets are leading the transition to electric?" (Washington, DC: International Council on Clean Transportation, 2017), p. 4. http://www.theicct.org/sites/default/files/publications/World-EV-capitals_ICCT-Briefing_08112017_vF.pdf.

246 Based on OECD/IEA, op. cit. note 135.

247 Sustainable Urban Transport Project, *Electromobility* (Eschborn, Germany: GIZ, 2016), https://www.sutp.org/files/contents/documents/resources/B_Technical-Documents/GIZ_SUTP_TD15_E-Mobility.pdf; Sophie Mbugua, "Electric taxis – a welcome drop in Nairobi's pool of emissions", Deutshe Welle, 24 August 2019, https://www.dw.com/en/electric-taxis-a-welcome-drop-in-nairobis-pool-of-emissions/a-50108136; Steve Hanley, "LEVC says electric taxis have saved £3.5 million in fuel costs for London cabbies", CleanTechnica, 31 July 2019, https://cleantechnica.com/2019/07/31/levc-says-electric-taxis-have-saved-3-5-million-in-fuel-costs-for-london-cabbies/.

248 Charlotte Pointing, "This London cab runs on renewable vegan energy", Live Kindly, 6 March 2019, https://www.livekindly.co/cab-renewable-vegan-energy/; Bio-Nett, *Biofuels Handbook: Best Practice Tools and Pilot Projects* (Brussels: 2007), https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/bio-nett_biofuels_handbook_en.pdf.

249 "Hydrogen fuel cell taxi makes debut in Seoul", NNA Business News, 10 September 2019, https://www.nna.jp/english_contents/news/show/20190910_0006; Hydrogen Mobility Europe, "Green light for green taxis", 17 January 2019, https://h2me.eu/2019/01/17/green-light-for-green-taxis/.

250 IEA, op. cit. note 172.

251 Ibid.

252 OECD/IEA, op. cit. note 166.

253 IEA, op. cit. note 172.

254 GIZ, *Two-and Three-wheelers: A Policy Guide to Sustainable Mobility Solutions for Motorcycles* (Eschborn, Germany: GIZ, 2018), https://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB4_Vehicles-and-Fuels/GIZ_SUTP_TUMI_SB4c_Two-%20and%20Three-Wheelers_EN.pdf.

255 OECD/IEA, op. cit. note 166.

256 Ibid.

257 Crunchbase, "Electric scooter and bike sharing companies", https://www.crunchbase.com/lists/electric-scooter-and-bike-sharing/ab3db36e-6d78-43a9-a41e-153f5246b12a/organization.companies, viewed 16 July 2019.

258 Lime, "About us", https://www.li.me/about-us, viewed 16 July 2019; Lime, "Lime Green", https://www.li.me/lime-green, viewed 16 July 2019; Lime, "Locations", https://www.li.me/locations, viewed 16 July 2019; Tom McKay, "You lost how much on scooters?" Gizmodo, 22 October 2019, https://gizmodo.com/you-lost-how-much-on-scooters-1839245178.

259 OECD/IEA, op. cit. note 166.

260 UNIDO, "World's first hydrogen-powered three-wheelers launched in New Delhi", press release (New Delhi: 9 January 2012), https://www.unido.org/news/worlds-first-hydrogen-powered-three-wheelers-launched-new-delhi.

261 OECD/ITF, *Towards Road Freight Decarbonisation* (Paris: 2018), https://www.itf-oecd.org/towards-road-freight-decarbonisation.

262 OECD/IEA, *The Future of Trucks* (Paris: 2017), https://www.iea.org/publications/freepublications/publication/TheFutureofTrucksImplicationsforEnergyandtheEnvironment.pdf.

263 Calculated from OECD/ITF, op. cit. note 137.

264 OECD/ITF, op. cit. note 261; SLoCaT, op. cit. note 142.

265 OECD/IEA, op. cit. note 262.

266 Ibid.

267 Ibid.

268 Ibid.

269 Michael Torregrossa, "A Thiverval, Sepur alimente ses BOM au gaz naturel", Gaz-Mobilite.fr, 14 July 2019, https://www.gaz-mobilite.fr/actus/thiverval-sepur-alimente-bom-gaz-naturel-2350.html.

270 OECD/IEA, op. cit. note 262.

271 OECD/IEA, op. cit. note 166.

272 Ibid.

273 OECD/IEA, op. cit. note 172.

274 OECD/IEA, op. cit. note 262.

275 NGV America, "Refuse", https://www.ngvamerica.org/vehicles/refuse/, viewed 14 November 2019.

276 Michael Torregrossa, "Bennes GNV de Grenoble: le déploiement de la station d'Eybens expliqué par Ingeole et SPMO", Gaz-Mobilite.fr, 14 February 2019, https://www.gaz-mobilite.fr/actus/bennes-gnv-grenoble-ingeole-spmo-appui-partie-avitaillement-2209.html; Michael Torregrossa, "Grenoble: la Métropole reçoit ses premières bennes à ordures GNV", Gaz-Mobilite.fr, 21 January 2019, https://www.gaz-mobilite.fr/actus/grenoble-metropole-recoit-premieres-bennes-ordures-gnv-2182.html; Michael Torregrossa, "En Mayenne, des bennes à ordures au gaz naturel pour Château Gontier", Gaz-Mobilite.fr, 24 September 2019, https://www.gaz-mobilite.fr/actus/mayenne-bennes-ordures-gaz-naturel-chateau-gontier-2392.html.

277 Clean Energy Fuels, "California refuse vehicles go full circle with Redeem™; "Waste Pro widens CNG footprint; natural gas powers DeKalb 'Best Fleet'; BC Transit expands", press release (Newport Beach, CA: 20 February 2019), https://www.cleanenergyfuels.com/press-room/california-refuse-vehicles-go-full-circle-with-redeem-waste-pro-widens-cng-footprint-natural-gas-powers-dekalb-best-fleet-bc-transit-expands/.

278 Christina Ausley, "Meet the 'Green Fleet': Seattle's eco-friendly garbage trucks", KomoNews, 16 June 2019, https://komonews.com/news/local/meet-the-green-fleet-seattles-eco-friendly-garbage-trucks.

279 Clean Energy Fuels, op. cit. note 277.

280 City of Surrey, "Facility", https://www.surreybiofuel.ca/facility, viewed 14 November 2019; City of Surrey, "Waste collection fleet",

23 November 2016, https://www.surreybiofuel.ca/news-media/blog/waste-collection-fleet.

281 EBA, op. cit. note 154.

282 Ibid.

283 European Commission, op. cit. note 197.

284 Jonathan M. Gitlin, "Seattle makes history with electric garbage truck", Ars Technica, 22 May 2019, https://arstechnica.com/cars/2019/05/seattle-makes-history-with-electric-garbage-truck/.

285 Kyle Field, "BYD inks deal for 200 electric refuse trucks in Indaiatuba, Brazil", CleanTechnica, 22 May 2018, https://cleantechnica.com/2018/05/22/byd-inks-deal-for-200-electric-refuse-trucks-inindaiatuba-brazil/; Kyle Field, "BYD lands deal for 500 electric refuse trucks with two companies in Shenzhen", CleanTechnica, 16 May 2018, https://cleantechnica.com/2018/05/16/byd-lands-deal-for-500-electric-refuse-trucks-with-two-companies-in-shenzhen/; Mark Kane, "Rio de Janeiro deploys fleet of BYD electric waste trucks", Inside EVs, 7 October 2019, https://insideevs.com/news/374832/rio-de-janeiro-byd-electric-waste-trucks/.

286 Gitlin, op. cit. note 284; Tony Bosworth, "First electric waste truck go into service in Victoria", The Driven, 4 October 2018, https://thedriven.io/2018/10/04/waste-trucks/.

287 Bellona, "Norway's first electrified waste collection truck – uncovering the potential of decarbonising urban duty vehicles", 20 February 2017, https://bellona.org/news/transport/2017-02-norways-first-electrified-waste-collection-truck-uncovering-the-potential-of-decarbonising-urban-duty-vehicles.

288 East Waste, "First electric-powered waste collection truck for SA", 2 September 2019, https://www.eastwaste.com.au/first-electric-powered-waste-collection-truck-for-sa/.

289 GIZ, *Urban Freight and Logistics: The State of Practices in India* (Eschborn, Germany: 2016), https://www.sutp.org/files/contents/documents/resources/C_Case-Studies/GIZ_SUTP_CS_Urban-Freight-and-logistics_India.pdf.

290 Ibid.

291 FedEx, "FedEx acquires 1,000 Chanje electric vehicles", 20 November 2018, https://about.van.fedex.com/newsroom/fedex-acquires-1000-chanje-electric-vehicles/; Meagan Nichols, "FedEx goes electric", Biz Journals, 2 August 2018, https://www.bizjournals.com/memphis/news/2018/08/02/fedex-goes-electric.html; Peters, op. cit. note 37; IKEA, "Rethinking transportation as part of the climate agenda", 27 March 2019, https://newsroom.inter.ikea.com/about-us/rethinking-transportation-as-part-of-the-climate-agenda/s/a4455d63-ad1f-46d5-8e33-58ee2f6fe9dc. **Table 4** based on the following sources: Michael Coren, "Amazon orders 100,000 electric delivery trucks, doubling the fleet in Europe and North America", Quartz, 19 September 2019, https://qz.com/1712151/amazon-orders-100000-electric-delivery-trucks/; Brittany Chang, "From electric vans to autonomous robots, here are all the vehicles Amazon has and will use to deliver packages to your doorstep", Business Insider, 19 September 2019, https://www.businessinsider.com/amazon-vehicles-used-deliver-packages-2019-7?IR=T#rivian-electric-vans-10; Amazon, "Sustainable transportation", https://sustainability.aboutamazon.com/sustainable-transportation, viewed 14 November 2019; Carrefour, 1er distributeur français à déployer une flotte de camions roulant au biomethane", Decisions-Achats.fr (2017), https://www.decision-achats.fr/Thematique/fleet-management-1232/Breves/Carrefour-1er-distributeur-fran-ais-deployer-flotte-camions-roulant-biomethane-316077.htm; Deutsche Post DHL Group, *Mission 2050: Zero Emissions* (Bonn: 2017), https://www.dpdhl.com/content/dam/dpdhl/en/media-center/responsibility/dpdhl-flyer-gogreen-zero-emissions.pdf; DHL, "Streetscooter and the future of electric vehicles", 30 November 2018, https://discover.dhl.com/business/business-ethics/future-of-electric-vehicles; The Climate Group, "La Poste becomes first French company to join RE100", 28 October 2015, https://www.theclimategroup.org/news/la-poste-becomes-first-french-company-join-re100; "La Poste runs largest electric fleet in Europe", Fleet Europe, 21 February 2017, https://www.fleeteurope.com/en/financial-models//article/la-poste-runs-largest-electric-fleet-europe; Blagojce Krivevski, "Swiss Post and Austrian Post announce move to fully electric fleet by 2030", Electric Cars Report, 8 March 2019, https://electriccarsreport.com/2019/03/swiss-post-and-austrian-post-announce-move-to-fully-electric-fleets-by-2030/; Kyle Field, "The Swiss & Austrian Post announce commitment to 100% EVs by 2030", CleanTechnica, 27 April 2019, https://cleantechnica.com/2019/04/27/the-swiss-austrian-post-announce-commitment-to-100-evs-by-2030/; PostNord, "Electric vehicles", 30 October 2019, https://www.postnord.com/en/sustainability/our-environmental-responsibility/electric-vehicles/; "Rebecca Harris, "Waitrose fuels delivery trucks with renewable biomethane", Canadian Grocer, 1 March 2017, http://www.canadiangrocer.com/worth-reading/waitrose-fuels-delivery-trucks-with-renewable-biomethane-71154.

292 GIZ, op. cit. note 254.

293 Ibid.

294 "Camion & utilitaire GNV: Dernières actualités", Gaz-Mobilite.fr, https://www.gaz-mobilite.fr/actus/camion-utilitaire-gnv/, viewed 14 November 2019; "Carrefour, 1er distributeur français à déployer une flotte de camions roulant au biomethane", op. cit. note 291.

295 Harris, op. cit. note 291.

296 OECD/IEA, op. cit. note 262.

297 Ibid.; Katie Fehrenbacher, "UPS to buy huge amount of renewable natural gas to power its truck fleet", GreenBiz, 22 May 2019, https://www.greenbiz.com/article/ups-buy-huge-amount-renewable-natural-gas-power-its-truck-fleet.

298 OECD/IEA, op. cit. note 262.

299 Coren, op. cit. note 291.

300 The Climate Group, *Business Driving Demand for Electric Vehicles. EV100 Progress and Insights Annual Report* (London/ New York / New Delhi: 2019), https://www.theclimategroup.org/sites/default/files/downloads/ev100_annual_progress_and_insights_annual_report_february_2019.pdf.

301 Ibid.

302 DHL, op. cit. note 291.

303 Ibid.; Deutsche Post DHL Group, op. cit. note 291.

304 IKEA, "IKEA Group commits to zero emissions targets for home delivery in five major cities by 2020", press release (Leiden, The Netherlands: 13 September 2018), https://www.ikea.com/us/en/this-is-ikea/newsroom/ikea-group-commits-to-zero-emissions-targets-for-home-delivery-in-five-major-cities-by-2020-pub33626f11.

305 Krivevski, op. cit. note 291.

306 The Climate Group, op. cit. note 300.

307 FedEx, op. cit. note 291; Nichols, op. cit. note 291.

308 Coren, op. cit. note 291.

309 PostNord, op. cit. note 291; Field, op. cit. note 291.

310 Blagojce Krivevski, "DPD to deliver with electric vehicles exclusively", Electric Cars Report, 23 November 2018, https://electriccarsreport.com/2018/11/dpd-to-deliver-with-electric-vehicles-exclusively/.

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1 Data are based on the output of the BloombergNEF Desktop database and reflect the timing of investment decisions. The following renewable energy projects are included: all biomass and waste-to-energy, geothermal and wind power projects of more than 1 megawatt (MW); all hydropower projects of between 1 and 50 MW; all solar power projects, with those less than 1 MW estimated separately and referred to as small-scale projects or small-scale distributed capacity; all ocean power projects; and all biofuel projects with an annual production capacity of 1 million litres or more.

2 Cities Climate Finance Leadership Alliance (CCFLA), *The State of City Climate Finance 2015* (Paris: 2015), https://sustainabledevelopment.un.org/content/documents/2201CCFLA-State-of-City-Climate-Finance-2015.pdf; C40 Cities Finance Facility and CDP, *The Demand for Financing Climate Projects in Cities* (London: 2018), https://cff-prod.s3.amazonaws.com/storage/files/QMDd8kN4kaVWSbyCrR7zN4NveA1gh9NgOCOscnhG.pdf.

3 Projects include all renewable energy types, a majority of which are solar PV and wind power. These numbers do not represent actual investment flows but rather project costs (in some cases projects for which cities still need financing) and thus can be seen as a demand for financing. C40 Cities Finance Facility and CDP, op. cit. note 2.

4 Ibid.

5 International Finance Corporation (IFC), *Climate Investment Opportunities in Cities* (Washington, DC: 2018), https://www.ifc.org/wps/wcm/connect/bffd2386-ff4c-454d-8366-8d801bf3b9c5/201811-CIOC-IFC-Analysis.pdf?MOD=AJPERES.

6 Ibid.

7 Ibid.

8 Lili Liu, Michael De Angelis and Sally Torbert, *Municipal Pooled Financing of Infrastructure in the United States: Experience and Lessons* (Washington, DC: World Bank, 2017), https://openknowledge.worldbank.org/bitstream/handle/10986/28547/WPS8212.pdf?sequence=1&isAllowed=y.

9 CCFLA, op. cit. note 2.

10 IFC, op. cit. note 5.

11 Anton Cartwright et al., *Developing Prosperous and Inclusive Cities in Africa – National Urban Policies to the Rescue?* (London and Washington, DC: Coalition for Urban Transitions, 2018), https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2018/09/CUT18_Africa_NatUrbanPolicies_final.pdf.

12 Ibid.

13 Graham Floater et al., *Global Review of Finance for Sustainable Urban Infrastructure* (London and Washington, DC: Coalition for Urban Transitions, 2017), https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2018/01/NCE2017_CUT_GlobalReview_02012018.pdf; James Alexander et al., *Financing the Sustainable Urban Future: Scoping a Green Cities Development Bank* (London: Overseas Development Institute (ODI) et al., April 2019), https://www.odi.org/sites/odi.org.uk/files/resource-documents/12680.pdf.

14 Joshua Hudson, "How to invest in municipal bonds: Making cities smarter with municipal bonds", MunicipalBonds.com, 3 August 2017, https://www.municipalbonds.com/investing-strategies/making-smarter-cities-with-municipal-bonds/.

15 CCFLA, op. cit. note 2.

16 World Bank, "City Creditworthiness Initiative: A partnership to deliver municipal finance", https://www.worldbank.org/en/topic/urbandevelopment/brief/city-creditworthiness-initiative, viewed 3 November 2019.

17 Peta Wolpe, Sustainable Energy Africa, personal communication, with Renewable Energy Policy Network for the 21st Century (REN21), 10 September 2019.

18 Climate – KIC, "City Climate Finance Planning and Creditworthiness", https://local.climate-kic.org/projects/city-climate-finance-planning-creditworthiness/, viewed 3 November 2019; Kaveh Rashidi, Martin Stadelmann and Anthony Patta, "Creditworthiness and climate: Identifying a hidden financial co-benefit of municipal climate adaptation and mitigation policies", *Energy Research & Social Science*, vol. 48 (February 2019), pp. 131-138, https://www.sciencedirect.com/science/article/pii/S2214629618304481; John Probyn and Joshua Gallo, "Chapter 6: Creditworthiness", in Marco Kamiya and Le-Yin Zhang, eds., *Finance for City Leaders Handbook: Improving Municipal Finance to Deliver Better Services* (Nairobi: UN-Habitat, 2017), https://www.mypsup.org/library_files/downloads/Finance%20for%20City%20Leaders%20Handbook%20-2nd%20Edition.pdf.

19 Alexander et al., op. cit. note 13.

20 Fiera Capital, *Study on the Role of Municipal Bonds in a Canadian Institutional Bond Portfolio* (Montreal: 2018), pp. 1-11, https://www.fieracapital.com/sites/default/files/Why_Municipals_in_Canadian_Fixed_Income_Portfolio_0.pdf.

21 IFC, op. cit. note 5.

22 Ibid.

23 Climate Bonds Initiative, "Climate bonds for beginners", https://www.climatebonds.net/resources/overview/climate-bonds-for-beginners, viewed 30 October 2019; Climate Bonds Initiative, https://www.climatebonds.net/, viewed 30 October 2019.

24 Neighborly, "Fiber broadband infrastructure to connect communities: A full-service solution for open access networks", https://neighborly.com/learn/history-of-municipal-bonds-chapter-2/, viewed 15 October 2019; Invesco Distributors Inc., *Primer on Municipal Bonds: What Investors Need to Know* (Atlanta, GA: September 2019), https://www.invesco.com/static/us/investors/contentdetail?contentId=96ca582c5ed1d510VgnVCM100000c2f1bf0aRCRD&dnsName=us.

25 Dan Hahn, "Never heard of municipal solar financing? You probably will soon", Solar Power Rocks, https://www.solarpowerrocks.com/solar-politics/municipal-solar-financing/, viewed 15 October 2019.

26 Sifma, *Municipal Bond Credit Report: Fourth Quarter and Full Year 2018* (New York and Washington, DC: February 2019), https://www.sifma.org/wp-content/uploads/2019/02/US-Municipal-Report-2019-02-11-SIFMA.pdf.

27 Ramakrishna Nallathiga, "Municipal bonds as a source of finance for urban infrastructure development in India", paper prepared for the 23rd Thinkers and Writers Forum, Skoch Development Foundation, 11-12 June 2015, pp. 1-15, https://www.researchgate.net/publication/313367892_Municipal_Bonds_as_a_Source_of_Finance_for_Urban_Infrastructure_Development_in_India; Hudson, op. cit. note 14.

28 James Chen, "Revenue bond", Investopedia, 6 March 2018, https://www.investopedia.com/terms/r/revenuebond.asp.

29 Ivan T. Ivanov and Tom Zimmermann, *The "Privatisation" of Municipal Debt*, 12 July 2018, https://www.brookings.edu/wp-content/uploads/2018/04/Ivanov-Zimmermann-7.12.18.pdf; Jared Cummans, "Municipal bonds 101: How do municipal bonds work?" MunicipalBonds.com, 24 June 2015, https://www.municipalbonds.com/education/the-basics-of-municipal-bonds/. Note that figures are for 2000-2009, the latest period for which data are available. Octaviano Canuto and Lili Liu, "Subnational debt finance and the global financial crisis", *Economic Premise* (World Bank), no. 13 (May 2010), https://openknowledge.worldbank.org/bitstream/handle/10986/10186/545070BRI0EP130Box349420B01PUBLIC1.pdf?sequence=1&isAllowed=y; Fiera Capital, op. cit. note 20.

30 Liu, De Angelis and Torbert, op. cit. note 8.

31 Ibid.

32 Luis Schloeter, "Financing urban infrastructure in emerging cities: Municipal bonds", Ciudades Sostenibles, 19 February 2016, https://blogs.iadb.org/ciudades-sostenibles/en/municipal-bonds/.

33 Liu, De Angelis and Torbert, op. cit. note 8.

34 Ibid.

35 Lars M. Andersson and Pavel Kochanov, "Chapter 8: Municipal Pooled Financing Mechanisms", in Kamiya and Zhang, eds., op. cit. note 18.

36 Global Fund for Cities Development (FMDV), *Creating the Local Financing Framework for Sustainable Development Goals: The Potential Catalytic Role of Subnational Pooled Financing Mechanisms* (Montreuil, France: 2016), https://www.urbanet.info/wp-content/uploads/2016/08/FMDV_Policy-Paper_-SPFM-ENG.pdf.

37 Monica Filkova, *The Green Bond Market in the Nordics 2018* (London: Climate Bonds Initiative, 2018), https://www.comunicarseweb.com/sites/default/files/cbi-the_green_bond_market_in_the_nordics.pdf.

38 Jean François Habeau, "Those innovative instruments are now recognised as effective instruments to finance urban development", Urbanet, 2 August 2016, https://www.urbanet.info/subnational-pooled-finance-mechanisms/; World Bank, "Pooled Municipal Bond Issuance in Tamil Nadu (India)" (Washington, DC: August 2016), http://documents.worldbank.org/curated/en/702211472040099035/pdf/107974-BRI-P159188-BlendedFinanceCasesIndia-PUBLIC.pdf; Andersson and Kochanov, op. cit. note 35.

39 Stephan Brand and Johannes Steinbrecher, "Green bonds – a sustainable alternative for municipal infrastructure finance?" *KfW Research Focus on Economics*, no. 245 (March 2019), https://www.kfw.de/PDF/Download-Center/Konzernthemen/Research/PDF-Dokumente-Fokus-Volkswirtschaft/Fokus-englische-Dateien/Fokus-2019-EN/Fokus-No.-245-March-2019-Green-Bonds.pdf.

40 Monica Filkova, Camille Frandon-Martinez and Amanda Giorgi, *Green Bonds: The State of the Market 2018* (London: Climate Bonds Initiative, 2019), https://www.climatebonds.net/files/reports/cbi_gbm_final_032019_web.pdf.

41 Climate Bonds Initiative, *Green Bonds Market Summary H1 2019* (London: July 2019), https://www.climatebonds.net/files/files/H1%202019%20Highlights_final.pdf.

42 Ibid.

43 Filkova, Frandon-Martinez and Giorgi, op. cit. note 40.

44 Ibid.

45 Ibid.

46 Climate Bonds Initiative, personal communication with REN21, 11 September 2019.

47 Ibid.

48 City of Gothenburg, "Capital market programmes", https://finans.goteborg.se/en/greenbonds/projects/, updated 10 January 2018.

49 Anita V. Shankar, Mary Alice Onyura and Jessica Alderman, *Understanding Impacts of Women's Engagement in the Improved Cookstove Value Chain in Kenya* (Washington, DC: Global Alliance for Clean Cookstoves, 2015), https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/356-1.pdf; Sarah Colenbrander and Ian Palmer, "African cities can raise more money. Kenya and South Africa offer useful lesson", *The Conversation*, 23 October 2018, https://theconversation.com/african-cities-can-raise-more-money-kenya-and-south-africa-offer-useful-lessons-102819; OneWorld, Sustainable Energy Africa and adelphi, *Multi-level Climate Governance in South Africa. Catalysing Finance for Local Climate Action.* (Berlin and Cape Town: 2018), https://www.adelphi.de/en/publication/multi-level-climate-governance-south-africa; CDP, "CDP Cities 2017 Information Request, City of Cape Town", https://www.cdp.net/en/formatted_responses/pages?locale=en&organization_name=City+of+Cape+Town& organization_number=35858&program=Cities&project_year=2017&redirect= https%3A%2F %2Fwww.cdp.net% 2Fsites% 2F2017%2F58% 2F35858%2FCDP+ Cities+2017%2FPages%2FDisclosureView.aspx, viewed 10 October 2019.

50 C40 Cities Climate Leadership Group, *Clean Energy Business Model Manual* (London: November 2018), https://c40-production-images.s3.amazonaws.com/other_uploads/images/2008_C40_Clean_Energy_Business_Model_Manual_-_Ezgi_Kelleher.original.pdf.

51 PACENation, "PACE market data", https://pacenation.org/pace-market-data/, viewed 15 October 2019.

52 United Nations Conference on Trade and Development (UNCTAD), *Supporting Infrastructure Development to Promote Economic Integration: The Role of Public and Private Sectors* (Geneva: March 2013), https://unctad.org/meetings/en/SessionalDocuments/cimem6d2_en.pdf.

53 Ibid.

54 World Bank, *2016 Private Participation in Infrastructure Annual Update* (Washington, DC: 2017), https://development-data-hub-s3-public.s3.amazonaws.com/ddhfiles/98975/2016-ppi-update.pdf.

55 World Bank, *January – June 2017 Private Participation in Infrastructure (PPI) Half Year Update* (Washington, DC: 2017), https://development-data-hub-s3-public.s3.amazonaws.com/ddhfiles/98975/ppi2017_halfyear_update_0_0_0.pdf.

56 Ibid.

57 Ibid.

58 Toyota, "Public-private partnership to test end-to-end hydrogen supply chain", 14 March 2016, https://global.toyota/en/detail/11362388.

59 Sarah Colenbrander et al., *Financing Low Carbon, Climate Resilient Cities* (London and Washington, DC: Coalition for Urban Transitions, 2018), https://citiesipcc.org/wp-content/uploads/2018/03/IPCC-Background-Paper-Financing-Low-Carbon-Climate-Resilient-Cities.pdf; Damian Thomas, *Land Value Capture and Urban Public Transport* (Dublin: National Economic & Social Council, 2018), http://files.nesc.ie/nesc_secretariat_papers/No_13_LandValueCaptureandUrbanPublicTransport.pdf.

60 Oladapo Olajide and Manuel Arcé, "Funding wisely: Unlocking urban transit with land value capture", KPMG, 10 May 2017, https://home.kpmg/xx/en/home/insights/2017/05/funding-wisely-unlocking-urban-transit-with-land-value-capture.html.

61 REN21, *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf.

62 Malcolm Campbell et al., *Land Value Capture to Fund Transport Investment in Cities* (Wellington, New Zealand: BRANZ, 2016), https://www.branz.co.nz/cms_show_download.php?id=fc48351d0ce7828989b845d4e7e246dc29b23be5.

63 HafenCity Hamburg, "Clean thermal energy for a new part of town", https://www.hafencity.com/en/concepts/clean-thermal-energy-for-a-new-part-of-town.html, viewed 22 October 2019.

64 Thomas, op. cit. note 59; Go 100% Renewable Energy, "Freiburg 100% renewable region", http://www.go100percent.org/cms/index.php?id=69&tx_ttnews[tt_news]=168&cHash=c5afc4d363d29e9b5ecff9f6f99bc03b, viewed 22 October 2019.

65 IFC, op. cit. note 5.

66 CCFLA, op. cit. note 2.

67 Alexander et al., op. cit. note 13.

68 Development banks that provided data include ADB, AFD, AfDB, CAF, EIB, IDB, JICA KfW and the World Bank. Data are from 2013. CCFLA, op. cit. note 2.

69 Debbie Caldwell, *Final Evaluation of the CDKN Rwanda FONERWA Capacity Building Support Project* (London: Climate and Development Knowledge Network, March 2015), http://cidt.org.uk/wp-content/uploads/2015/03/Final-Evaluation-of-the-CDKN-Rwanda-FONERWA-Capacity-Building-Support-Project-approved.pdf; FONERWA, "About", http://www.fonerwa.org/about, viewed 15 October 2019; Government of Rwanda, *FONERWA: Sustainable Financing Mechanism for Environment and Climate Change Initiative in Rwanda*, https://cdkn.org/wp-content/uploads/2012/03/1106_cidt_engagement_webready.pdf.

70 KfW Group, "KfW provides EUR 500 million for climate-friendly metro system in India", press release (Frankfurt, Germany: 4 January 2016), https://www.kfw.de/KfW-Group/Newsroom/Latest-News/Pressemitteilungen-Details_345728.html; "'Greenest metro' in Nagpur sets new standards", New Indian Express, 11 June 2019, http://www.newindianexpress.com/nation/2019/jun/11/greenest-metro-in-nagpur-sets-new-standards-1988521.html.

71 IFC, op. cit. note 5.

72 Sophie Vorrath, "Kiribati leads by example on solar, slashes dependence on diesel fuel", One Step Off the Grid, 26 September 2016, https://onestepoffthegrid.com.au/kiribati-leads-example-solar-slashes-dependence-diesel-fuel/; "Ha'apai first to reach 50% renewable energy generation", Matangi Tonga Online, 3 July 2017, https://matangitonga.to/2017/06/19/haapai-first-reach-50-renewable-energy-generation.

73 Organisation for Economic Co-operation and Development (OECD), *Green Investment Banks: Scaling Up Private Investment in Low-carbon, Climate-resilient Infrastructure* (Paris: 2016), https://www.oecd-ilibrary.org/finance-and-investment/green-investment-banks_9789264245129-en; Green Bank Network, "What is a Green Bank?", https://greenbanknetwork.org/what-is-a-green-bank-2/, viewed 15 October 2019; Montgomery County Green Bank, "Highlights for you", https://mcgreenbank.org/, viewed 15 October 2019; US Environmental Protection Agency, "Clean Energy Finance: Green Banking Strategies for

Local Governments" (Washington, DC: October 2018), https://www.epa.gov/sites/production/files/2018-10/documents/usepa_greenbankingstrategies_october_2018.pdf.

74 "Southern Africa establishes Climate Finance Facility", Smart Cities World, 26 August 2019, https://www.smartcitiesworld.net/energy/energy/southern-africa-establishes-climate-finance-facility.

75 Green Bank Network, "Green Bank Network impact through June 2019", https://greenbanknetwork.org/gbn-impact/, viewed 15 October 2019.

76 Ibid.

77 Alexander et al., op. cit. note 13.

78 Kate Gasparro, *Funding Municipal Infrastructure: Integrating Project Finance and Crowdfunding* (Palo Alto, CA: Stanford University, Global Projects Center, 2015), https://gpc.stanford.edu/sites/g/files/sbiybj8226/f/wp87.pdf.

79 See, for example the following: Indiegogo, "Coffee for biogas energy & farmer's climate school", https://www.indiegogo.com/projects/coffee-for-biogas-energy-farmer-s-climate-school#/, viewed 15 October 2019; Indiegogo, "PAYG community solar pumps for marginal farms", https://www.indiegogo.com/projects/payg-community-solar-pumps-for-marginal-farmers#/, viewed 15 October 2019; Trine, "The progress of making change", https://trine.com/our-progress, viewed 15 October 2019.

80 Kelsey Misbrener, "Geneva Community Power reaches subscription goal for community solar project", Solar Power World, 28 June 2019, https://www.solarpowerworldonline.com/2019/06/geneva-community-power-reaches-subscription-goal/; Triodos Bank, "Somerset community energy scheme crowdfunding £4m for 36,000-panel solar farm" press release (Somerset, UK: 4 July 2018), https://www.triodos.co.uk/press-releases/2018/somerset-community-energy-scheme-crowdfunding-gbp4m-for-36000-panel-solar-farm; United Nations Climate Change, "Crowdfunding for community solar projects | The Netherlands", https://unfccc.int/climate-action/momentum-for-change/financing-for-climate-friendly-investment/crowdfunding-for-community-solar-projects, viewed 15 October 2019; Crowdcube, "Andersen EV", https://www.crowdcube.com/companies/andersen-ev/pitches/qnpMnZ, viewed 15 October 2019.

81 Euroheat, *TEMPO: Crowdfunding as a Novel Financial Tool for District Heating Projects* (Brussels: 2018), https://www.euroheat.org/wp-content/uploads/2018/12/TEMPO-Crowdfunding-Report-FINAL.pdf.

82 Start Engine, "Sun Fund", https://www.startengine.com/sun-fund-dc, viewed 15 October 2019; Start Engine, "Solar Direct", https://www.startengine.com/solar-direct, viewed 15 October 2019; Start Engine, "Power2Peer", https://www.startengine.com/power2peer, viewed 15 October 2019.

83 CrowdfundRES, *Crowdfunding Renewable Energy: A Practical Guide for Crowdfunding Platforms, Project Developers, Investors and Policy Makers* (Brussels and Munich: 2018), https://eurocrowd.org/wp-content/blogs.dir/sites/85/2018/01/Crowdfunding-Renewable-Energy_protected.pdf.

84 C40 Cities Climate Leadership Group, op. cit. note 50.

85 Urban Grid, "Types of power purchase agreements for offsite renewable energy projects", 21 January 2019, https://www.urbangridsolar.com/types-of-power-purchase-agreements-for-offsite-renewable-energy-projects.

86 World Bank, "Power Purchase Agreements (PPAs) and Energy Purchase Agreements (EPAs)", 9 October 2019, https://ppp.worldbank.org/public-private-partnership/sector/energy/energy-power-agreements/power-purchase-agreements.

87 See, for example, the following: Emma Foehringer Merchant, "Texas municipal utility signs new super-low solar PPA", Greentech Media, 14 December 2018, https://www.greentechmedia.com/articles/read/utility-signs-new-low-solar-ppa-in-texas#gs.2bgj18; Philadelphia Energy Authority, "Mayor signs legislation for large-scale purchase of renewable energy", 19 December 2018, https://philaenergy.org/philadelphia-mayor-signs-legislation-for-large-scale-purchase-of-renewable-energy/; C40 Cities Climate Leadership Group, "How cities can create demand for large-scale clean energy generation", March 2019, https://www.c40knowledgehub.org/s/article/How-cities-can-create-demand-for-large-scale-clean-energy-generation?language=en_US.

88 C40 Cities Climate Leadership Group, op. cit. note 87.

89 Lacey Shaver and Heidi Bishop Ratz, "4 creative ways cities are transitioning to a clean energy future", WRI blog, 26 February 2019, https://www.wri.org/blog/2019/02/4-creative-ways-cities-are-transitioning-clean-energy-future; City of Melbourne, "Melbourne renewable energy project: A new generation of energy", https://www.melbourne.vic.gov.au/business/sustainable-business/mrep/Pages/melbourne-renewable-energy-project.aspx, viewed 15 October 2019.

90 OECD / International Energy Agency (IEA), "Energy service companies", https://www.iea.org/topics/energyefficiency/escos/, viewed 15 October 2019.

91 Ibid.

92 IFC, *China Energy Service Company (ESCO) Market Study* (Washington, DC: 2017), https://www.ifc.org/wps/wcm/connect/5d1cfd04-36fc-4f80-9900-c419940bd69b/IFC+final+ESCO+report-EN+.pdf?MOD=AJPERES&CVID=jZVnBBO.

93 Peter Larsen et al., Berkeley Lab, "State of the U.S. ESCO Industry: Market Characteristics and Project Performance 1990-2017", presentation, 2017, http://eta-publications.lbl.gov/sites/default/files/state_of_esco_industry_final_-_doe_reviewed.pdf.

94 OECD/IEA, op. cit. note 90.

95 Larsen et al., op. cit. note 93; Elizabeth Stuart et al., *U.S. Energy Service Company (ESCO) Industry: Recent Market Trends* (Berkeley, CA: Berkeley Lab, October 2016), https://www.naesco.org/data/industryreports/esco_recent_market_trends_30sep2016.pdf.

96 Larsen et al., op. cit. note 93; Stuart et al., op. cit. note 95; REN21, op. cit. note 61.

97 Sonia Dunlop and Alexandre Roesch, *EU-Wide Solar PV Business Models: Guidelines for Implementation*, (Brussels: PV FINANCING project, November 2016), http://resource-platform.eu/files/knowledge/reports/EU-wide-solar-PV-business-models-PV-Financing.pdf.

98 Jasper Ole Jensen and Jesper Rohr Hansen, "ESCO in Danish municipalities: Experience, innovations, potential", Energy Efficiency in Domestic Appliances and Lighting (EEDAL), 6th International Conference on Energy Efficiency in Domestic Appliances and Lighting, Copenhagen, Denmark, 24 May 2011, https://orbit.dtu.dk/en/publications/esco-in-danish-municipalities(128f6d1f-f8c5-4d79-ab36-237b162273a6).html.

99 Sunrun, "Solar lease", https://www.sunrun.com/solar-lease, viewed 30 October 2019.

100 ARC Advisory Group, "Electric bus battery leasing raises municipal adoption", 3 June 2019, https://www.arcweb.com/blog/electric-bus-battery-leasing-raises-municipal-adoption; Sunrun, op. cit. note 99.

101 Sunrun, op. cit. note 99.

102 See, for example, the following: Sola Future, "Solar Finance/PPA", https://www.solafuture.co.za/solar-leasing-ppa-finance/, viewed 16 May 2019; Solar Philippines, "Who we are", https://www.solarphilippines.ph, viewed 16 May 2019; Alpex Solar, "Renewable Energy Services/ Supply Company (RESCO)", http://www.alpexsolar.com/solar-electricity-(resco).html, viewed 15 October 2019; NEM Solar Malaysia, "Supply Agreement of Renewable Energy (SARE) Malaysia", http://nemsolarmalaysia.com/sare-malaysia, viewed 15 October 2019; Stadwerke Heidelberg, "Mehr Unabhängigkeit, mehr Komfort: mit heidelberg ENERGIEDACH Solarstrom intelligent selbst erzeugen", https://www.swhd.de/ENERGIEDACH, viewed 15 October 2019; Baset Asaba, "Dubai's South Energy signs first solar project agreement", Middle East Utilities, 14 March 2019, https://www.utilities-me.com/news/12502-dubais-south-energy-signs-first-solar-project-agreement; Solar Financial Solutions, "Solar leasing", https://www.solarfinance.com.au/, viewed 15 October 2019.

103 Peter Bronski et al., *The Carbon-Free City Handbook* (Basalt, CO: Rocky Mountain Institute, 2017), https://rmi.org/wp-content/uploads/2017/11/the-Carbon-Free-City-Handbook-1.0.pdf.

104 Sunrun, *2018 Annual Report* (San Francisco: 2019), http://www.annualreports.com/HostedData/AnnualReports/PDF/NASDAQ_RUN_2018.pdf.

105 Zola Electric, "About us", https://zolaelectric.com/about-us/, viewed 4 November 2019.

106 ARC Advisory Group, op. cit. note 100.

107 Asian Development Bank, "People's Republic of China: Cleaner urban transport for clearer skies", 8 November 2018, https://www.adb.org/results/cleaner-urban-transport-clearer-skies-prc.

108 Darshan Devaiah BP, "Bengaluru: BMTC gives clearance to induct 300 e-buses", Indian Express, 3 October 2019, https://indianexpress.com/article/cities/bangalore/bmtc-calls-tender-for-300-e-buses-for-bengaluru-6051700/.

109 Copenhagen Centre on Energy Efficiency, "ADB supports leasing of 'green' buses on urban roads in China", 23 February 2017, https://c2e2.unepdtu.org/adb-supports-leasing-of-green-buses-on-urban-roads-in-china/.

110 ZeEUS, *ZeEUS: eBus Report #2, An Updated Overview of Electric Buses in Europe* (Brussels: 2017), https://zeeus.eu/uploads/publications/documents/zeeus-ebus-report-2.pdf.

111 ARC Advisory Group, op. cit. note 100; Rueben Scriven, "LATAM electric bus market is strong, but may fail to reach its potential", Intelligent Transport, 13 March 2019, https://www.intelligenttransport.com/transport-articles/76651/electric-bus-market-latin-america/.

112 Maria Gallucci, "An increasingly urbanised Latin America turns to electric buses", *Yale Environment 360*, 9 September 2019, https://e360.yale.edu/features/an-increasingly-urbanized-latin-america-turns-to-electric-buses.

113 ARC Advisory Group, op. cit. note 100; Sustainable Bus, "Proterra and Mitsui, a battery lease program to facilitate electric bus adoption", 16 April 2019, https://www.sustainable-bus.com/news/proterra-and-mitsui-a-battery-lease-program-to-facilitate-electric-bus-adoption/.

114 Sustainable Bus, op. cit. note 113.

115 Deloitte, *Car Sharing in Europe: Business Models, National Variations and Upcoming Disruptions*, Monitor Deloitte, 2017, https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-industrial-products/CIP-Automotive-Car-Sharing-in-Europe.pdf.

116 Sandra Phillips, "Carsharing market & growth analysis 2019", Movmi, 10 July 2019, http://movmi.net/carsharing-market-growth-2019/.

117 WeShare, "WeShare electrifies Berlin", https://www.we-share.io/en/#electric-fleet, viewed 15 October 2019.

118 EVgo, "Why EVgo?", https://www.evgo.com/, viewed 15 October 2019; Chris Teale, "EVgo commits to powering chargers with 100% renewable energy", Utility Dive, 8 May 2019, https://www.utilitydive.com/news/evgo-commits-to-powering-chargers-with-100-renewable-energy/554340/.

119 REN21, *Renewables 2018 Global Status Report* (Paris: 2018), https://www.ren21.net/wp-content/uploads/2019/08/Full-Report-2018.pdf; Toby Shapshak, "How Kenya's M-Kopa brings prepaid solar power to rural Africa", *Forbes*, 28 January 2016, https://www.forbes.com/sites/tobyshapshak/2016/01/28/how-kenyas-m-kopa-brings-prepaid-solar-power-to-rural-africa/; Lighting Global, *Pay-As-You-Go Market Attractiveness Index* (Washington, DC: IFC, 2019), https://www.lightingglobal.org/wp-content/uploads/2019/06/PAYGo-MAI-2019-Report.pdf.

120 Kenya Climate Innovation Center, *Kenya Solar PV Market Assessment* (Nairobi: 2016), https://www.kenyacic.org/sites/default/files/publications/KCIC%20Solar%20Survey-3.pdf; Geoge Kibala Bauer, "Why off-grid energy providers are increasingly paying attention to urban areas – insights from the DRC and beyond", GSMA, 17 July 2019, https://www.gsma.com/mobilefordevelopment/blog/why-off-grid-energy-providers-are-increasingly-paying-attention-to-urban-areas-insights-from-the-drc-and-beyond/.

121 The Climate Group, *The Business Case for Off-grid Energy in India* (New Delhi: 2015), https://www.theclimategroup.org/sites/default/files/archive/files/The-business-case-for-offgrid-energy-in-India.pdf; Lumos Global, "Boost for off-grid solar as Lumos Global reports exponential growth in 2017", press release (Lagos, Nigeria: 15 January 2018), https://www.prnewswire.com/news-releases/boost-for-off-grid-solar-as-lumos-global-reports-exponential-growth-in-2017-669359343.html; Elisa Minischetti and Bill Gallery, "Harnessing the power of fintech in Myanmar", Frontier Myanmar, 23 February 2018, https://frontiermyanmar.net/en/harnessing-the-power-of-fintech-in-myanmar.

122 "Amped Innovation and BioCellection top San Jose's recent funding news", Yahoo News, 22 October 2019, https://news.yahoo.com/amped-innovation-biocellection-top-san-100336610.html.

123 Infinite Energy, "What is peer-to-peer energy trading?" 1 July 2019, https://www.infiniteenergy.com.au/peer-to-peer-energy-trading.

124 Verv, "We've just executed the UK's first energy trade on the blockchain as we look to power a London housing community with sunshine!" Medium, 12 April 2019, https://medium.com/@VLUX/weve-just-executed-the-uk-s-first-energy-trade-on-the-blockchain-as-we-look-to-power-a-london-2e22a522ba30; "EDF Energy to trial peer-to-peer energy trading", Utility Week, 12 February 2019, https://utilityweek.co.uk/edf-energy-trial-peer-peer-energy-trading/; Power Ledger, "Power Ledger deploys P2P renewable energy trading platform in largest U.S. wholesale electricity market", Medium, 13 November 2018, https://medium.com/power-ledger/power-ledger-deploys-p2p-renewable-energy-trading-platform-in-largest-u-s-925d058f036b; Andy Colthorpe, "Blockchain enables Australia's peer-to-peer power trading kick-off", Energy Storage News, 7 August 2018, https://www.energy-storage.news/news/blockchain-enables-australias-peer-to-peer-power-trading-kick-off; "Lition is the world's first operational peer-to-peer energy trading platform", Bitcoinist, 21 July 2018, https://bitcoinist.com/lition-is-the-worlds-first-operational-peer-to-peer-energy-trading-platform/.

125 Marija Maisch, "Power Ledger launches P2P solar trading trial in Bangkok", pv magazine, 22 August 2018, https://www.pv-magazine-australia.com/2018/08/22/power-ledger-launches-p2p-solar-trading-trial-in-bangkok/; Chen-Sheng Hong, "Thailand's renewable energy transitions: A pathway to realise Thailand 4.0", The Diplomat, 9 March 2019, https://thediplomat.com/2019/03/thailands-renewable-energy-transitions-a-pathway-to-realize-thailand-4-0/.

126 David Donnerer and Sylvie Lacassagne, *Blockchains and Energy Transition: What Challenges for Cities?* (Heidelberg, Germany: Energy Cities, 2018), https://energy-cities.eu/wp-content/uploads/2019/01/energy-cities-blockchain-study_2018_en.pdf.

127 HullCoin, "Giving your community the credit it deserves", https://www.hull-coin.org/, viewed 15 October 2019; Oliver Sylvester-Bradley, "Hullcoin: Can blockchain unlock the hidden value in Hull's economy?" Open, 23 April 2018, https://open.coop/2018/04/23/hullcoin-can-blockchain-unlock-hidden-value-hulls-economy/.

CITIZEN PARTICIPATION

1 Harriet Bulkeley, *Cities and Climate Change* (London: Routledge, 2013), https://www.taylorfrancis.com/books/9780203077207 (viewed 13 November 2019).

2 Emily Creamer et al., "Community energy: Entanglements of community, state, and private sector", *Geography Compass*, vol. 12, no. 7 (2018), pp. 1-16, https://onlinelibrary.wiley.com/doi/full/10.1111/gec3.12378; Arwen D. Colell and Angela Pohlmann, "Community energy projects redefining energy distribution systems: Examples from Berlin and Hamburg", in Fanny Lopez, Margot Pellegrino and Olivier Coutard, eds., *Local Energy Autonomy: Spaces, Scales, Politics, Volume 1* (London: ISTE, 2019), http://www.iste.co.uk/book.php?id=1481.

3 Henner Busch, *Entangled Cities: Transnational Municipal Climate Networks and Urban Governance* (Lund, Sweden: Lund University, 2016), https://lup.lub.lu.se/search/ws/files/13139045/e_nailing_Henner.pdf.

4 Vivien Foster and Anshul Rana, *Revisiting Power Sector Reform in the Developing World* (Washington, DC: World Bank, 2019), https://openknowledge.worldbank.org/bitstream/handle/10986/32335/9781464814426.pdf?sequence=4&isAllowed=y.

5 Annica Kronsell, "Legitimacy for climate policies: Politics and participation in the Green City of Freiburg", *Local Environment*, vol. 18, no. 8 (2013), pp. 965-82, https://www.tandfonline.com/doi/abs/10.1080/13549839.2012.748732.

6 Ali Hortaçsu, Seyed Ali Madanizadeh and Steven L. Puller, "Power to choose? An analysis of consumer inertia in the residential electricity market", *American Economic Journal: Economic Policy*, vol. 9, no. 4 (2017), pp. 192-226, https://www.researchgate.net/publication/320771826_Power_to_Choose_An_Analysis_of_Consumer_Inertia_in_the_Residential_Electricity_Market.

7 Michelle Froese, "Setting the bar for utilities of 100% renewable electricity", Wind Power Engineering & Development, 22 July 2019, https://www.windpowerengineering.com/setting-the-bar-for-utilities-of-100-renewable-electricity/, viewed 21 October 2019

8 Jiillian Ambrose, "E.ON UK to supply 3.3m customers with 100% renewable electricity", *The Guardian* (UK), 9 July 2019, https://www.theguardian.com/business/2019/jul/09/eon-uk-to-supply-3m-customers-with-100-renewable-electricity, viewed 7 October 2019

9 US Environmental Protection Agency, "Utility green power products", https://www.epa.gov/greenpower/utility-green-power-products, viewed 15 May 2019.

10 Eric O'Shaughnessy, Jenny Heeter, and Jenny Sauer, *Status and Trends in the U.S. Voluntary Green Power Market (2017 Data)* (Golden, CO: US National Renewable Energy Laboratory (NREL), 2018), https://www.nrel.gov/docs/fy19osti/72204.pdf.

11 Paul Ciampoli, "Public power utilities make NREL top 10 lists for green pricing programs", American Public Power Association, 4 June 2018, https://www.publicpower.org/periodical/article/public-power-utilities-make-nrel-top-10-lists-green-pricing-programs.

12 Guido Pepermans, "European energy market liberalization: experiences and challenges", *International Journal of Economic Policy Studies*, vol. 13, no. 1 (2019), pp. 3-26, doi:10.1007/s42495-018-0009-0.

13 Verivox, "Ökostrom-Vergleich mit dem testsieger", https://www.verivox.de/oekostrom-vergleich/, viewed 3 September 2019.

14 Elpriskollen, "Jämför el och elavtal här!", https://www.ei.se/sv/Elpriskollen/, viewed 3 September 2019.

15 IEA et al., *Tracking SDG 7: The Energy Progress Report 2019* (Washington, DC: 2019), https://trackingsdg7.esmap.org/data/files/download-documents/2019-Tracking%20SDG7-Full%20Report.pdf

16 Joni Karjalainen et al., *Radical Solar Energy Startups in Kenya and Tanzania* (Turku, Finland: Finland Futures Research Centre, 2018), https://www.utu.fi/sites/default/files/public%3A//media/file/NeoCarbon-WP1-2-2018.pdf.

17 Alix Bolle, Energy Cities, personal communication with REN21, 5 April 2019.

18 C40 Cities, "Case Study: 98% of Copenhagen city heating supplied by waste heat", 3 November 2011, https://www.c40.org/case_studies/98-of-copenhagen-city-heating-supplied-by-waste-heat; Sven Werner, "District heating and cooling in Sweden", *Energy*, vol. 126 (2017), pp. 419-29, doi:10.1016/j.energy.2017.03.052.

19 Kacper Szulecki, "Conceptualizing energy democracy", *Environmental Politics*, vol. 27, no. 1 (2018), pp. 21-41, https://www.tandfonline.com/doi/full/10.1080/09644016.2017.1387294; Yael Parag and Benjamin K. Sovacool, "Electricity market design for the prosumer era", *Nature Energy*, vol. 1, no. 16032 (2016), pp. 1-6, https://www.nature.com/articles/nenergy201632.

20 IEA Implementing Agreement for Renewable Energy Technology Deployment (IEA-RETD), *Residential Prosumers – Drivers and Policy Options (Re-prosumers)* (Paris: 2014), http://iea-retd.org/wp-content/uploads/2014/09/RE-PROSUMERS_IEA-RETD_2014.pdf; IEA-RETD, *Tapping the Potential of Commercial Prosumers* (Utrecht, The Netherlands: 2016), http://iea-retd.org/wp-content/uploads/2016/08/RE-COM-PROSUMERS-Report.pdf; UNIDO, *Industrial Prosumers of Renewable Energy: Contribution to Inclusive and Sustainable Industrial Development* (Vienna: 2015), https://www.unido.org/sites/default/files/2015-04/PROSUMERS_Energy_0.pdf. Eric O'Shaughnessy et al., "Solar plus: Optimization of distributed solar PV through battery storage and dispatchable load in residential buildings", *Applied Energy*, vol. 213 (October 2017), pp. 11–21, doi:10.1016/j.apenergy.2017.12.118.

21 REN21, *Renewables 2019 Global Status Report* (Paris: 2019), http://www.ren21.net/cities/wp-content/uploads/2019/05/REC-GSR-Low-Res.pdf.

22 Mike Roberts et al., *Solar Trends Report for Solar Citizens* (Sydney: University of New South Wales and Australian PV Institute, 2018), http://apvi.org.au/wp-content/uploads/2018/12/Solar-Trends-Report-for-Solar-Citizens-FINAL_11-12-18_2_logos.pdf; Australian PV Institute, "Mapping Australian photovoltaic installations", https://pv-map.apvi.org.au/historical#7/-31.812/140.900, viewed 22 October 2019.

23 Intec, *The Nigerian Energy Sector: An Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification*, 2nd Edition (Abuja, Nigeria: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Nigerian Energy Support Programme and Federal Ministry of Power, June 2015), p. 74, https://www.giz.de/de/downloads/giz2015-en-nigerian-energy-sector.pdf; " Top 5 solar energy inventions from Africa", Deutsche Welle, 15 December 2018, https://www.dw.com/en/top-5-solar-energy-inventions-from-africa/a-41814145.

24 IÖW, "Auf den Spuren der Prosumer in China und Japan", 30 July 2019, https://www.ioew.de/news/auf-den-spuren-der-prosumer-in-china-und-japan/.

25 Greencape, *Energy Services – 2019 Market Intelligence Report* (Cape Town, South Africa: 2019), https://www.greencape.co.za/assets/Uploads/ENERGY-SERVICES-MARKET-INTELLIGENCE-REPORT-WEB.pdf; City of Cape Town, "Requirements for small-scale embedded generation" (Cape Town, South Africa: 21 August 2018), http://resource.capetown.gov.za/documentcentre/Documents/Procedures%2C%20guidelines%20and%20regulations/Requirement%20for%20Samll-Scale%20Embedded%20Generation.pdf; Mike Rycroft, "Small scale solar PV: Current status and future prospects", EE Publishers, 27 September 2017, http://www.ee.co.za/article/small-scale-solar-pv-current-status-future-prospects.html.

26 eThekwini Municipality, "Tariff details", http://www.durban.gov.za/City_Services/electricity/Generation/Pages/Tariff-Details.aspx, viewed 16 May 2019; Greencape, *Energy Services – 2019 Market Intelligence Report* (Cape Town, South Africa: 2019), https://www.greencape.co.za/assets/Uploads/ENERGY-SERVICES-MARKET-INTELLIGENCE-REPORT-WEB.pdf; City of Cape Town, "Requirements for small-scale embedded generation" (Cape Town, South Africa: 21 August 2018), http://resource.capetown.gov.za/documentcentre/Documents/Procedures%2C%20guidelines%20and%20regulations/Requirement%20for%20Samll-Scale%20Embedded%20Generation.pdf

27 City of Cape Town, "Property Assessed Clean Energy (PACE) Programme", presentation at Urban Energy Network Meeting, 13 June 2019.

28 Nelson Mandela Bay Municipality, "250 MW programme" http://www.nelsonmandelabay.gov.za/Residents.aspx?pageID=292, viewed 5 July 2019.

29 KIREC Seoul 2019, "IREC 2019 in Seoul", http://www.kirec2019.kr/sub01/about.html, viewed 22 October 2019.

30 C40, "Cities 100: 100 City Projects Making the Case for Climate Action", 2019, https://www.cities100report.com.

31 Beyond Zero Emissions, ICLEI – Local Governments for Sustainability (ICLEI Oceania) and Ironbark Sustainability, *Australian Local Government Climate Review 2018* (Melbourne: 2018), http://media.bze.org.au/ZCC/Australian%20Local%20Government%20Climate%20Review%20FINAL.pdf.

32 Interreg Baltic Sea Region, "Törneby Solpark & Nöbble Solpark – solar PV from a local source in Kalmar, Sweden", April 2019, http://co2mmunity.eu/wp-content/uploads/2019/04/Factsheet-Kalmar.pdf.

33 Ibid.

34 BSW-Solar, "Statistische Zahlen der deutschen Solarwärmebranche" (Berlin: March 2019), https://www.solarwirtschaft.de/fileadmin/user_upload/bsw_faktenblatt_st_2019_3.pdf; BSW-Solar, op. cit. note 21.

35 Henner Busch and Kes McCormick, "Local power: Exploring the motivations of mayors and key success factors for local municipalities to go 100% renewable energy", *Energy, Sustainability and Society*, vol. 4, no. 1 (2014), p. 5, https://link.springer.com/article/10.1186/2192-0567-4-5.

36 36 Gordon Walker and Patrick Devine-Wright, "Community renewable energy: What should it mean?" *Energy Policy*, vol. 36, no. 2 (2008), pp. 497-500, https://www.sciencedirect.com/science/article/pii/S0301421507004739; REN21, *Renewables 2018 Global Status Report* (Paris: 2018), http://www.ren21.net/gsr-2018/.

37 German Cooperation, "2nd Thai-German Community-based Renewable Energy Conference 2016", https://www.thai-german-cooperation.info/en_US/2nd-thai-german-community-based-renewable-energy-conference-2016/, viewed 16 May 2019; The Beam, "The community power movement is on the rise in Japan", Medium, 13 February 2017, https://medium.com/thebeammagazine/community-power-gears-up-global-renewable-energy-movement-dccbc184fea6; Natural Resources Canada, "Integrated Urban Community Energy Project", https://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/16159, viewed 16 May 2019; Eric O'Shaughnessy, NREL, "Community Solar: Status, Legal Trends and Financing Issues", webinar, 9 March 2016, https://www.epa.gov/sites/production/files/2016-03/documents/webinar_20160309_oshaughnessy.pdf.

38 Ksenia Chmutina et al., "Concern or compliance? Drivers of urban decentralised energy initiatives", *Sustainable Cities and Society*, vol. 10 (2014), pp. 122–129, https://doi.org/10.1016/j.scs.2013.07.001.

39 **Box 4** from Transition Network, "Transition near me", https://transitionnetwork.org/transition-near-me/, viewed 24 November 2019.

40 O'Shaughnessy, op. cit. note 39; Caroline Julian and Rosie Olliver, *Community Energy: Unlocking Finance and Investment – The Way Ahead* (London: ResPublica, 2014), http://www.respublica.org.uk/wp-content/uploads/2014/12/Community-Energy-Unlocking-Finance-and-Investment-The-Way-Ahead.pdf.

41 REScoop "Who we are", https://www.rescoop.eu/federation, viewed 26 March 2019; Josh Robers, REScoop, personal communication with REN21, 14 March 2019

42 Ibid.; Josh Roberts, REScoop, personal communication with REN21, 14 March 2019; Roberts, op. cit. note 44.

43 Die Genossenshaften, "DGRV annual survey of energy cooperatives", https://www.dgrv.de/weben.nsf/web/annualsurveyenergycooperatives, viewed 17 August 2019

44 Die Genossenshaften, "DGRV annual survey of energy cooperatives", https://www.dgrv.de/weben.nsf/web/annualsurveyenergycooperatives, viewed 17 August 2019

45 August Wierling et al., "Statistical evidence on the role of energy cooperatives for the energy transition in European countries", *Sustainability (Switzerland)*, vol. 10, no. 9 (2018), doi:10.3390/su10093339.

46 T. Bauwens, B. Gotchev and L. Holstenkamp, "What drives the development of community energy in Europe? The case of wind power cooperatives", *Energy Research and Social Science*, vol. 13 (2016), pp. 137-47, https://www.iass-potsdam.de/en/output/publications/2016/what-drives-development-community-energy-europe-case-wind-power

47 Community Energy England and Community Energy Wales, *Community Energy – State of the Sector Report 2019* (Sheffield, UK: 2019), https://communityenergyengland.org/pages/state-of-the-sector-report%0Afiles/386/CommunityEnergy-StateoftheSectorReport.pdf.

48 Centre for Sustainable Energy, "Urban Community Energy Fund (UCEF)", https://www.cse.org.uk/projects/view/1249, viewed 9 October 2019.

49 Community Energy England, "State of the Sector Report 2018", https://communityenergyengland.org/pages/state-of-the-sector-report-2018/, viewed 17 August 2019

50 Dick Magnusson and Jenny Palm, "Come together—The development of Swedish energy communities", *Sustainability*, vol. 11, no. 4 (2019), p. 1056, doi:10.3390/su11041056.

51 Ibid.

52 Interreg Baltic Sea Region, "The Housing Association Vilde 70 in Tallinn, Estonia carries out an energy efficiency renovation including a solar PV installation", October 2018, http://co2mmunity.eu/wp-content/uploads/2018/10/Fact-sheet-Housing-Association-Vilde-70.pdf.

53 Middelgrundens Vindmøllelaug, "About Middelgrunden Wind Cooperative", http://www.middelgrunden.dk/middelgrunden/?q=en/node/35, viewed 9 September 2019.

54 Services Industriels de Genève, "Mon m² solaire au Stade de Genève", https://ww2.sig-ge.ch/particuliers/nos-offres/electricite/mon_m2_solaire?nd=monm2solaire, viewed 3 June 2019.

55 Energy Cities, *How Cities Can Back Renewable Energy Communities* (Brussels: 2019), https://www.eumayors.eu/news-and-events/news/1698-learn-about-the-potential-of-community-renewable-energy-with-a-comprehensive-guidebook.html

56 US Community Renewable Energy, "Statistics", https://www.communityenergyus.net/Statistics, viewed 15 August 2019.

57 US Solar Energy Industries Association, "Community solar", https://www.seia.org/initiatives/community-solar, viewed 9 May 2019.

58 Geronimo Energy, "Geronimo Energy fulfills community solar garden subscriptions with recognizable, Minnesota-based organizations", press release (Minneapolis, MN: 6 January 2015, https://www.marketwatch.com/press-release/geronimo-energy-fulfills-community-solar-garden-subscriptions-with-recognizable-minnesota-based-organizations-2015-01-06.

59 Douglas Gagne, "Community solar: Lifting the energy burden on low-income households", NREL, 2 July 2018, https://www.nrel.gov/state-local-tribal/blog/posts/community-solar-lifting-the-energy-burden-on-low-income-households.html.

60 Illinois Solar For All, https://www.illinoissfa.com/programs/community-solar/, viewed 12 August 2019; Denver Housing Authority, "DHA's community solar project keeps housing affordable", https://www.lowincomesolar.org/dha-community-solar-project-keeps-housing-affordable/, viewed 12 August 2019.

61 United Nations Development (UNDP) Nepal, "Renewable Energy for Rural Livelihood (RERL)", http://www.np.undp.org/content/nepal/en/home/projects/rerl.html, viewed 12 August 2019.

62 Community Power Agency, http://cpagency.org.au/, viewed 10 May 2019; The Beam, op. cit. note 39; REN21, *Renewables 2017 Global Status Report* (Paris: 2017), http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf%.

63 Hironao Matsubara, Institute for Sustainable Energy Policies (ISEP), Tokyo, personal communication with REN21, 1 May 2018. Capacity of community solar PV projects increased from 45 MW in 2016 to 86 MW in 2017, from idem.

64 Ibid; Tetsunari Iida, personal communication with REN21, 05 October 2019

65 The Beam, op. cit. note 37.

66 Shota Furuya, "Japan's "Do it Ourselves" model for community power", The Beam, 22 August 2017, https://medium.com/thebeammagazine/japans-do-it-ourselves-model-for-community-power-5fc28fb99af4.

67 Community Power Agency, " Community energy map", https://cpagency.org.au/resources/map/, viewed 4 September 2019.

68 Inner West Community Energy, "Exciting new solar power installation in Newcastle", 12 July 2019, https://innerwestcommunityenergy.org.au/exciting-new-solar-power-installation-in-newcastle/.

69 Pinglala, "Fairer energy", https://pingala.org.au/, viewed 4 September 2019.

70 Solar Citizens, "Stucco housing cooperative's solar and storage story", YouTube video, 11 January 2017, https://www.youtube.com/watch?v=0bTB90emJCM.

71 Farming the Sun, "Lismore", https://farmingthesun.net/lismore/, viewed 15 September 2019.

72 Julie L. MacArthur and Anna L. Berka, "Energy transitions without grassroots innovation? Local and community energy in Aotearoa (New Zealand)", May 2019, https://www.researchgate.net/publication/333614725_Energy_transitions_without_grassroots_innovation_Local_and_community_energy_in_Aotearoa_New_Zealand; Julie L. MacArthur, personal communication with REN21, 11 September 2019.

73 Lea Ranalder, *[Em]powering Communities?* (Lund, Sweden: Lund University, 2017).

74 C40 Cities, Case study: Solar energy for social housing in Curitiba", 13 December 2018, https://www.c40.org/case_studies/solar-energy-for-social-housing-in-curitiba.

75 Ibrahim Togola, Mali Folkecenter, personal communication with REN21, 13 June 2019.

76 76 Africa Coalition for Sustainable Energy and Access, *Africa Renewable Energy Initiative for Africa: African Civil Society Organizations Perspective,* 2017, https://germanwatch.org/sites/germanwatch.org/files/publication/18246.pdf.

77 77 Sustainable Energy Africa, *Sustainable Energy Solutions for South African Local Government: A Practical Guide* (Cape Town: 2017), p. 274 http://www.cityenergy.org.za/uploads/resource_434.pdf.

78 C40 Cities, "Case Study: Cities100: Tshwane – Small-scale farming reaps big community benefits, 15 November 2016, https://www.c40.org/case_studies/cities100-tshwane-small-scale-farming-reaps-big-community-benefits.

79 Togola, op. cit. note 75.

80 Community Power and Friends of the Earth Ireland, "Community Energy", https://www.foe.ie/download/pdf/supporting_communities_in_renewable_energy.pdf, viewed 17 May 2019.

81 Energy Cities, op. cit. note 55.

82 Ibid.

83 Som Energia, " Welcome to Som Energia", https://www.somenergia.coop/es/welcome-to-som-energia/, viewed 22 October 2019; Energy Democracy, "Som Energia, Catalonia (Spain)", http://www.energy-democracy.net/?p=1050, viewed 22 October 2019.

84 Coopérnico, https://www.coopernico.org/pt, viewed 22 October 2019

85 Alix Bolle, Energy Cities, personal communication with REN21, 5 April 2019.

86 Sara Giovannini, "Lisbon, a solar city", Energy Cities, 27 May 2019, https://energy-cities.eu/lisbon-a-solar-city/

87 Vladimir Spasić, "Funds raised for Croatia's first renewable energy crowdfunding Project", Balkan Green Energy News, 28 May 2018, https://balkangreenenergynews.com/funds-raised-for-croatias-first-renewable-energy-crowdfunding-project/.

88 Croenergy, http://croenergy.eu/, viewed 14 August 2019.

89 Mine Islar and Henner Busch, "We are not in this to save the polar bears!" – The link between community renewable energy development and ecological citizenship", *Innovation: The European Journal of Social Science Research*, vol. 29, no. 3 (2016), pp. 303-19, https://www.tandfonline.com/doi/abs/10.1080/13511610.2016.1188684.

90 **Box 5** from Salvatore Ruggiero, Mari Martiskainen and Tiina Onkila, "Understanding the scaling-up of community energy niches through strategic niche management theory: Insights from Finland", *Journal of Clean Energy*, vol. 170, (1 January 2018), pp. 581-90, https://www.sciencedirect.com/science/article/pii/S0959652617321388#!.

91 Martin David, "The role of organized publics in articulating the exnovation of fossil-fuel technologies for intra- and intergenerational energy justice in energy transitions", *Applied Energy*, vol. 228 (2018), pp. 339-50, https://ideas.repec.org/a/eee/appene/v228y2018icp339-350.html; Colell and Pohlmann, op. cit. note 1.

92 Dirk De Vos, "Can any South African nuclear energy procurement ever succeed?" Daily Maverick, 5 May 2017, https://www.dailymaverick.co.za/article/2017-05-05-op-ed-can-any-south-african-nuclear-energy-procurement-ever-succeed/.

93 Sofia Avila-Calero, "Contesting energy transitions: wind power and conflicts in the Isthmus of Tehuantepec", *Journal of Political Ecology*, vol. 24, no. 1 (2018), p. 992, doi:10.2458/v24i1.20979.

94 Tsvetomira Tsanova, "Norway not to halt 288-MW Fosen Vind project", Renewables Now, 26 December 2018, https://renewablesnow.com/news/norway-not-to-halt-288-mw-fosen-vind-project-637761/.

95 Szulecki, op. cit. note 19.

96 Energy Cities, op. cit. note 55.

97 Naturspeicher, "Unser pilotprojekt in Gaildorf", http://www.naturspeicher.de/de/pilotprojekt/pilotprojekt.php, viewed 24 August 2019.

98 Enschede wekt op, http://enschedewektop.nl/, viewed 14 August 2019.

99 "Grenoble: Citizen engagement at the core of the energy transformation of the 'Capital of the Alps'", in Tatjana Veith, *Local Energy and Climate Roadmaps* (Brussels: Energy Cities, 2018), https://energy-cities.eu/best-practice/citizen-engagement-at-the-core-of-the-energy-transformation/.

100 Energy Cities, op. cit. note 55.

101 Klawitter et al., op. cit. note 76.

102 South Africa National Planning Commission, *National Development Plan: Pathways for a Just Transition* (2018), p. 3, https://oneworldgroup.co.za/wp-content/uploads/2019/04/Social_Partner_Dialogue_Report.pdf.

103 Neil Overy, *The Role of Ownership in a Just Energy Transition* (Cape Town: Project 90 by 2030, 2018), https://90by2030.org.za/wp-content/uploads/2018/06/Just-Energy-Transition-low-res.pdf.

104 International Institute for Environment and Development, "CHOICES community energy project, South Africa", https://www.iied.org/choices-community-energy-project-south-africa, viewed 14 August 2019.

105 City of Cape Town, "About the Energy Water Waste Forum", http://www.capetown.gov.za/Work%20and%20business/Greener-business/energy-water-waste-forum/about-the-energy-water-waste-forum, viewed 8 October 2019.

106 Satoko Kishumoto and Oliver Petitjean, *Reclaiming Public Services: How Cities and Citizens Are Turning Back Privatisation* (Amsterdam and Paris: Transnational Institute, 2017), https://www.tni.org/en/publication/reclaiming-public-services

107 Ibid.

108 Sören Becker, Ross Beveridge and Matthias Naumann, "Remunicipalization in German cities: contesting neo-liberalism and reimagining urban governance?" *Space and Polity*, vol. 19, no. 1 (2015), pp. 76-90, https://www.tandfonline.com/doi/abs/10.1080/13562576.2014.991119

109 Sören Becker, Matthias Naumann and Timothy Moss, "Between coproduction and commons: understanding initiatives to reclaim urban energy provision in Berlin and Hamburg", *Urban Res. Pract.*, vol. 10, no. 1 (2017), pp. 63-85, https://www.researchgate.net/publication/297895402_Between_coproduction_and_commons_understanding_initiatives_to_reclaim_urban_energy_provision_in_Berlin_and_Hamburg.

110 Busch and McCormick, op. cit. note 35.

111 Energia Barcelona, "Barcelona Energia, the metropolitan electricity company", http://energia.barcelona/en/barcelona-energia-municipal-electricity-company, viewed 12 August 2019.

112 Mine Islar and Ezgi Irgil, "Grassroots practices of citizenship and politicization in the urban: The case of right to the city initiatives in Barcelona", *Citizenship Studies*, vol. 22, no. 5 (2018), pp. 491-506, https://www.tandfonline.com/doi/full/10.1080/13621025.2018.1477919.

113 Stephen Burgem "Power to the people: how Spanish cities took control of energy", *The Guardian* (UK), 14 June 2019, https://www.theguardian.com/environment/2019/jun/14/power-to-the-people-how-spanish-cities-took-control-of-energy.

114 Ibid.

115 Smart City Wien, "Smart – simple", https://smartcity.wien.gv.at/site/en/citizens-solar-power-plants/, viewed 21 October 2019.

116 Ibid.

117 Ibid.

118 Robin Hood Energy Ltd., https://robinhoodenergy.co.uk/, viewed 14 August 2019.

119 Bristol Energy, "About us", https://www.bristol-energy.co.uk/about-us/public-ownership, viewed 14 August 2019.

BACK

REFERENCE TABLES

1 **Tables R1, R2, R3 and R4** from the following sources: **Multiple targets** from the following: REN21, *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/gsr-2019/; CDP, "2018 – Cities Renewable Energy Targets", 6 June 2019, https://data.cdp.net/Renewable-Energy/2018-Cities-Renewable-Energy-Targets/eai5-mrwy; CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data; Carbonn Center, www.carbonn.org, viewed 17 September 2019; Tatjana Veith, *Local Energy and Climate Roadmaps: 5 City Visions for 2050* (Brussels: Energy Cities, 2018), https://energy-cities.eu/wp-content/uploads/2019/02/local_energy_climate_roadmaps_final-1.pdf; Opendatasoft, "Renewables Targets by Cities", https://data.opendatasoft.com/explore/dataset/world-city-level-examples-renewable-targets-2015-2050%40kapsarc/export/?disjunctive.country&disjunctive.city&disjunctive.indicator&sort=capacity_mw, viewed 22 August 2019; Energy Cities, *Cities Heading Towards 100% Renewable Energy by Controlling Their Consumption: Food for Thought and Action* (Brussels: Energy Cities, 2016), p. 8, http://www.energy-cities.eu/IMG/pdf/publi_100pourcent_final-web_en.pdf; Export.gov; NC Clean Energy Technology Center, *Database of State Incentives for Renewables & Efficiency* (DSIRE), "Data and tools", http://www.dsireusa.org/resources/data-and-tools/, viewed 15 November 2019. **Various US cities** from BloombergNEF, "US City Renewable Energy Targets and Strategies", 15 August 2017, https://www.bloomberg.com/impact/operations/renewable-energy/. **Other cities** from the following: Siemens, *Carbon Neutral Aarhus, City Performance Tool – May 2016*, https://assets.new.siemens.com/siemens/assets/public.1541967487.c22c381c0805bf9636cfe8f1bf621f2bdf35ee78.summary-aarhus-cypt-report-may-2016.pdf; City of Adelaide, "Carbon Neutral Adelaide Policy and Strategy", https://www.cityofadelaide.com.au/city-living/sustainable-adelaide/carbon-neutral-adelaide/carbon-neutral-adelaide-policy-and-strategy/, viewed 28 March 2019; *City of Alexandria, Environmental Action Plan 2030* (Alexandria, Egypt: 2009), https://www.alexandriava.gov/uploadedFiles/tes/eco-city/info/EAP%202030_Final_6-23-09_Scanned_Lower%20Resolution(1).pdf; CSR Europe, "Vattenfall invests for fossil free district heating in Amsterdam", 3 April 2019, https://www.csreurope.org/vattenfall-invests-fossil-free-district-heating-amsterdam; City of Amsterdam, "Policy: Renewable energy", https://www.amsterdam.nl/en/policy/sustainability/renewable-energy/, viewed 15 November 2019; "Avon commits to 100% renewable electricity at all operations and facilities", Vail Daily, 28 May 2019, https://www.vaildaily.com/news/avon-commits-to-100-renewable-electricity-at-all-operations-and-facilities/; "Beijing sees renewable energy growth", *Xinhua*, 8 September 2018, http://www.xinhuanet.com/english/2018-09/08/c_137454885.htm; KTC, "Skive bygger Europas storste power to gas-anlaeg", 20 April 2016, https://www.ktc.dk/artikel/skive-bygger-europas-stoerste-power-gas-anlaeg; Sustainable Bus, "Keolis wins a contract for Bergen bus fleet on renewable energy", https://www.sustainable-bus.com/news/keolis-wins-a-contract-for-bergen-bus-fleet-on-renewable-energy/r-us-transit-agencies-future-for-buses-electric, viewed 17 September 2019; Berlin Senate Department for the Environment, Transport and Climate Protection, "Climate Protection in Berlin", https://www.berlin.de/senuvk/klimaschutz/bek_berlin/index_en.shtml, viewed 10 October 2019; Berlin Senate Department for the Environment, Transport and Climate Protection, "Masterplan Solar City", https://www.berlin.de/sen/energie/energie/erneuerbare-energien/masterplan-solarcity/, viewed 10 October 2019; EBP, "City of Bern Energy and Climate Strategy 2025", https://www.ebp.ch/en/projects/city-bern-energy-and-climate-strategy-2025, viewed 17 September 2019; Sierra Club, "Boise becomes first Idaho city to commit to 100 percent renewable energy", press release (Boise, ID: 2 April 2019), https://www.sierraclub.org/press-releases/2019/04/boise-becomes-first-idaho-city-commit-100-percent-renewable-energy; Bex Bastable, "Brighton and Hove Buses wins millions in funding for eco-friendly vehicles – in Crawley", *Brighton & Hove Independent*, 6 February 2019, https://www.brightonandhoveindependent.co.uk/news/traffic-and-travel/brighton-and-hove-buses-wins-millions-in-funding-for-eco-friendly-vehicles-in-crawley-1-8799206; City of Brussels, "Climate Plan", https://www.brussels.be/climate-plan, viewed 14 October 2019; Buenos Aires Ciudad, "Consumo responsible", https://www.buenosaires.gob.ar/areas/med_ambiente/apra/des_sust/consumo_sust/eficiencia_edificios_publicos.php?menu_id=32415, viewed 29 May 2019; Burgas Municipality, *Burgas Municipality Strategy for Sustainable Energy Development 2011-2020, Action Plan 2011-2013* (Burgas, Bulgaria: 2011), https://www.burgas.bg/uploads/aa9ecc8f220b5b3ac3a6c18c243dbd4b.pdf; City of Charleston, "Cleaner energy", in *Charleston Green Plan* (Charleston, SC: 2016), https://www.charleston-sc.gov/DocumentCenter/View/1463/Green-Plan-Cleaner-Energy?bidId=; City of Charlotte, *Charlotte 2030: A Sustainable Vision for Our Region* (Charlotte, NC: 2010), https://www.sustaincharlotte.org/vision; Sophie Hirsh, "Chicago pledges 100 percent renewable energy by 2040", Green Matters, April 2019, https://www.greenmatters.com/p/chicago-pledges-renewable-energy; James Brasuell, "Cincinnati switching to 100% renewable energy for municipal facilities", Planetizen, 6 December 2017, https://www.planetizen.com/news/2017/12/96143-cincinnati-switching-100-renewable-energy-municipal-facilities; GrowSmarter, "Lighthouse city: Cologne", http://www.grow-smarter.eu/lighthouse-cities/cologne/, viewed 17 September 2019; Annie Ropeik, "Concord to begin planning process for renewable energy goals", New Hampshire Public Radio, 22 January 2019, https://www.nhpr.org/post/concord-begin-planning-process-renewable-energy-goals#stream/0; City of Dakar, *Plan Directeur d'Urbanisme de Dakar et ses Environs Horizon, 2035* (Dakar, Senegal: 2016), p. 28, http://open_jicareport.jica.go.jp/pdf/12250023.pdf; Power Technology, "Dubai makes progress on clean energy targets", 17 October 2018, https://www.power-technology.com/comment/dubai-clean-energy-targets/; Export.gov, "United Arab Emirates – Renewable Energy", 23 April 2018, https://www.export.gov/article?id=United-Arab-Emirates-Renewable-Energy; The Energy Mix, "Edmonton sets 2030 deadline for 100% re operations as Texas mayor explains renewable transition", 27 September 2018, https://theenergymix.com/2018/09/27/edmonton-sets-2030-deadline-for-100-re-operations-as-texas-mayor-explains-renewable-transition/; Eilat-Eilot, "About Eilat-Eilot", http://www.eilatenergy.org/about/, viewed 15 October 2019; City of El Paso, *Resilient El Paso* (El Paso, TX: 2017), https://www.elpasotexas.gov/~/media/files/coep/sustainability/el%20paso%20tx%20livable%20city%20sustainability%20plan.ashx?la=en; Enschede Municipality, "Enschede wekt op", http://enschedewektop.nl/, viewed 14 August 2019; *City of Fort Lauderdale, Sustainability Action Plan: Progress Report 2015* (Fort Lauderdale, FL: 2015), https://gyr.fortlauderdale.gov/home/showdocument?id=9892; Adam Wentworth, "Gothenburg places major order for new electric buses", Climate Action, 3 July 2018, http://www.climateaction.org/news/gothenburg-places-major-order-for-new-electric-buses; Wouter v Bolhuis and Faris Nizamic, "Energy lecture: Energy neutrality: The case of Groningen", Energy Academy, 28 November 2018, https://www.energyacademy.org/energy-lecture-groningens-energy-neutrality-sustainable-buildings-november-28th/; The Energy Mix, "Halifax declares climate emergency, aims for net zero carbon before 2050", 30 January 2019, https://theenergymix.com/2019/01/30/halifax-declares-climate-emergency-aims-for-net-zero-carbon-before-2050/; "HCC eyes 25% in renewable energy by 2025" Newsday, 7 June 2017, https://www.newsday.co.zw/2017/06/hcc-eyes-25-renewable-energy-2025/; Kirk Caldwell and Dawn Lippert, "Hawaii's mayors just committed to 100% renewable transportation by 2045", *Fast Company*, 21 December 2017, https://www.fastcompany.com/40511006/why-hawaicabbis-mayors-just-committed-to-100-renewable-transportation-by-2045; World Council on City Data, "#DATAFORCITIES – Celebrating Heerlen, the Netherlands", 29 November 2018, http://news.dataforcities.org/2018/11/dataforcities-celebrating-heerlen.html; Helsingin kaupungin ympäristökeskus, *Helsinki's Climate Roadmap* (Helsinki: 2015), https://issuu.com/helsinginymparistokeskus/docs/helsinki_climate_roadmap_20150427; Siemens, "Helsinki's 2030 Climate Technologies", March 2016, https://assets.new.siemens.com/siemens/assets/public.1541967614.6e7bf141ed1cc5b2f57a45d987d7ebec4529daa8.summary-helsinki-cypt-report-mar-2016.pdf; Hillsboro City, "Resolution N. 2494", https://www.hillsboro-oregon.gov/home/showdocument?id=7256, viewed 15 November 2019; *City of Hollywood, Sustainability Action Plan* (Hollywood, CA: 2017), http://fl-hollywood2.civicplus.com/DocumentCenter/View/11559/Full-SAP-document-3-7-17?bidId=; City of Honolulu, "City and County of Honolulu: Climate Advisor", https://www.resilientoahu.org/climate-advisor, viewed 15 November 2019; TVA, *TVA Valley Sustainable Community Program, City of Huntsville* (Huntsville, AL: 2016), https://3jzi0q2zthm01oqpx2h96lz1-wpengine.netdna-ssl.com/wp-content/uploads/2015/06/Huntsville-Inventory-Rev-9-26-2016.pdf; Kampala Capital City Authority, *Kampala Climate Change Action* (Kampala, Uganda: 2016),

https://www.kcca.go.ug/uDocs/Kampala-Climate-Change-Action.pdf; Renewables Networking Platform, "Aiming for 100% Renewable Energy: Kaposvár, Hungary", https://www.renewables-networking.eu/documents/HU-Kaposvar.pdf, viewed 17 September 2019; Annie Ropeik, "Keene joins N.H. towns working toward all-renewable energy goals", New Hampshire Public Radio, 18 January 2019, https://www.nhpr.org/post/keene-joins-nh-towns-working-toward-all-renewable-energy-goals; Kfar Sava from Zafrir Rinat, "Israeli cities take the lead in recycling and renewable energy", Haaretz, March 2018, https://www.haaretz.com/israel-news/israeli-cities-take-the-lead-in-recycling-and-renewable-energy-1.5867242; Matt Thomas, Mayor of London, "Zero Carbon London by 2050: Decentralised Energy Enabling Project", presentation, 24 July 2018, https://www.london.gov.uk/sites/default/files/deep_2018_stakeholder_event_presentations.pdf; Renewable Networking Platform, "Case Study: Loos in Transition", https://www.renewables-networking.eu/documents/CaseStudyLoos-en-Gohelle-FR.pdf, viewed 17 September 2019; Sierra Club, "Los Angeles commits to 100 percent clean energy to power all electricity, buildings, and transportation", press release (Los Angeles, CA: 30 April 2019), https://www.sierraclub.org/press-releases/2019/11/los-angeles-commits-100-percent-clean-energy-power-all-electricity-buildings; Sierra Club, "100% Campaign", https://www.sierraclub.org/ready-for-100/campaign, viewed 14 November 2019; City for Life, "Lviv will move to renewable energy by 2050: Andriy Sadovy signed the memorandum", 14 September 2018, https://cityforlife.org/lviv-will-move-to-renewable-energy-by-2050-andriy-sadovy-signed-the-memorandum/; Masdar from "Shams 1", https://masdar.ae/en/masdar-clean-energy/projects/shams-1, viewed 9 August 2019; Climatescope, "Liberia", http://global-climatescope.org/results/lr, viewed 19 April 2019; The Energy Mix, "Foundations, C40 Cities to help Montreal deliver on 2050 carbon neutral target", 14 December 2018, https://theenergymix.com/2018/12/14/foundations-c40-cities-to-help-montreal-deliver-on-2050-carbon-neutral-target/; Stadtwerke München, "Geothermie-Anlage beim Heizkraftwerk Süd", https://www.swm.de/privatkunden/unternehmen/energieerzeugung/geothermie.html, viewed March 2019; Christine Croniger, "Geothermal district heating for Munich", presentation at Baltic Nations Geothermal Symposium, Offenburg, Germany, 13 February 2019, http://iea-gia.org/publications-2/working-group-publications/2019-baltic-nations-symposium-presentations; Go100%RE, "Munich, Germany", 26 June 2015, http://www.go100re.net/properties/munich/; European Commission, "2018 – Nijmegen", https://ec.europa.eu/environment/europeangreencapital/winning-cities/2018-nijmegen/, viewed 15 November 2019; Andrew Woods, "Nottingham aims to be first carbon neutral city in the UK by 2028", Energy Digital, 24 January 2019, https://www.energydigital.com/energy-management/nottingham-aims-be-first-carbon-neutral-city-uk-2028; *State of Pennsylvania, Pennsylvania Electric Vehicle Roadmap* (Harrisburg, PA: 2019), http://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf; *City of Salzburg, Master Plan 2025* (Salzburg, Austria: 2015), https://www.stadt-salzburg.at/pdf/smart_city_masterplan_2025_stadt_salzburg.pdf; Go100%, "San Francisco – 100% renewable power by 2030", https://www.go100percent.org/cms/index.php?id=77&tx_ttnews[tt_news]=79&cHash=064a35afc66d04fe0785cee33ef04ba0, viewed 6 November 2019; IRENA, *City in Focus: Sao Paulo – Local Government Regulation Ordinances and Laws to Promote Renewable Energy* (Abu Dhabi: 2013), pp. 3-6, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/Jan/IRENA-cities-case-6-Sao-Paulo.pdf; Scarborough from The Energy Mix, "UK resort town declares climate emergency, seeks funds for net zero carbon target", 11 January 2019, https://theenergymix.com/2019/01/11/uk-resort-town-declares-climate-emergency-seeks-funds-for-net-zero-carbon-target/; City of Springfield, Strong, *Healthy and Just: Springfield's Climate Action and Resilience Plan* (Springfield, MA: 2017), http://www.pvpc.org/sites/default/files/SHJ_REPORT_FINAL_REV_2017.pdf; Triangulum, "Stavenger, Norway", https://www.triangulum-project.eu/?page_id=2326, viewed 15 November 2019; Sydney, "Getting ready to go 100% renewable", 17 October 2019, https://news.cityofsydney.nsw.gov.au/articles/getting-ready-to-go-100-renewable; Joshua S. Hill, "City of Sydney announces 100% renewable energy target", CleanTechnica, 2 April 2019 https://cleantechnica.com/2019/04/02/city-of-sydney-announces-100-renewable-energy-target/; City of Sydney, *Environmental Action 2016-2021: Strategy and Action Plan* (Sydney, Australia: March 2017), https://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0007/284749/Environmental-Action-strategy-and-action-plan.pdf; City of Sydney, "The big picture: Achieving net zero together", 27 September 2018, https://www.cityofsydney.nsw.gov.au/vision/sustainable-sydney-2030/sustainability/carbon-reduction; City of Sydney Environment Committee, "Inclusion of Requirement for 100 Per cent Renewables in Electricity Procurement", 4 March 2019, https://meetings.cityofsydney.nsw.gov.au/documents/s25434/Inclusion%20of%20Requirement%20for%20100%20per%20cent%20Renewables%20in%20Electricity%20Procurement.pdf; Cascade, "Tampere: Transforming Into a Smart Eco-City", http://nws.eurocities.eu/MediaShell/media/Tampere_eco%20construction.pdf, viewed 17 September 2019; Tartu City Government, *Tartu Energy Efficiency Action Plan* (Tartu, Estonia: 2017), http://www.pleecproject.eu/downloads/Reports/Work%20Package%206/Energy%20Efficiency%20Action%20Plans/tartu_eeap_-_english.pdf; City of Turku, "Turku's new climate plan to the global forefront", 8 June 2018, https://www.turku.fi/en/news/2018-06-08_turkus-new-climate-plan-global-forefront; IRIS Smart cities, "Municipality of Utrecht (UTR), The Nederlands", https://irissmartcities.eu/content/municipality-utrecht-utr-nederlands, viewed 15 November 2019; City of Vancouver, *Renewable City Strategy* (Vancouver, Canada: 2015), https://vancouver.ca/files/cov/renewable-city-strategy-booklet-2015.pdf.

2 **Table R5** from the following sources: **Multiple targets** from the following: Carbonn Center, www.carbonn.org, viewed 17 September 2019; CDP, "2018 – Cities Renewable Energy Targets", 6 June 2019, https://data.cdp.net/Renewable-Energy/2018-Cities-Renewable-Energy-Targets/eai5-mrwy; CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data; CDP, "Cities Renewable Energy Targets, map", 11 February 2019, https://data.cdp.net/Renewable-Energy/2017-Cities-Renewable-Energy-Targets-Map/xe6h-je5w; REN21, *Renewables 2019 Global Status Report*, op. cit. note 1; REN21, *Renewables 2018 Global Status Report* (Paris: 2018), http://www.ren21.net/gsr-2018/; Opendatasoft, "Renewable targets by cities", https://data.opendatasoft.com/explore/dataset/world-city-level-examples-renewable-targets-2015-2050%40kapsarc/table/?disjunctive.country&disjunctive.city&disjunctive.indicator&sort=capacity_mw, viewed 14 October 2019. **Specific cities** from the following: Beijing Development and Reform Commission, "Beijing Municipality 13th Five Year Plan RE Targets", 6 September 2016, http://www.beijing.gov.cn/zfxxgk/110002/zzqgh33/2016-10/21/content_742180.shtml; Bristol Is Open, "Bristol to generate as much solar energy as an average nuclear power station", https://www.bristolisopen.com/bristol-to-generate-as-much-solar-energy-as-an-average-nuclear-power-station-2/, viewed 17 September 2019; Moneyweb, "Ekurhuleni fast-forwards its green energy programme", 5 September 2019, https://www.moneyweb.co.za/news/south-africa/ekurhuleni-fast-forwards-its-green-energy-programme/; Gobierno de Mar del Plata, *Plan de Acción Mar del Plata Sostenible* (Mar del Plata, Argentina: March 2013), pp. 78-79, https://issuu.com/ciudadesemergentesysostenibles/docs/mar_del_plata_sostenible; Merida from United Nations Climate Change, "Global Climate Action", https://climateaction.unfccc.int/views/total-actions.html, viewed 26 April 2019; Kang Seung-woo, "Seoul to generate 1 GW of energy from solar by 2022", *Korea Times*, 27 November 2018, https://www.koreatimes.co.kr/www/nation/2018/11/281_259295.html; Shenzhen Development and Reform Commission, "Shenzhen 13th Five-Year-Plan Power Development", 1 August 2017, http://www.sz.gov.cn/szfgw/xxgk/ghjh/zxgh/201612/t20161227_5773598.htm; International Solar PV Network, "Tianjin City 13 Five Year Plan Renewable Energy Targets", 21 December 2016, http://solar.in-en.com/html/solar-2282220.shtml.

3 **Table R6** from the following sources: **Multiple targets** from Partnership for Sustainable, Low Carbon Tranport (SLoCaT), *E-mobility Trends and Targets* (Shanghai: 2019), http://www.slocat.net/sites/default/files/e-mobility_overview.pdf, and from C40, *Green and Healthy Streets Fossil Fuel Free Streets Declaration: Planned Action to Develop Commitments* (London: 2019), https://c40-production-images.s3.amazonaws.com/other_uploads/images/1426_G_HS_160919.original.pdf; **Specific cities** from the following: Athens, Madrid and Mexico City from "Four of world's biggest cities to ban diesel cars from their centres", *The Guardian* (UK), 2 December 2016, https://www.theguardian.com/environment/2016/dec/02/four-of-worlds-biggest-cities-to-ban-diesel-cars-from-their-centres; Bangalore from Invest Karnataka,

"Karnataka State Vehicle & Energy Storage policy, 2017", http://www.investkarnataka.co.in/assets/downloads/Karnataka-State-Electric-Vehicle-&-Energy-Storage-Policy-2017.pdf; Zhao Cheng, "Gas-to-electric cab conversion in Beijing brings opportunity worth 9 bln yuan", *National Business Daily*, 23 February 2017, http://www.nbdpress.com/articles/2017-02-23/1613.html; Zhang Chun, "Beijing limits on car registration boost electric vehicles", *Climate Home News*, 28 November 2016, https://www.climatechangenews.com/2016/11/28/beijing-limits-on-car-registration-boost-electric-vehicles/; Bellona, "Brussels aims to fully electrify its bus fleet by 2030", 19 May 2016, http://bellona.org/news/transport/electric-vehicles/2016-05-brussels-aims-to-fully-electrify-its-bus-fleet-by-2030; City of Buenos Aires, "Cuatro líneas de colectivo tendrán buses eléctricos a fin de año en la ciudad", 1 March 2018, https://www.argentina.gob.ar/noticias/cuatro-lineas-de-colectivo-tendran-buses-electricos-fin-de-ano-en-la-ciudad; Copenhagen from State of Green, https://stateofgreen.com/en/, viewed 26 April 2019; "Dubai sets new green mobility targets", *Gulf News*, 20 January 2017, https://gulfnews.com/uae/transport/dubai-sets-new-green-mobility-targets-1.1965138; Foshan from CitiesSHIFT, "Accelerating electrification in public transport", webinar, 8 July 2019, https://www.youtube.com/watch?v=jdf1_3-6gvY; *Environmental Protection Department*, "Promotion of electric vehicles in Hong Kong", http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/promotion_ev.html, viewed 11 July 2019; *City of London, Mayor's Transport Strategy* (London: 2017), https://consultations.tfl.gov.uk/policy/mayors-transport-strategy/user_uploads/pub16_001_mts_online-2.pdf; City of Los Angeles, *The pLAn* (Los Angeles, CA: 20170, http://plan.lamayor.org/wp-content/uploads/2017/03/the-plan.pdf; City of Montreal, *Electrifying Montreal – Transportation Electrification Strategy 2016-2020* (Montreal, Canada: 2016), http://ville.montreal.qc.ca/pls/portal/docs/PAGE/PROJ_URBAINS_FR/MEDIA/DOCUMENTS/TRANSPORTATION_ELECTRIFICATION_STRATEGY_2016_2020_.PDF; City of New Delhi, *Electric Policy* (New Delhi: 2018), http://transport.delhi.gov.in/sites/default/files/All-PDF/Electric%20Policy%202018.pdf; Car and Bike, "Delhi Government plans to roll-out 1000 electric buses", 22 March 2018, https://auto.ndtv.com/news/delhi-government-plans-to-roll-out-1000-electric-buses-1827372; City of New York, *NYC Clean Fleet* (New York, NY: 2015), http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/NYC%20Clean%20Fleet.pdf; Gina Coplon-Newfield and Conner Smith, "For U.S. transit agencies, the future for buses is electric", Sierra Club, 21 February 2019, https://www.sierraclub.org/articles/2019/02/for-us-transit-agencies-future-for-buses-electric; City of New York, "ONENYC: Mayor announces city electric vehicle fleet ahead of schedule, half way toward goal", press release (New York, NY: 20 April 2017), http://www1.nyc.gov/office-of-the-mayor/news/245-17/onenyc-mayor-city-electric-vehicle-fleet-ahead-schedule-half-way-toward-goal; ZEV Alliance, "International ZEV Alliance Announcement", press release (Washington, DC: 3 December 2015), http://www.zevalliance.org/international-zev-alliance-announcement/, viewed 26 April 2019; City of Oslo, *Climate and Energy Strategy for Oslo* (Oslo, Norway: 2016), https://www.oslo.kommune.no/getfile.php/13166797/Content/English/Politics%20and%20administration/Green%20Oslo/Plans%20and%20programmes/Climate%20and%20Energy%20Strategy%20Oslo.pdf; City of Paris, "Renewable energy", https://api-site-cdn.paris.fr/images/97041, viewed 11 July 2019; *RATP, Bus 2025: The Ambitious RATP plan for a 100% Ecologically Friendly Fleet* (Paris: 2014), https://www.ratp.fr/en/groupe-ratp/join-us/100-environmentally-friendly-bus-fleet-thanks-bus2025-plan; City of Portland, "History and key documents of climate planning and action in Portland", https://www.portlandoregon.gov/bps/article/531984, viewed 11 July 2019; JN, "STCP vai ter mais 86 autocarros elétricos nas ruas do Porto", 9 November 2018, https://www.jn.pt/local/noticias/porto/porto/stcp-vai-ter-mais-86-autocarros-eletricos-e-de-elevada-performance-ambiental-10155430.html; City of Reykjavik, "Reykjavik and climate", http://reykjavik.is/en/reykjavik-and-climate, viewed 11 July 2019; Kristine Lofgren, "Rome is banning all oil-burning cars by 2024", Inhabitat, 3 January 2018, https://inhabitat.com/rome-is-banning-all-oil-burning-cars-by-2024/; City of San Francisco, The Mayor's Electric Vehicle Working Group, *Proposed Electric Vehicle Roadmap for San Francisco* (San Francisco, CA: 2019), https://www.sfmta.com/sites/default/files/reports-and-documents/2019/07/evroadmap_final_june2019.pdf; City of Seattle, "Mayor, O'Brien: 30 percent electric vehicle use in Seattle by 2030, new investments in EV charging stations", 14 September 2016, https://council.seattle.gov/2016/09/14/mayor-obrien-30-percent-electric-vehicle-use-in-seattle-by-2030-new-investments-in-ev-charging-stations/; Kang Seung-woo, "Seoul to encourage electric delivery motorcycles as anti-fine dust measure", *Korea Times*, 15 April 2019, https://www.koreatimes.co.kr/www/nation/2019/04/371_267193.html; Ovidiu Sandru, "Seoul's bus fleet plans to turn half electric by 2020", Green Optimistic, 5 January 2011, https://www.greenoptimistic.com/seoul-electric-buses-20110105/#.WW807oiGOUk; City of Stockholm, "Summary of the City of Stockholm's electric vehicle Strategy", https://urbact.eu/sites/default/files/import/Projects/EVUE/documents_media/Stockholm_s_EV_strategy_summary__Eng_.pdf, viewed 11 July 2019; Phil Dzikiy, "Toronto's first all-electric city bus hits the road, 60 electric buses to join fleet by early 2020", *Electrek*, 3 June 2019, https://electrek.co/2019/06/03/toronto-electric-bus-60-2020/; Gyotongn, "Ulsan replaces the city bus 'Hydrogen bus' by 2035", 5 September 2018, http://www.gyotongn.com/news/articleView.html?idxno=186789 (using Google Translate); Utrecht from Charlotte Huisman and Marcel Van Lieshout, "De (letterlijk) stille revolutie van het openbaar vervoer: bussen steeds vaker elektrisch", de Volkskrant, 6 September 2017, https://www.volkskrant.nl/nieuws-achtergrond/de-letterlijk-stille-revolutie-van-het-openbaar-vervoer-bussen-steeds-vaker-elektrisch~be7c44ab/; City of Vancouver, *Vancouver's EV Ecosystem Strategy* (Vancouver, CA: 2016), https://vancouver.ca/files/cov/EV-Ecosystem-Strategy.pdf.

4 **Table R7** from the following sources: IQ AirVisual, "World most polluted cities 2018 (PM2.5)", https://www.airvisual.com/world-most-polluted-cities; Umair Urfan, "The law that's helping fuel Delhi's deadly air pollution", Vox, 13 November 2019, https://www.vox.com/science-and-health/2019/11/8/20948348/delhi-india-air-pollution-quality-cause; International Energy Agency Policies and Measures Database, "Abu Dhabi: Renewable Energy Deployment Strategy", 5 September 2016, https://www.iea.org/policiesandmeasures/pams/unitedarabemirates/name-31246-en.php; City of Amsterdam, "Policy: Renewable energy", https://www.amsterdam.nl/en/policy/sustainability/renewable-energy/, viewed 12 November 2019; Amsterdam renewable energy policy from CDP, "2017 - Cities Renewable Energy Targets", https://data.cdp.net/Renewable-Energy/2017-Cities-Renewable-Energy-Targets-Map/xe6h-je5w, viewed 12 November 2019; Amsterdam renewable power target from David Thorpe, "One Planet" *Cities: Sustaining Humanity within Planetary Limits* (Abingdon, UK: Routledge, 2019), https://www.routledge.com/One-Planet-Cities-Sustaining-Humanity-within-Planetary-Limits-1st-Edition/Thorpe/p/book/9781138615106; Amsterdam renewable heating and cooling target from REN21, *Renewables 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf; Yang Yi, "Beijing sees renewable energy growth", *Xinhua*, 8 September 2018, http://www.xinhuanet.com/english/2018-09/08/c_137454885.htm; "China steps up green energy push with revised renewable target of 35 per cent by 2030", *South China Morning Post*, 26 September 2018, https://www.scmp.com/news/china/politics/article/2165831/china-steps-green-energy-push-revised-renewable-target-35-2030; Luke Sherlock et al., *Constructing a New, Low-Carbon Future: How Chinese Cities Are Scaling Ambitious Building Energy Efficiency Solutions* (Berkeley, CA: C40 China Buildings Programme (CBP), Lawrence Berkeley National Laboratory, 2018), https://www.c40.org/researches/constructing-a-new-low-carbon-future-china; Berlin climate policy, renewable energy policy, and renewable heating and cooling target from Senate Department for the Environment, Transport and Climate Protection, "Climate-neutral Berlin 2015", https://www.berlin.de/senuvk/klimaschutz/politik/en/ziele.shtml, viewed 12 November 2019; Berlin air pollution policy from Benjamin Wehrmann, "Berlin restricts diesel on some roads and sets speed limits to tackle air pollution", Clean Energy Wire, 2019, https://cleanenergywire.org/news/berlin-restricts-diesel-some-roads-and-sets-speed-limits-tackle-air-pollution; Bern renewable power and renewable heating and cooling targets from EBP, "City of Bern Energy and Climate Strategy 2025", https://www.ebp.ch/en/projects/city-bern-energy-and-climate-strategy-2025, viewed 12 November 2019; Brussels climate policy and renewable energy policy from Brussels Administration, "Climate plan", https://www.brussels.be/climate-plan, viewed 12 November 2019; Brussels air pollution policy from Feargus O'Sullivan, "Brussels makes an extreme plan to fight pollution emergencies", CityLab, 1 March 2018, https://www.citylab.com/environment/2018/03/

brussels-pollution-emergency-plan-transit-energy/554363/; Umair Irfan, "The law that's helping fuel Delhi's deadly air pollution", Vox, 8 November 2019, https://www.vox.com/science-and-health/2019/11/8/20948348/delhi-india-air-pollution-quality-cause; Mai Nguyen, "Bikes out, trees in: Hanoi tackles air pollution woes", *Reuters*, 23 July 2018, https://www.reuters.com/article/us-vietnam-pollution/bikes-out-trees-in-hanoi-tackles-air-pollution-woes-idUSKBN1KD14T; Bambang Nurbianto, "Air pollution policy", *Jakarta Post*, 14 September 2019, https://www.thejakartapost.com/academia/2019/09/14/jakarta-needs-tough-air-pollution-control-are-we-ready.html; New Climate Institute et al., *Assessment of Subnational and Non-State Climate Action* (Cologne and Berlin: 2019), https://newclimate.org/wp-content/uploads/2019/09/19-9117_Factsheet_Indonesia_Country.pdf; Kampala City Authority, *Kampala Climate Change Action* (Kampala, Uganda: 2016), http://www.kcca.go.ug/uDocs/Kampala%20Climate%20Change%20Action.pdf; Carbonn Center, www.carbonn.org, viewed 17 September 2019; Lisbon climate policy from Covenant of Mayors for Climate & Energy, "Lisbon present ambitious climate action plans", 2019, https://www.eumayors.eu/news-and-events/news/1668-lisbon-present-ambitious-climate-action-plans.html, viewed 12 November 2019; Lisbon renewable power policy from CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data; London climate policy and renewable energy policy from Mayor of London, *Zero Carbon London: A 1.5C Compatible Plan* (London: 2018), https://www.london.gov.uk/sites/default/files/1.5c_compatible_plan.pdf; London renewable heating and cooling policy from Mayor of London, *London Environment Strategy* (London: 2018), https://www.london.gov.uk/sites/default/files/osd21_es_executive_summary.pdf; Luxembourg City climate policy from Heledd Pritchard, "Climate strategy to achieve 40% emission reduction target", *Luxembourg Times*, 28 January 2018, https://luxtimes.lu/luxembourg/32619-climate-strategy-to-achieve-40-emission-reduction-target; Luxembourg City air pollution policy from Laureen Fagan, "Praise may be premature for Luxembourg's transport plan", Sustainability Times, 24 December 2018, https://www.sustainability-times.com/clean-cities/praise-may-be-premature-for-luxembourgs-transport-plan/; Luxembourg City renewable energy policy from "Luxembourg sets target of 25% renewable energy by 2030", Chronicle, 8 May 2019, https://chronicle.lu/category/energy/29151-luxembourg-sets-target-of-25-renewable-energy-by-2030; Luxembourg City renewable power target from Kate Oglesby and Patrick Jacquemot, "10% of electricity in Luxembourg from renewable sources", *Luxembourg Times*, https://luxtimes.lu/luxembourg/38764-10-of-electricity-in-luxembourg-from-renewable-sources; Mexico City climate and renewable energy policy from C40, "Mexico city hospitals lead the way in energy transition", 14 September 2017, https://www.c40.org/case_studies/cities100-mexico-city-hospitals-lead-the-way-in-energy-transition; Mongolia climate policy from United Nations, "UNICEF Executive Board Annual Session 2019 – Statement by H.E. Mr. Sukhbold Sukhee, Ambassador Extraordinary and Plenipotentiary, Permanent Representative of Mongolia to the United Nations (on Agenda Item 4)", 11 June 2019, https://www.un.int/mongolia/statements_speeches/unicef-executive-board-annual-session-2019-statement-he-mr-sukhbold-sukhee; "Ulaanbaatar, Mongolia's capital city, plans to go green by 2050", GIZ Office Bangkok, 2018, https://www.thai-german-cooperation.info/en_US/ulaanbaatar-mongolias-capital-city-plans-to-go-green-by-2050/; Moscow renewable energy policy and renewable power target from CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data; Paris climate policy, air pollution policy, renewable transport target, renewable energy, and renewable heating and cooling targets from City of Paris, *Paris Climate Action Plan: Towards a Carbon Neutral City and 100% Renewable Energies* (Paris: 2018), https://api-site-cdn.paris.fr/images/101081, viewed 8 November 2019; Paris renewable energy policy from CDP, "2018 – Cities Renewable Energy Targets", 6 June 2019, https://data.cdp.net/Renewable-Energy/2018-Cities-Renewable-Energy-Targets/eai5-mrwy; City of Paris, "Renewable energy", https://api-site-cdn.paris.fr/images/97041, viewed 11 July 2019; REN21, *Renewables 2019 Global Status Report*, op. cit. note 1; Prague air pollution policy from Air Quality in Europe, "Prague", http://www.airqualitynow.eu/city_info/prague/page4.php, viewed 11 November 2019; Singapore climate policy from Climate Action Tracker, "Singapore", https://climateactiontracker.org/countries/singapore/, viewed 12 November 2019; Singapore air pollution policy from National Environment Agency of Singapore, "Air Quality", https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality, viewed 12 November 2019; Singapore renewable energy policy from Audrey Tan, "Singapore to ramp up solar energy production to power 350,000 homes by 2030", The Straits Times, https://www.straitstimes.com/singapore/environment/solar-energy-to-meet-4-of-singapores-energy-demand-by-2030-up-from-less-than-1; Sofia from Republic of Bulgaria, *Fourth National Communication on Climate Change* (Sofia, Bulgaria: 2006), https://unfccc.int/resource/docs/natc/bgrnc4.pdf; Seoul climate policy from Yoo Jae-hee, "Seoul reduces 10 million tons of greenhouse gases by 2020", E-Daily, 9 February 2015, https://www.edaily.co.kr/news/realtime/realtime_NewsRead.asp?newsid=02378006609268880 (using Google Translate); Seoul air pollution policy from Seoul Metropolitan Government, "Fine dust common sense" https://bluesky.seoul.go.kr/finedust/common-sense (using Google Translate), viewed 8 November 2019; Seoul renewable energy policy from Seoul Urban Solutions Agency, "Energy policy", http://susa.or.kr/ko/content/energy?ckattempt=1 (using Google Translate), viewed 8 November 2019; Seoul renewable power policy from CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data; Taipei climate policy and renewable energy policy from Environmental Protection Department, *New Taipei City Government, City of New Taipei Climate Action Plan* (Taipei: 2015), http://www.globalcovenantofmayors.org/wp-content/uploads/2015/09/City-of-New-Taipei-Climate-Action-Plan.pdf; Taipei renewable power target from REN21, *Renewables 2019 Global Status Report*, op. cit. note 1; Tel Aviv climate policy and renewable energy policy from Tel-Aviv Government, "Smart environment", https://www.tel-aviv.gov.il/en/abouttheCity/Pages/SmartEnvironment.aspx, viewed 11 November 2019; Tokyo climate policy from Ryusei Takahashi, "Why aren't more young people fighting climate change in Japan?" *Japan Times*, 5 November 2019, https://www.japantimes.co.jp/news/2019/11/05/national/barriers-climate-activism-in-japan/; Tokyo renewable energy policy from CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data; Tokyo renewable power target from REN21, Renewables 2019 *Global Status Report*, op. cit. note 1; Vienna climate policy, heating and cooling target, and transport target from Vienna City Administration, *Smart City Wien Framework Strategy* (Vienna: 2014), https://www.wien.gv.at/stadtentwicklung/studien/pdf/b008384a.pdf, viewed 11 November 2019; Vienna renewable energy policy from Karl Buchberger et al., *The Energy Framework Strategy for Vienna* (Vienna: 2017), https://www.wien.gv.at/stadtentwicklung/energie/pdf/energierahmenstrategie-2030-en.pdf; Warsaw from Eurocities, *City Profile: Warsaw* (Brussels: 2012), http://nws.eurocities.eu/MediaShell/media/CASCADE_Warsaw_profile.pdf; CDP, "Cities Renewable Energy Targets", 11 February 2019, https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p/data.

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RENEWABLES IN CITIES 2019 GLOBAL STATUS REPORT

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ISBN 978-3-9818911-9-5