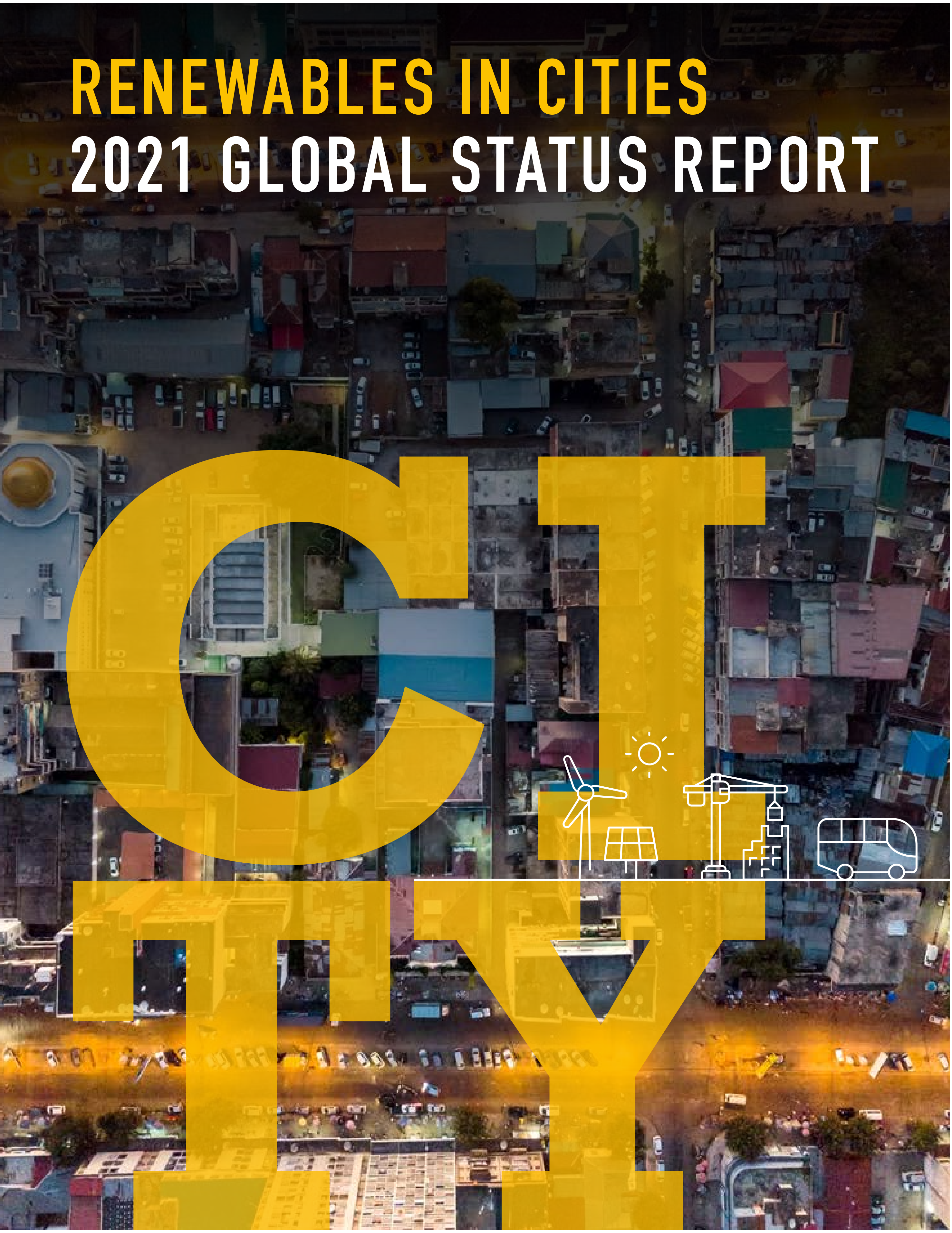
REN21
RENEWABLES NOW

RENEWABLES IN CITIES
2021 GLOBAL STATUS REPORT



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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 shift to renewable energy happen – now.

The most successful organisms, such as an octopus, have a **decentralised intelligence** and "sensing" function. This increases responsiveness to a changing environment. REN21 incarnates this approach.

Our more than **2,000 community members** guide our co-operative work. They reflect the vast array of backgrounds and perspectives in society. As REN21's eyes and ears, they collect information and share intelligence, by sending input and feedback. REN21 takes all this information to better understand the current thinking around renewables and change norms. We also use this information to connect and grow the energy debate with non-energy players.

Our annual publications, the *Renewables in Cities Global Status Report* and the *Renewables Global Status Report*, are probably the world's most comprehensive crowdsourced reports on renewables. It is a truly collaborative process of co-authoring, data collection and peer reviewing.

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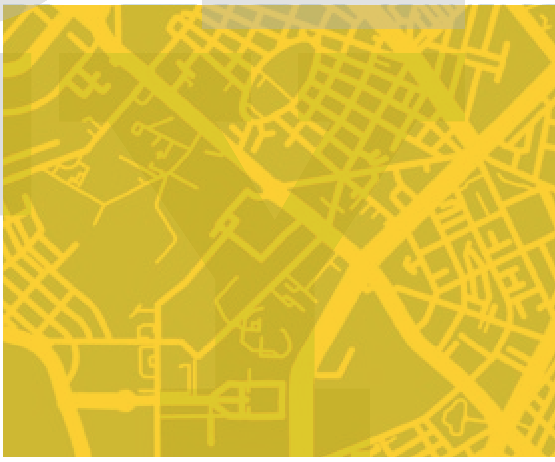

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FOREWORD

As we launch the second edition of the *Renewables in Cities Global Status Report* (REC), we find ourselves in a period of global flux. Economic activity and public life have been disrupted around the world. But we have also witnessed an increasing consciousness and public pressure around the importance of clean and healthy living environments – particularly in cities. Citizens are engaging with renewable energy and pushing local and national governments to act. Many decision makers also are becoming aware of the opportunities that renewables offer for a green recovery.

Despite the global challenges triggered by the COVID-19 crisis, we encountered many encouraging stories. Many city governments have installed, purchased or contracted for renewable energy to meet the demand of their own operations. They have also continued to adopt renewable energy targets and to implement policies to incentivise local consumption and generation of renewables, have set net-zero targets and have banned fossil fuels for various uses.

As inspirational as these stories are, we're still a far cry from what is needed. As United Nations Secretary-General António Guterres stated, "Cities are where the climate battle will largely be won or lost." Cities are high-impact areas: they are home to more than 55% of the global population and account for around three-quarters of global final energy consumption. Cities also are essential for accelerating the development of renewables in sectors that continue to lag behind, namely buildings and transport. Still, some national governments underestimate the value of cities to achieve national decarbonisation goals. And some city governments do not have the resources and expertise or just may not recognise their critical role in the shift to a renewables-based economy.

Some things don't change, even with an ongoing global pandemic. We need good, reliable/trusted, and shared data and knowledge to create awareness, inform and convince decision makers, and tell the stories of renewables. At REN21, we collaborate with our international community to provide such data. REC 2021 has benefited from data, expertise and insights from more than 350 renewable energy and city experts, contributors, researchers and authors that have worked together to identify the trends and developments of renewables in cities.

On behalf of the REN21 Secretariat, I would like to thank all those who contributed to the successful production of REC 2021. Special thanks go to all chapter authors; Special Advisors Janet Sawin, Maryke van Staden and Peta Wolpe; Project Manager Lea Ranalder; and the entire team at the REN21 Secretariat. I would also like to thank the Advisory Committee for their guidance, continuous support and pioneering spirit to start building a continuous database to track advancement on renewable energy at the city level.

We hope that REC 2021 will contribute to an active exchange of views on renewables in cities and serve as an inspiration for continuous action to accelerate the uptake of renewables now.

Rana Adib
Executive Director, REN21

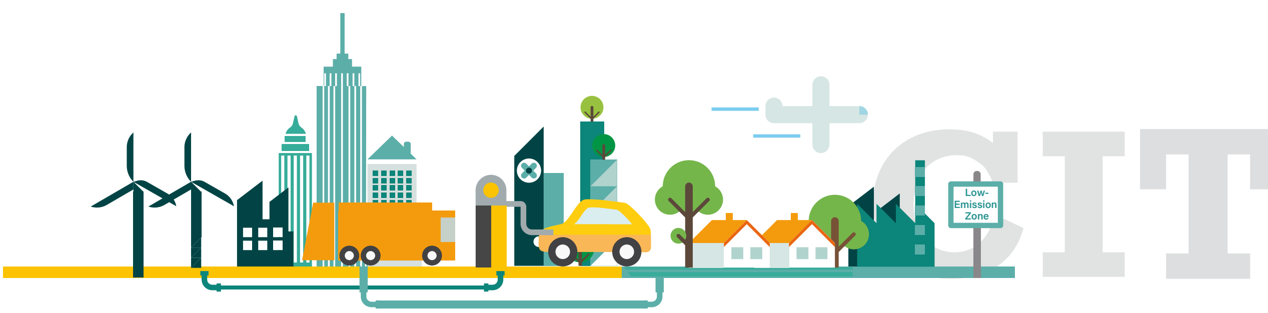
PURPOSE OF THIS REPORT

City governments around the world are taking action to accelerate the global uptake of renewable energy, both in municipal operations as well as city-wide. Municipalities have installed, purchased and contracted for renewable energy to meet the demand of their own buildings and vehicle fleets; adopted renewable energy targets and policies to incentivise the local generation and use of renewables; and supported urban community energy projects.

Traditionally, national governments have been the main entities tasked with governing the energy supply and driving the transition to renewables. Still today, many city governments continue to perceive the national government as the primary entity responsible for defining and implementing the energy agenda. However, city governments are uniquely positioned to lead locally in the shift from fossil fuel-based systems towards renewables, while curbing energy use and related greenhouse gas emissions. Decarbonising heating, cooling and transport, which together represent more than 80% of final energy demand, requires local solutions. Thus, cities – including their governments, inhabitants, and commercial and industrial actors – are essential to building a renewables-based economy, and their active participation is critical in helping to define and implement the energy agenda at the local, national and global levels.

REN21's *Renewables in Cities Global Status Report* (REC) series provides an overview of the status, trends and developments of renewable energy in cities, using the most up-to-date information and data available. The REC's neutral, fact-based approach documents in detail the annual developments in policies, markets, investments and citizen action, with a particular focus on renewables in public, residential and commercial buildings as well as public and private urban transport. The REC complements REN21's *Renewables Global Status Report*, which covers renewable energy market, industry and policy trends. Jointly, these reports contribute to making renewable energy visible in the global debate, drawing decision makers' attention to renewables and continuously providing better data and tracking to inform energy decisions worldwide.

REC 2021 is the result of a collaborative effort, building on REN21's unique data and reporting culture (→ *see Data Collection and Validation section*), with more than 330 data contributors and peer reviewers and over 30 individual interviews from around the world. The report is endorsed by an Advisory Committee of more than 20 organisations, including major renewable energy players and city networks. In this collaborative process, data are collected on hundreds of cities, ranging from mega-cities to small and medium-sized cities and towns. Collectively, this report aims to inform decision makers and to create an active exchange of views and information around urban renewable energy.



EXECUTIVE SUMMARY

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01 GLOBAL OVERVIEW OF RENEWABLES IN CITIES

Cities around the world are taking action to accelerate the global uptake of renewable energy. City governments increasingly recognise the potential of renewables to help create clean, liveable and equitable cities: overall, more than 1 billion people lived in a city with a renewable energy target and/or policy in 2020.

National governments typically are seen as the main bodies responsible for governing energy supply and infrastructure and for driving the transition to a renewables-based energy system. However, city governments are uniquely positioned to curb energy use and related greenhouse gas emissions while accelerating the uptake of renewable energy.

Cities are home to more than 55% of the world's population and contribute around three-quarters of the carbon dioxide (CO_2) emissions from global final energy use. In recent years, energy demand in cities has increased rapidly due to rising global population growth, urbanisation and urban economic activity. Although the urban electrification rate is high in most of the world, more than 176 million city dwellers continue to lack electricity access. Municipal governments can play a key role in expanding energy access and achieving other Sustainable Development Goals while contributing to the objectives of the Paris climate agreement by increasing the production and consumption of renewable energy.

Most of the energy in cities is consumed directly either for electricity, for heating and cooling buildings and industrial activities, or for transporting people and goods. City governments themselves use only a small portion of this energy for municipal buildings and fleets; the rest is used city-wide for residential and commercial buildings, industrial activities and private transport. Thus, achieving urban renewable energy targets depends not only on political commitment and municipal investment in renewables, but also on governments' ability to mobilise the wider uptake of renewables by other actors, including through comprehensive policies, awareness-raising and stakeholder dialogue.

55% of the world's population

lives in cities.

Renewable energy action in cities often has progressed faster than trends and policy steps at the national level. During 2019 and 2020, municipal governments around the world demonstrated leadership on advancing the energy and climate agendas. Reporting on government operations and city-wide energy and climate targets increased, and several cities raised their ambition by adopting higher targets or setting earlier target years for reaching their goals. Strong sub-national leadership sends a signal to industries and service providers as well as to regional and national governments, and also helps to inform overall procurement processes that require clean services and products.

The possibilities and strategies for municipal governments to scale up renewables to achieve their climate and energy targets depend on a variety of factors. One decisive variable in a city's ability to advance the deployment and use of renewable energy is the degree of regulatory and financial power that national governments grant to city governments. Existing regulatory frameworks at the state/provincial, national and regional levels also influence local renewable energy production, target-setting and policy making. In addition, the ability of cities to scale up renewables is greatly affected by market rules, energy regulations and policies set by higher levels of government (including the political dynamics that shape these instruments) and by the degree of economic dependence on fossil fuels.

In 2020, the unfolding of the COVID-19 pandemic and the government-initiated lockdowns to slow the spread of infections had major impacts on both cities and the drivers for renewables. Economic activity fell sharply in the early months of the pandemic, reducing energy demand globally and severely affecting urban energy use, notably in the transport sector. These developments resulted in a shift in government (especially municipal) priorities, as efforts to ensure public health and well-being were pushed up the policy agenda. Images of blue skies and clearer air helped to increase societal pressure towards reduced pollution and a green recovery. Although COVID-19 recovery plans were still being prepared as of early 2021, initial proposals emphasised local economic development and job creation, with some municipal governments announcing green recovery packages – including renewable energy options – in line with similar plans proposed at the national and supra-national levels.

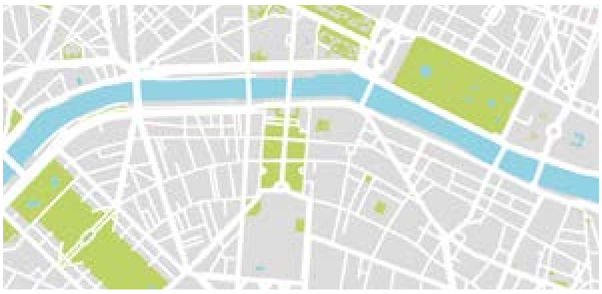
02 URBAN POLICY LANDSCAPE

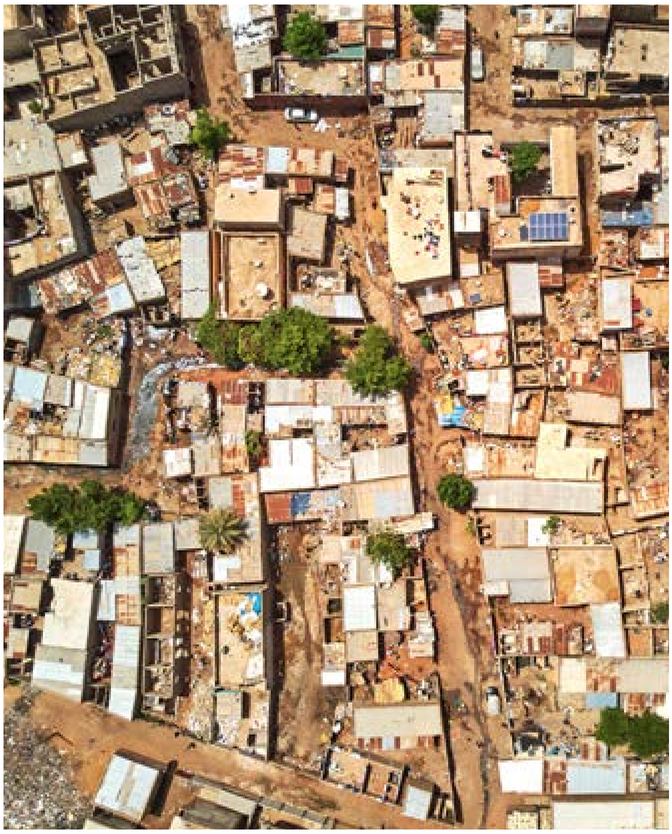
To achieve their energy and climate targets, municipal governments have procured renewables for their own operations, scaled up renewable energy generation on public buildings and for municipal fleets, and expanded their policy portfolios to encourage the uptake of renewables city-wide.

TARGETS

Globally, at least 834 cities in 72 countries, covering 558 million people, had adopted a renewable energy target in at least one sector by the end of 2020. Altogether, these cities had a combined total of 1,088 targets, including 653 targets for 100% renewable energy use either in municipal operations or city-wide. While municipal renewable energy targets have grown around the world, they are most common in Europe and the United States and remain less widespread in Asia, Latin America and the Caribbean, and Sub-Saharan Africa.

Although renewable energy target-setting has focused heavily on the power sector, targets have grown in the heating and cooling and transport sectors. Several cities have adopted detailed plans to transition to renewables in their heating systems, while the number of cities adopting targets to increase renewables in the transport sector and to expand the use of battery electric or hydrogen vehicles (which can be powered by renewables) has grown. By the end of 2020, at least 67 cities had e-mobility targets, up from 54 in mid-2019, creating opportunities for wider use of renewables in transport.





These sector-specific targets are being adopted alongside municipal targets to reduce CO_2 emissions, which, along with energy efficiency measures, enable the uptake of renewables. By the end of 2020, more than 10,500 cities had passed CO_2 emission reduction targets, and around 800 cities had committed to net-zero emissions, with the number of such net-zero targets increasing roughly eight-fold from 2019. Only a small number of cities had action plans or binding legislation to achieve their net-zero targets, and it remains to be seen how municipal governments specify a role for renewables.

POLICIES

For municipal governments that have direct control over city infrastructure, increasing the share of renewables in their own operations, buildings and fleets often has been a first step towards expanding the use of these technologies city-wide. To achieve their energy and climate targets, municipal governments have supported renewable energy progress either by procuring energy from renewable sources for their own operations or by investing in on-site/distributed renewable generation capacity on public buildings (such as schools, hospitals, sport centres and social housing) and for municipal transport fleets.

However, the success of meeting urban renewable energy targets relies not only on political commitment and municipal investments in renewables, but also on the decisions of individual households, communities, businesses and other urban actors. Municipal governments have expanded their policy portfolios to encourage and support the broader uptake of renewables. By the end of 2020, at least 799 municipal governments had in place regulatory policies, fiscal and financial incentives as well as indirect support policies to enable the uptake of renewables in buildings and transport city-wide (for a combined total of 1,107 policies, with some cities having more than one policy). Most of the cities with policies were in the United States and Europe, followed by Asia and Latin America and the Caribbean.

In the **buildings** sector, municipal governments differentiate their policy approaches between new and existing buildings, as well as by building type (residential, commercial, industrial, public). The number of building codes and mandates that include renewable energy for electricity or heating (usually solar photovoltaics (PV) or solar thermal) has grown. These codes typically apply to new buildings; for existing buildings, renewables often are encouraged via financial and fiscal incentives such as grants, rebates and low-interest loans. Compared to the power sector, city-level policies to increase the share of renewables in heating and cooling in buildings have been less widespread, although these sectors have attracted growing attention, notably in the European Union. Several cities also have adopted policies to support both power and heating (typically for solar PV and solar thermal).

At least
1,107 policies
were supporting renewables in cities, mostly concentrated in the United States and Europe.

In the heating sector, municipal governments increasingly use fossil fuel bans and restrictions that enable the deployment of energy efficiency and renewable energy solutions. By the end of 2020, a total of 53 cities spanning 10 countries had either introduced or planned a ban or restriction on the use of natural gas, oil or coal in buildings for space and water heating purposes, up from only a handful of countries in 2015. In addition, municipal governments are facilitating the integration of renewables into their district energy networks, often in co-operation with public or private partners.

Policy efforts to increase the share of renewables in urban **transport** systems have expanded in recent years, and while biofuels – especially locally produced biofuels – still play a role in some cities' transport decarbonisation plans, momentum is shifting rapidly towards electrification. Several cities have adopted mandates for installing electric vehicle (EV) charging infrastructure in new buildings, which provide a critical entry point for higher uptake of renewables in transport, especially if combined with renewable electricity policies.

In addition to public procurement and direct investment by municipal governments, the transition in the transport sector has been driven mainly by subsidies, grants and rebates for battery electric and fuel cell vehicles. The growing numbers of low-emission zones and of bans/restrictions on certain fuels or vehicles – in place in 249 and 14 cities, respectively, as of late 2020 – also have implications for the use of electricity and renewable fuels in urban transport. A few cities have developed local strategies for the production and use of renewable hydrogen in fleets.

Many cities rely on financial incentives and other support policies set by national and/or state governments to complement the limited resources they themselves have to spend on renewable energy programmes. Policy coherence and integration across different levels of government is key to enable a timely and cost-effective transition to a renewables-based energy system.

03 MARKETS AND INFRASTRUCTURE IN CITIES

Cities are both consumers and producers of energy. Because cities – their governments, inhabitants, and commercial and industrial entities – account for around three-quarters of global final energy use, they have the potential to drive a substantial amount of renewable energy deployment.

No city is an island in the context of energy procurement and use, with each linked in some measure to its surroundings via power grids, fuel pipelines or other regional supply networks. As the renewable component of the regional energy supply rises, generally so does the share of renewables in a city's energy mix. In addition, more and more cities around the world are taking active steps to increase their local use of renewable energy.

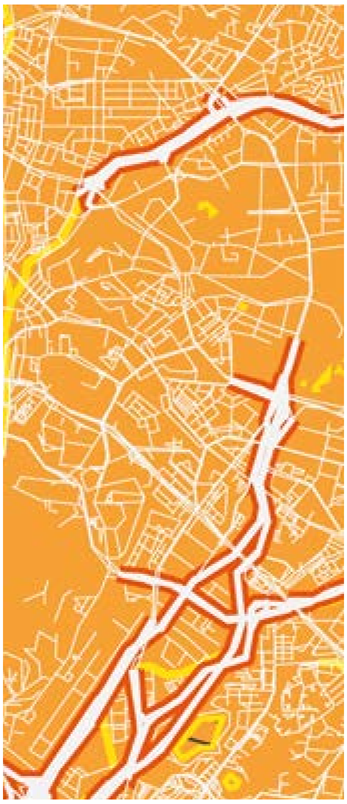
City governments tend to focus first on addressing their own municipal energy demand, where they typically can control procurement criteria, and then on enacting policies and programmes that aim to reshape the broader urban supply and demand structure. The private sector (including individuals and businesses) also plays an important role in advancing renewables in urban areas.

BUILDINGS AND INDUSTRY

In cities around the world, municipal governments and other urban actors are producing and procuring renewable electricity to power building systems (including street lighting) and run all forms of commercial and industrial activity. The available options vary according to the local context and can include: installing renewable power generation systems at or near the point of demand (on-site); purchasing renewable electricity through green tariff programmes; and signing power purchase agreements with developers for projects within and outside of urban areas.

Where these options are not available or are insufficient, city governments are pursuing alternative avenues, such as partnering with stakeholders (including utilities and other cities) to engage with national- or state-level legislators and regulators to remove barriers. Many city governments are pursuing community aggregation or the municipalisation of utilities to facilitate direct control of renewable energy supply.

For thermal applications, municipal governments and other city entities are deploying modern renewable energy systems for space and water heating in buildings, and for process heat in industry. Although generally not at the scale of renewable electricity use in cities, a growing amount of direct thermal renewable capacity is being installed for use on-site, in stand-alone applications for individual buildings, and to feed into district energy systems. Direct thermal renewable energy is derived from the combustion of sustainable biofuels as well as from geothermal and solar thermal sources; renewable electricity also is used for thermal applications, powering appliances such as heat pumps.



Kuala Lumpur, Malaysia

TRANSPORT

In many cities, transport consumes more energy than do buildings or industry, and globally urban transport accounts for around 40% of total transport-related CO_2 emissions. The share of renewables in global transport remains low, at 3.7% (the majority provided by biofuels), but many cities are working to increase the penetration of renewable energy in the sector at the local level.

In response to calls for a "green recovery" amid the pandemic, several cities initiated or strengthened efforts in 2020 to ensure that communities have access to safe, reliable, affordable and sustainable transport. Cities continued to lead on vehicle electrification and EV charging infrastructure (facilitating greater penetration of renewables in transport) and were scaling up efforts to increase local production and use of renewable carriers in transport.

Electrification has expanded beyond rail to all modes of urban transport, including buses, cars, vans, two-/three-wheelers as well as some trucks and ferries. In some cases, renewable power capacity is being installed, purchased or contracted to cover the demand of electric vehicles in cities. Biofuel blends and renewable hydrogen are used mostly in heavy-duty transport such as buses and trucks.

The shares of renewables in **transport and buildings** remain low, especially compared to the electricity sector.

Moscow, Russian Federation

DISTRIBUTION INFRASTRUCTURE

Virtually all cities are physically tied to or otherwise reliant on a larger regional and global network of energy systems, infrastructure and supply lines. All cities depend on their surrounding territories not only for the bulk of energy supply, but also to manage and balance the flow of energy with the pulse of activity within the city. The larger the city, the larger must be the consideration for interactions with wider energy systems and infrastructure.

As cities pivot their energy procurement towards renewable sources, originating from both within and outside of city boundaries, their interactions with and requirements from regional energy systems and infrastructure may change, with implications that go well beyond city boundaries. Likewise, external changes in supply and infrastructure affect cities in ways beyond their control.

In 2019 and 2020, cities took steps including: addressing challenges to local and regional electricity distribution infrastructure (for example, by upgrading existing assets or deploying battery storage capacity); expanding existing district heat networks or commissioning new systems that rely (at least in part) on renewable thermal energy or on heat pumps powered by renewable electricity; and installing EV charging stations, including some that deliver 100% renewable electricity.

04 FINANCING AND INVESTMENT IN CITIES

Global investment in renewable energy capacity has trended upward for the last decade, and the COVID-19 pandemic has not hampered this sustained growth.

Global investment in new renewable energy capacity, including power and fuels (but not including hydropower projects larger than 50 megawatts) totalled USD 282.2 billion in 2019, up 1% over 2018. In the first half of 2020, global investment in new renewable energy capacity rose 5% relative to the first half of 2019. Although the exact share of investment in renewable energy projects within urban boundaries is unknown, a combined 171 renewable energy projects were reported in the pipeline in cities worldwide in 2019, with total project costs of USD 31.2 billion.

Each city operates within a distinctive framework that affects the financial power of city governments and, consequently, the amount and type of renewable energy financing and investment available. Variables include the policies and regulations that govern city actions, the nature of relationships with higher levels of government, partnerships with the private sector, and ownership rights of the electric grid, among others. Municipal governments are responsible for only a small share of the total financing that occurs within a city.

Municipal governments and private actors in cities that aim to increase the shares of renewables in the power, heating and cooling, and transport sectors have many options for financing such projects. These options can be grouped into three general categories:

- the actors may have their own capital available for funding renewable energy projects;
- if they do not have their own capital available, they may be able to raise funds through bonds, or make use of funds provided by other levels of government or external actors (such as local or domestic banks and development banks); and
- they may participate in agreements such as public-private partnerships or power purchase agreements to leverage external funds for a given project.

Regardless of their location (in cities or elsewhere), renewable energy projects face inherent financing challenges, including higher upfront technology costs, information gaps and hard lock-ins – all of which raise the investment risks and related financing costs. Municipal governments may face limited budgetary flexibility, multiple competing claims on their resources and soft lock-ins including limits to institutional capacity and institutional inertia. Barriers also can exist in co-funding arrangements with higher levels of government or limits to borrowing power. Cities in developing countries may face additional barriers to investing in renewable energy projects, such as insufficient tax bases or inadequate perceptions of creditworthiness.

05 CITIZEN PARTICIPATION

Citizens have been increasingly active in engaging in the energy transition, as well as in creating markets for renewable energy at the local level. Among other steps, they have strengthened their roles as prosumers, formed urban community energy projects and participated in urban energy and climate planning.

Individual citizens have supported renewables in cities by choosing green tariffs, purchasing energy from green pay-as-you-go schemes and getting energy from peer-to-peer energy systems, which typically are based on renewable energy generation. Deregulation and technological progress have enabled many city dwellers to become "prosumers" (both consumers and producers of energy) by setting up their own renewable energy systems connected to the grid.

Previously mainly a rural phenomenon, community energy projects have gained more footing in cities. In such projects, citizens come together to collectively manage and often own renewable energy installations. Many municipal governments have supported community energy projects, for example by providing roof space on public buildings such as schools or town halls, and some even have become partners in such projects by providing funding and becoming a shareholder. In 2020, Europe remained a hotspot for community energy projects, but many other countries around the world were joining the trend, including the Republic of Korea, South Africa and the United States.

Increasingly, citizens have made their voices heard in urban energy planning and development, often by invitation from city administrations that include local citizens in planning, budgeting and policy development processes. Against the backdrop of rising global climate movements during 2019-20, citizens also have exerted pressure on their city (and national) governments to push for stricter local climate and energy policies. Partly in response to this, by the end of 2020, a record 1,852 municipal governments in 29 countries had issued climate emergencies and 231 municipal governments had submitted a climate action plan alongside their declaration, in some cases using this to outline and financially support renewable energy deployment.

Citizens have put
increasing pressure
on governments to adopt more ambitious climate and energy targets and policies.

06 FEATURE: RENEWABLE ENERGY IN SUB-SAHARAN AFRICAN CITIES

Despite facing many challenges, city governments across Sub-Saharan Africa have heeded the call to act on renewable energy and have joined global initiatives to advance the deployment and use of renewables.

Due to rapid population growth and urbanisation, as well as rising energy demand, cities across Sub-Saharan Africa increasingly recognise the opportunities around renewable energy use. Common drivers for renewables in the region include improving energy access and reducing energy poverty, as well as boosting the resilience and reliability of power systems.

Cities in Sub-Saharan Africa have supported local renewable energy deployment in a variety of ways, including by facilitating collaborative projects led by national governments, development finance institutions and/or private actors. Some local governments, especially in cities where transport is responsible for a large share of energy consumption, have entered into public-private partnerships to advance e-mobility (sometimes linked to renewable electricity) at the city level. In addition, cities have joined networks such as the Covenant of Mayors in Sub-Saharan Africa (CoM SSA) that help to build knowledge and internal capacity regarding renewable energy data and projects.

While city governments have played a key role in shaping the region's energy landscape – including advancing efforts to meet renewable energy targets set at the country level – legislative, financial and technological constraints persist in many cities. These constraints include weak fiscal decentralisation, limited municipal mandates across key sectors, and limited human capacity to execute municipal functions.

Key barriers and opportunities for advancing renewables in urban settings of Sub-Saharan Africa fit into four categories:

Policy and regulation: Through the CoM SSA, the C40 Climate Action Planning Africa Programme and other initiatives, municipal governments have enacted policies to accelerate the deployment of distributed renewables. These policies cover all energy-consuming sectors, although with less of a focus on the power sector because it remains largely the domain of national governments and/or centralised utilities. While city authorities often have limited powers, they are well placed to co-ordinate efforts to encourage local renewable energy deployment, which require collaboration across various stakeholders, including national policy makers.

Access to financial markets: Most local governments in Africa depend on national government grants as their main source of revenue, which is spent largely on operations instead of capital investments. This leaves little funding to invest in new infrastructure projects such as distributed renewable generation. Nonetheless, cities across the region have demonstrated progressive leadership on renewables through piloting various demonstration projects.

Data needs: Scarcity of primary data in the African context, particularly at the city level, is a major barrier for private investment in grid expansion plans and energy projects more generally. This places local governments, which generally are closer to the population (potential customers), in a unique position to provide investors with such information or to engage with relevant entities, including electric utilities, to facilitate data collection.

Internal capacity: Capacity constraints (in skills, experience and knowledge, and human and financial resources) have limited the ability of local governments to play a more pro-active role in renewable energy deployment. To build internal capacity and knowledge and to support renewable energy implementation, municipalities in Sub-Saharan Africa have formed partnerships with external organisations, established or joined city networks, and developed public-private partnerships to facilitate private sector engagement.


Ruiru, Kenya

Madrid
Milan
Paris
Swansea Bay City
Lille
Wuhan
Burlington
Auckland
Berlin
Bogota
Boston
London
Mexico City
Pakse
Fortaleza

1 GLOBAL OVERVIEW OF RENEWABLES IN CITIES

GLOBAL OVERVIEW OF RENEWABLES IN CITIES

More than
1 billion people
live in a city with a renewable energy target and/or policy.

City[i] governments around the world are taking action to accelerate the global uptake of renewable energy. During 2020, the engagement of local governments continued to grow, driven by air pollution concerns, public pressure, and the need to create clean, liveable and equitable communities, among other factors. In some cases, these actions have been reinforced by the global health and economic crisis triggered by the COVID-19 pandemic. City governments use different types of targets, policies and actions to show their renewable energy ambition: overall, more than 1 billion people – around 25% of the urban population – lived in a city with either a renewable energy target and/or policy in 2020 (→ *see Figure 1 and Table 1*).[1] Other actions indirectly support the shift to renewables – such as efforts to reduce carbon dioxide (CO_2) emissions, including through net-zero commitment goals and the electrification of public transport.

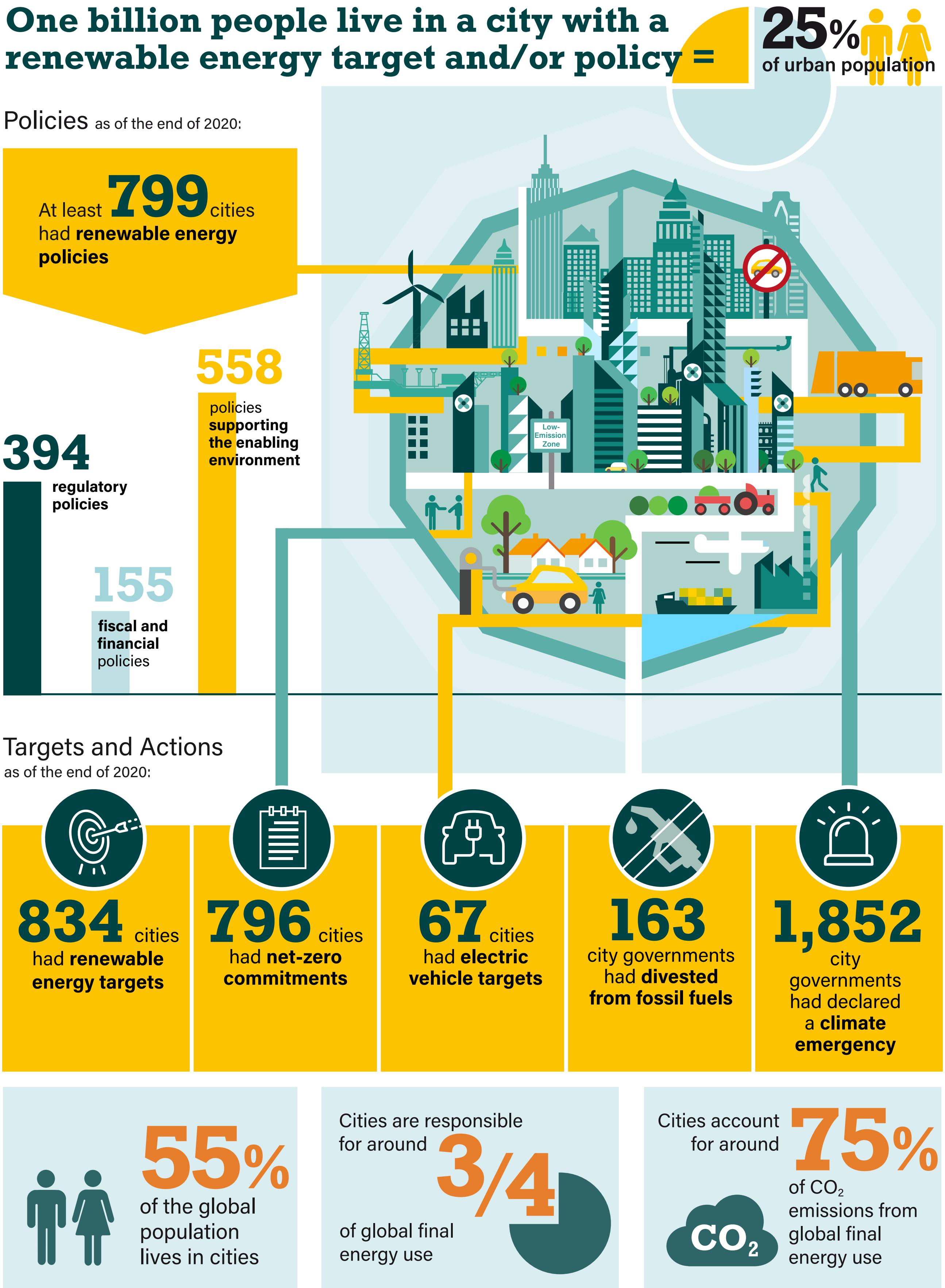
Cities' ambition to support the deployment of renewables is relevant because urban energy use has increased sharply in recent decades. In 1990, cities accounted for less than half (45%) of global final energy use, but by 2018 this share had risen to around three-quarters, and cities release a similar share of global energy-related CO_2 emissions.[2] Cities are now home to more than 55% of the world's population, and urban inhabitants worldwide are negatively affected by the burning of fossil fuels.[3]

Energy demand in cities has surged in all end-use sectors – power, transport, industry and buildings – due mainly to rising global population growth, urbanisation and urban economic activity. Municipal government operations account for only a small percentage of urban energy use, including for public buildings, municipal services and vehicle fleets[ii]. The bulk of urban energy is used at the city-wide level, in the form of electricity, heating and cooling (for residential and commercial buildings and industrial activities) and private transport.[4]

i According to the United Nations, the term "city" 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". Throughout this report, both "municipal government" and "city government" refer to city-level decision-making bodies and government authorities (the mayor's office, city council, etc.). "Local government" is a more generic term that can refer to different sub-national levels of public administration, including also counties, villages and other intermediate levels of government. In addition to municipal governments, key "urban actors" include individual citizens, groups of citizens and private enterprises, as well as various civil society groups that are active within the city.

ii Depending on ownership structures, municipal transport fleets may entail public transport (e.g., buses and rail systems), street sweeper and refuse collection vehicles, maintenance vehicles, vehicles assigned to police, fire and other public services, taxi and car-sharing fleets, and delivery vehicles (e.g., postal and courier services). See Glossary.

Figure 1. Key Facts and Trends in Cities, 2020

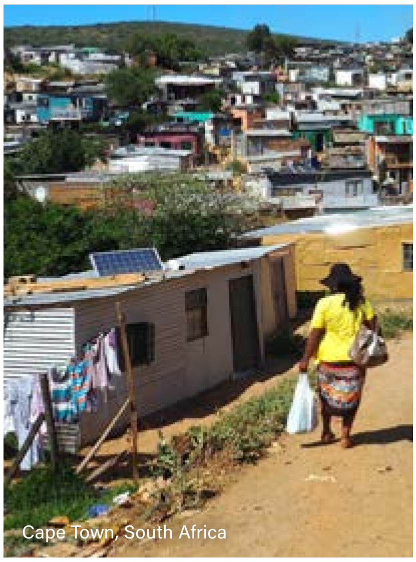


Source: See endnote 1 for this chapter.

Table 1. Overview of Targets, Policies and Actions in Cities, 2020

	Number
Renewable energy targets	
Cities with renewable energy targets and/or policies	1,327
Cities with renewable energy targets	834
Cities with 100% renewable energy targets	617
Cities with renewable power targets	612
Cities with renewable heating and cooling targets	145
Cities with renewable transport targets (excluding e-mobility)	65
Cities with economy-wide renewable energy targets	266
Other targets and declarations	
Cities with emission reduction targets	> 10,500
Cities with net-zero emission targets	796
Cities with e-mobility targets	65
Cities with climate emergency declarations	1,852
Policies	
Cities with renewable energy policies	**799**
Cities with renewable power policies	363
Cities with renewable heating and cooling policies	144
Cities with renewable transport policies	331
Cities with renewable energy policies in buildings	153

Over
1,300 cities
have renewable energy targets and/or policies, covering more than 1 billion people.


Cape Town, South Africa

Note: The number of cities with renewable energy policies by sector (power, heating and cooling, transport and buildings) does not equal the total number of renewable energy policies in cities, as cities with more than one policy in the same sector are counted only once. Cities with policies in multiple sectors are counted more than once. A total of 192 cities have policies in more than one sector.

Source: See endnote 1 for this chapter.

In addition, cities are responsible for global energy use that does not actually take place within urban boundaries.[5] They contribute indirectly to energy use (as well as to greenhouse gas emissions) through their supply chains, which include construction materials (concrete, steel, etc.), everyday goods (food, clothing, electronics, etc.) and other products consumed in cities but produced beyond their borders.[6] Thus, action in cities has the potential to make significant contributions to decarbonising the energy system, enhancing its resilience, and accelerating the development of renewable energy and other projects and investments – all of which contribute to key international goals such as limiting the average global temperature rise to 1.5 degrees Celsius (°C), as stipulated in the Paris Agreement.[7]

In cities with rapidly growing informal settlements and slums[i], often located in the periphery of urban areas, many inhabitants lack access to basic services, including modern energy sources and city infrastructure, such as sanitation and public transport.[8] Despite rising energy demand, 176 million people in urban areas still did not have access to electricity in 2019, and 2.6 billion people worldwide lacked access to clean cooking.[9] Municipal governments can play a key role in expanding sustainable energy access and reducing energy poverty for their residents, including the 1 billion urban and peri-urban dwellers living in slums and informal settlements.[10] Considering that the generation and use of renewable energy in cities is critical for achieving sustainable communities, and vice-versa, municipal governments can contribute to achieving United Nations Sustainable Development Goal 7 (on sustainable energy for all) as well as interlinked goals[ii].[11]

i Various factors have contributed to the emergence of informal settlements and slums, including population growth, urbanisation, lack of affordable housing, economic vulnerability, marginalisation and displacement. See endnote 8 for this chapter.

ii Urban areas are expected to play a key role in achieving the United Nations Sustainable Development Goals (SDGs), in particular SDG 11 on Sustainable Cities and Communities. By one estimate, meeting 65% of the targets of the SDGs depends on the involvement of local governments and how they can engage their citizens and civil society using their roles and core competences in areas such as infrastructure, transport, housing, water use, land use and energy.

DRIVERS AND OPPORTUNITIES FOR RENEWABLE ENERGY IN 2020

The drivers[i] for renewable energy in cities are broad, with efforts motivated by diverse economic, social and environmental objectives depending on the local context and priorities. Generally, municipal governments have pursued the uptake of renewables as an opportunity to create more liveable urban areas and to enable a better quality of life for residents.[12]

In 2020, the unfolding of the COVID-19 pandemic and the government-initiated lockdowns to slow the spread of infections had major impacts on both cities and the drivers for renewables. Economic activity fell sharply in the early months of the pandemic, reducing energy demand globally and severely affecting urban energy use, notably in the transport sector.[13] Physical distancing measures and fear of contagion led to an unprecedented drop in public transport ridership, greatly altering urban mobility patterns.[14]

These developments resulted in a shift in government (especially municipal) priorities, as efforts to ensure public health and well-being were pushed up the policy agenda.[15] Although COVID-19 recovery plans were still being prepared as of early 2021, initial proposals emphasised local economic development and job creation, with some municipal governments announcing "green recovery" packages – including renewable energy options – in line with similar plans proposed at the national and supra-national levels (such as the European Green Deal) (→ *see Sidebar 1*).[16]

Kuala Lumpur, Malaysia

Images of blue skies and clearer air during the early lockdowns helped to increase societal pressure towards reduced pollution and a green recovery.[17] Outdoor **air pollution**[ii] from the burning of fossil fuels – particularly coal, diesel and petrol – is a major source of fine particulate matter and was responsible for an estimated 8.7 million premature deaths in 2018 (earlier estimates were found to be greatly underreporting the effects of air pollution).[18] Increases in industrial activity, heat and power generation, and road transport have been the main sources of outdoor air pollution in many cities worldwide, and in some urban areas the use of charcoal and fuelwood for heating and cooking contributes to poor air quality indoors as well.[19] Several cities have pledged to jointly tackle local air pollution: as of 2020, 37 city governments worldwide had signed the C40 Clean Air Declaration (initiated in 2019), committing to pollution reduction targets and clean air policies by 2025.[20]

During 2019 and 2020, **citizens** also exerted growing pressure on their city (and national) governments to act on climate change.[21] Partly in response to this pressure, a record 1,852 cities had declared climate emergencies by the end of 2020 (up from around 1,400 governments in 2019), indicating a shift in priorities for municipal governments, some of which have used the declarations to plan and financially support renewable energy deployment.[22]

Other drivers for renewable energy uptake include:

- **Supporting local economic development** by attracting new industries and businesses, and creating local jobs.[23]
- **Mitigating climate change**, since renewables can help cities reduce emissions that contribute to global warming and address urban vulnerabilities to the impacts of climate change; these impacts include more-severe storms, fires, droughts, floods and sea-level rise, all of which put pressure on urban water supplies, sewage services, and food and energy security.[24]
- **Adapting to climate change and enhancing resilience**, since decentralised power generation from renewables can help make energy systems more resilient while reducing risks associated with dependence on external energy sources.[25]
- **Reducing expenses and managing costs**, by limiting cities' exposure to volatile fossil fuel prices and providing greater savings as the costs of electricity from solar photovoltaics (PV) and wind power continue to decline.[26]
- **Poverty alleviation**, since greater access to energy and new opportunities for learning and jobs can help reduce energy poverty and support sustainable development.[27]
- **Ensuring a stable and secure energy supply**, since renewables can support municipal governments in increasing energy security and independence while strengthening energy resilience.
- **Energy justice and democracy**, with sustainable energy access supporting an inclusive and just transition, with energy for all.

i For a detailed discussion of drivers, see REN21's *Renewables in Cities 2019 Global Status Report*, available at www.ren21.net/reports/cities-global-status-report.

ii More than 90% of urban areas were exposed to air pollution, and more than half of the population was exposed to air pollution at least 2.5 times above the guidelines established by the World Health Organization (WHO), from WHO, "9 out of 10 people worldwide breathe polluted air, but more countries are taking action", 2 May 2018, https://www.who.int/news/item/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action.

SIDEBAR 1. COVID-19: General Impact and Responses

The year 2020 was marked by lockdowns in response to the global health crisis precipitated by the COVID-19 pandemic. This triggered a major economic shock with disruptions to various sectors, including energy. Disease prevention and containment measures greatly altered global energy use patterns (including electricity demand) and mobility habits, especially in urban areas with high concentrations of people and economic activity.

Global electricity demand dropped 2.5% in the first quarter of 2020 compared to the same period in 2019. This decline in demand was clearly linked to government containment efforts, as demonstrated in the European Union (EU) where electricity demand returned to normal (2019) levels during August-October 2020, after restrictions were lifted. Despite these declines, renewable electricity supplies worldwide continued to grow. While the demand for coal and gas dropped sharply in 2020, renewables were the only source of electricity in the global energy mix to experience record growth due to low operating costs and priority grid access through regulations. In several EU countries, wind and solar power hit record shares in electricity generation during the lockdown period.

Despite these positive narratives around renewable electricity, however, COVID-19 also had negative impacts on renewable energy deployment. Notably, many cities experienced delays in the development of renewable energy projects due to supply chain disruptions, labour shortages and emerging financing challenges. These impacts varied by technology and region.

Road transport activity decreased 50-75% in cities with lockdowns by late March 2020, resulting in a 17% drop in daily global CO_2 emissions by early April (from average 2019 levels). In Europe, an 88% reduction in car and motorcycle emissions during lockdowns led to a 58% decline in CO_2 emissions. Nitrogen dioxide levels also fell sharply during lockdowns in Wuhan (China) and in European cities such as Madrid (Spain), Milan (Italy) and Paris (France). Overall, the reduced pollution from urban transport led to local air quality improvements during the first half of 2020.

However, the reduction in emissions was only temporary: by the end of 2020, emissions and air pollution increased again, especially in bigger cities, as people opted to drive private cars over using public transport, and because of higher heating demand as people worked from home during the colder months. In the United Kingdom, the use of gas boilers – a major source of local pollution[i] – increased an estimated 56% during the winter of 2020 as the majority of people continued to work from home.

In many places, the COVID-19 pandemic stimulated greater societal pressure on city authorities to plan their economic recoveries by adopting integrated, sustainable approaches that place higher emphasis on air quality and the overall living environment. Because municipal COVID-19 recovery plans were still under development as of early 2021, no consolidated overview was available of the role of renewable energy in these actions. However, some examples exist of municipal governments linking the recovery to a scale-up of renewables.

In June 2020, Swansea Bay City (Wales, UK) launched a GBP 60 million (USD 74 million) ocean energy project that aims to accelerate the city's climate actions and to help the county of Pembrokeshire in its COVID-19 economic recovery. Lille (France) allocated EUR 20 million (USD 24.5 million) through its Rebound Fund, a business support programme that requires small businesses to incorporate environmental actions and/or energy transition into their projects to be able to benefit from the fund. Burlington (Vermont, US) announced a Green Stimulus package in April 2020 that allocates USD 800,000 to advance energy efficiency and promote the uptake of heat pumps and electric vehicles (EVs) – both of which can run on renewable electricity – in support of the city's Net Zero Energy goal while helping with the local economic recovery.

The C40 Cities network, through its Global Mayors COVID-19 Recovery Task Force, launched the C40 Mayors Agenda for a Green and Just Recovery in July 2020, outlining steps for the post-COVID period. Through this agenda, more than 40 city mayors committed to an equitable and just recovery based on stimulus packages that focus only on sustainable transition, including providing green jobs, divesting from fossil fuel and creating liveable communities.

Local governments also took more immediate action to alleviate the COVID-19 challenge in their cities, such as establishing bicycle lanes and expanding safe public spaces for pedestrians. These measures were implemented in cities including Auckland (New Zealand), Berlin (Germany), Bogotá (Colombia), Boston (Massachusetts, US), London (UK), Mexico City (Mexico), Milan (Italy) and Paris (France).

In response to the economic and social impacts of COVID-19, several national governments passed economic stimulus packages, and some multilateral development banks and private institutions made available climate funds. However, of the USD 20.5 trillion pledged to recovery efforts as of late 2020, only USD 1.1 trillion was committed to cities, due in part to barriers in directly providing funding to cities.

Source: See endnote 16 for this chapter.

i In London alone, gas boilers account for 21% of total nitrogen oxide emissions across the city.

GLOBAL RENEWABLE ENERGY TRENDS

At a global level, renewable energy capacity has continued to grow in the power sector, where supportive policy frameworks have helped solar PV and wind power become the most affordable sources of new electricity nearly everywhere in the world[i].[28] Renewable energy broke another record in 2019, with the total installed power capacity of renewables increasing more than 200 gigawatts (GW).[29] The renewable power sector also demonstrated greater resilience than fossil fuels during the COVID-19 pandemic, as electricity supplied by renewables was the only source of power generation to grow in 2020.[30] The share of electricity production met by variable renewable energy sources (wind and solar PV) reached record levels in several markets during the year, including in China, Europe, India and the United States.[31]

Despite these advances, the global energy system is transforming at a slow pace. Renewables in the heating and cooling and transport sectors have gained significant ground only in a few countries, while globally these sectors continue to lag.[32] Unlike for renewable power, renewables in heating and transport have demonstrated greater vulnerability to global shocks, such as the COVID-19 pandemic, than other energy sources[ii].[33] Heating, cooling and transport are critical for shifting the entire energy sector to renewables, as they are responsible for around 80% of final energy demand (→ *see Figure 2*).[34] These sectors are nevertheless plagued by weak and inconsistent policy frameworks, which contribute to uncertain and risky long-term investment options.[35]

CITY RENEWABLE ENERGY COMMITMENTS

Action in cities often has progressed faster than trends and policy steps at the national level. In 2019 and 2020, city governments around the world demonstrated leadership on climate and energy and took action to accelerate the global uptake of renewables.[36] Reporting on government operations and city-wide energy and climate targets increased, and several cities raised their ambition by adopting higher targets or setting earlier target years for reaching their goals.[37] These city government commitments have taken different shapes, ranging from binding targets and comprehensive policies to participation in initiatives and campaigns. Strong sub-national leadership sends a signal to industries and service providers as well as to regional and national governments, and also helps to inform overall procurement processes that require clean services and products (→ *see Urban Policy Landscape chapter*).[38]

City governments have directly supported renewables by setting specific **renewable energy targets**, investing in renewables and passing policies to encourage renewables city-wide. By the end of 2020, city governments in at least 834 cities in 72 countries, covering 558 million people, had set renewable energy targets in at least one sector (power, heating and cooling, and/or transport)[iii]; this includes around 617 cities with targets for 100% renewables.[39] Altogether, cities worldwide had a combined 1,088 renewable energy targets.[40] Despite this momentum, data challenges remain regarding tracking and reporting on progress as well as the scope of application.[41] Geographically, renewable energy targets have increased in all regions of the world, although most targets are in North America[iv] and Europe, followed by Asia.[42]

In many cases, city targets and policies are far more ambitious than those in place at higher levels of government.[43] While most local renewable energy targets address the power sector – similar to national-level developments – momentum has grown for policies that go beyond power and are expanding to heating and cooling and the transport sector or an integrated policy approach (→ *see Leveraging Renewables City-wide section*).[44] Given slow advances at the national level worldwide, urban policies and decentralised renewable energy technologies play an important role in decarbonising these sectors.

Targets for renewables in cities are often more ambitious and have progressed faster than trends and policy steps at the national level.

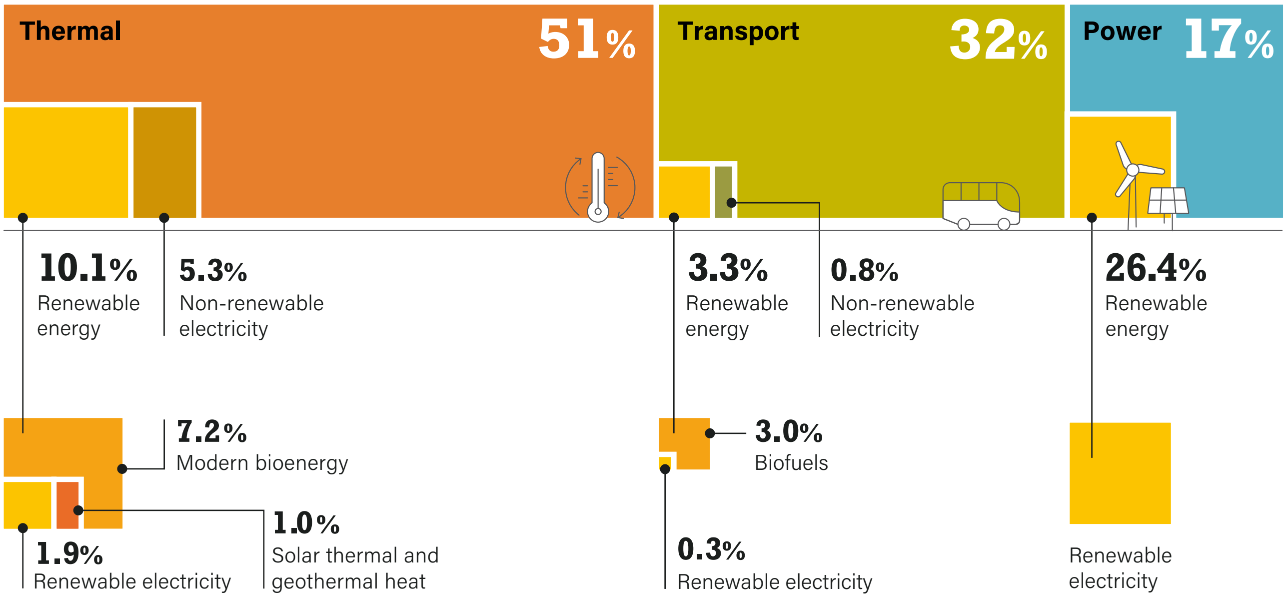
i Wind and solar energy have become increasingly cost-competitive with fossil fuel power plants. In countries on all six major continents, renewables are the cheapest source of new electricity generation, and in some of the world's major energy markets (including China, India, Europe and the United States), building new solar PV or wind plants is more cost-effective than continuing to operate existing coal-fired power plants. Renewables also are outcompeting natural gas-fired power plants on costs. See endnote 28 for this chapter.

ii This refers to the fact that consumption of renewable heat and production of biofuels, which account for the vast majority of renewable energy in transport, were both heavily affected during the crisis. The rapid increase in electric vehicle sales is a counterpoint to this statement; however, electric mobility continues to meet only a marginal share (around 1.3%) of energy demand in transport, and relies mostly on electricity from fossil fuels.

iii Based on REN21 Policy Database; list may not be comprehensive. This total includes multiple targets for the same city. It includes targets for renewable energy consumption of all energy, electricity, heating and cooling, and transport; targets for specific installed capacity; as well as targets for enabling technologies such as e-mobility.

iv In this report, North America includes Canada and the United States; Mexico is considered part of Latin America and the Caribbean.

Figure 2. Renewable Share of Total Final Energy Consumption, by Final Energy Use, 2017



Note: Data should not be compared with previous years because of revisions due to improved or adjusted methodology.

Source: Based on IEA data. See endnote 34 for this chapter.

The growing trend of emission reduction targets – including **net-zero**[i] commitments – had a record-breaking year in 2020. By year's end, more than 10,500 cities globally had adopted CO_2 emission reduction targets, and around 800 cities had committed to net-zero emissions – up sharply from the 100 cities with such commitments by the end of 2019.[45] Although emission reduction targets typically have not been linked explicitly with renewable energy development, they can stimulate the uptake of renewables indirectly by mandating the reduction or removal of greenhouse gas-emitting technologies. Many cities had yet to publish plans on how renewable energy is being deployed or used to achieve this goal.[46]

Increasingly, city governments are producing climate and/or energy action plans outlining how to achieve their targets. Abundant examples from Australia, Europe and North America are captured through reporting platforms such as the CDP-ICLEI Unified Reporting System (with local governments reporting progress over time), supported by city networks and initiatives including ICLEI – Local Governments for Sustainability and the Global Covenant of Mayors for Climate & Energy.[47] As such initiatives expand globally, reporting is increasingly supported in Asia, Latin America and Sub-Saharan Africa. Action plans are being developed or updated in cities ranging from Kigali (Rwanda) and Pakse (Lao PDR) to Fortaleza and Recife (Brazil).[48] Generally, city-level reporting and tracking of the electricity sector is more comprehensive, whereas most cities lack clear reporting on heating and cooling uses and transport (→ *see Box 1*).[49]


Pakse, Lao PDR

i "Net-zero" emissions can be achieved, for example, by using natural sinks, such as reforesting land or adopting agricultural best practices, or through a technological solution, such as carbon capture and storage. Net-zero targets also are referred to commonly as "climate-neutral", "carbon-neutral" or "zero-emission" targets, although technically these are not the same. Carbon neutrality refers to net-zero emissions of only CO_2, whereas climate neutrality indicates a broader focus on net-zero emissions of all greenhouse gases. There is no agreed-upon definition, and implementation of these targets also varies broadly. See endnote 45 for this chapter.

BOX 1. Data on Renewables in Cities

Tracking the evolution and uptake of renewable energy in urban areas is challenging because of cities' geographical distribution; their different political, economic, social and environmental contexts; and their diverse institutional capacities. As a result, the limited data that are available tend to be outdated and are rarely consolidated. In addition, these data often do not consider the changing roles that cities play in the energy system, including their ability to produce energy. Consolidated data on energy supply/production and energy demand/consumption thus are available only for relatively few cities worldwide.

Even where data are reported, imprecise terminology can limit their usefulness: in some instances, it remains unclear whether the data refer to electricity or to energy. Also, since electricity accounts for most cooling needs and for a growing share of heating needs, it can be difficult to identify what amount went to heating and cooling versus lighting and other appliances. In transport, reporting in most cities tracks only the number of electric, plug-in hybrid and hydrogen fuel cell vehicles, but does not track vehicles running on liquid biofuels and biomethane.

Increasingly, reporting is improving on financing indicators and city investment needs as well as on the trend of local governments to create their own funds to implement their renewable energy targets, particularly in the northern hemisphere. However, data gaps and limitations remain in the following key areas:

- shares of renewables in municipal and city-wide energy use;
- targets and policies that promote renewables in the power, heating and cooling, and transport sectors, both for municipal and for city-wide energy use;
- generation capacity for renewable electricity, heating and cooling, and transport fuels, either by municipal authorities and/or public utilities and other urban actors (private sector, residents, communities); and
- community energy projects in cities, including the number of projects, installed capacity and investments.

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

Source: See endnote 49 for this chapter.

Cape Town, South Africa

Madagascar

MULTI-LEVEL GOVERNANCE OF URBAN ENERGY SYSTEMS

The possibilities and strategies for municipal governments to scale up renewable energy to achieve their urban climate and energy targets depend on a variety of factors. Each city has its own characteristics such as urban form[i] and density, climate, geography and ownership structure[ii] for key infrastructure – all of which influence a city's ability to advance the deployment and use of renewables.[50]

Also, no city is an island in the context of local renewable energy procurement and use, target-setting and policy making. Depending on governance structures[iii], cities are subject to **market rules and energy regulations** set at the national and state/provincial levels, and to the political dynamics that shape these instruments.[51] The design of markets and infrastructure – and whether electricity markets are liberalised and decentralised – is determined largely at higher levels of government (→ *see Sidebar 2*).[52] In addition, municipal governments typically are required to enforce standards that have been established out of their control, at the state or national levels.[53]

Despite potential limitations resulting from different regulatory systems, city governments around the world have taken different actions to increase renewable deployment. Several local governments have engaged with or challenged higher levels of government to remove legislative or regulatory barriers to the production and procurement of local renewable energy. To raise their voices and increase their advocacy capacity, local governments also have joined forces in national, regional and global networks (→ *see City Leadership: Networks and Initiatives section*).

Persistent subsidies for fossil fuel consumption and production, issued at the national level, present a challenge to increasing the share of renewables in cities. Such policies contribute to ongoing economic dependence on fossil fuels in transport, households, industry and businesses, as well as in electricity production and supply.[54] Although global subsidies for fossil fuel consumption fell by USD 120 billion in 2019 (to USD 318 billion, down from USD 438 billion in 2018) – mainly because of lower average fuel prices during the year – both subsidies and low fossil fuel prices encourage greater demand for the fuels and challenge renewable energy developments.[55] If the true costs to society of fossil fuels were accounted for, including negative externalities related to climate change and air pollution, then their total "subsidies" would be considerably higher, at USD 5.2 trillion.[56]

Cities' **energy systems and infrastructure** are physically connected to national or regional systems and rely on them for most of their energy supply and to manage and balance their energy flow. However, the dynamics of this relationship have changed over the last decade as municipal governments have become more aware of the various potential benefits of renewables.[57]

The emergence of distributed renewable energy technologies (such as rooftop solar PV) and digital technologies (such as the Internet of Things) has reshaped the dynamics between end-users and the traditional energy system, which historically has been operated mainly by centralised utilities.[58] Coupled with new business models, this has enabled municipal governments (as well as households, businesses and communities) to scale up and diversify local production of renewables.[59] In 2019, households and small- to medium-sized companies installing solar PV on and near their buildings accounted for one-fifth of all renewable capacity deployed globally.[60] However, in 2020, COVID-related lockdown measures prevented access to many buildings, leading to a slowdown in distributed solar PV installations in cities.[61]


Vienna, Austria

i Urban form refers to a city's physical characteristics, including size, shape and population density. For example, low-density cities (per square kilometre of urban area) tend to have more land and rooftop space available for distributed solar PV, while compact high-density urban areas have the necessary business case for renewable district energy systems (where proximity of floor area is a major determinant). See endnote 50.

ii For example, where the city government is the owner and operator of municipal energy utilities or of public transport and associated infrastructure, it has greater capacity to develop and invest in renewable energy projects. If this infrastructure is not under municipal control, the shift to renewables entails co-ordination with a greater number of actors (such as national and state/provincial governments and private companies, for example through public-private partnerships) that may have conflicting priorities. In many developing and emerging economies, the lack of secure, reliable and affordable public transport, exacerbated by low density and sprawling cities, contributes to informal and private on-demand transport. This tends to be more difficult to regulate (and to enforce regulations), including shifting to renewable-based transport solutions.

iii The governance structure of a city determines the city's level of dependence on higher levels of government in policy making, regulation, renewable energy purchasing, etc.

SIDEBAR 2. Multi-level Governance: The Interdependence of National and Municipal Policies

It is increasingly clear that the fight against climate change will be won or lost in the world's cities. However, even the most empowered city governments can deliver only a fraction of their mitigation potential unilaterally. National leadership and co-ordination, and integration with national-level action – also known as multi-level governance – is vital. Supportive national policies, combined with ambitious and pro-active city targets and action, are key to ensure that rapid urban population growth drives economic productivity within a climate-friendly environment.

National governments generally have recognised the importance of cities in their climate and energy agendas, as evidenced by their endorsement in 2015 of the 2030 Agenda for Sustainable Development, which includes making "cities and human settlements inclusive, safe, resilient and sustainable". However, national governments worldwide are at varying stages of integrating this recognition in their economic strategies, budget allocations, infrastructure planning and governance structures. As of 2019, around half of all countries had a national strategy for cities[i], and only 23 of the 160 countries that had submitted their Nationally Determined Contributions (NDCs) for reducing emissions under the Paris Agreement acknowledged the urban opportunity for climate change mitigation.

The world is not on track to limit global warming to well below 2°C, let alone 1.5°C as stipulated in the Paris Agreement (to achieve this goal, CO_2 emissions would need to nearly halve by 2030 from 2010 levels, and to reach net-zero around 2050). As the major centres of production and consumption, cities play an important role in meeting the emission reduction targets set at various levels of government, from supra-national to sub-national. A large share of the potential for abating emissions in cities lies in decarbonising the urban electricity supply.

Yet at the same time, the electricity supply needs to expand rapidly to meet the demand of growing urban populations and to achieve the Sustainable Development Goals. This will require massive investments in renewable electricity generation and distribution infrastructure in and around cities to meet electricity demand across end-use sectors such as buildings and transport in a sustainable way. However, investment alone is not enough to address the challenges of the energy transition – energy systems and their evolving governance are also firmly in the spotlight. Energy policy historically has fallen under the mandate of national governments, with national or regional utilities typically supplying electricity to urban areas. In contrast, city governments have had minimal authority over energy supply.

National governments can support local climate action in cities in various ways, including by: clarifying the responsibilities and powers of different levels of government; supporting local actors in designing, financing and implementing low-carbon measures (including renewable energy projects); and fostering a culture of experimentation, participation and learning that enables successful local initiatives to be scaled and replicated nationwide. For example, the Digital City Strategy of Hamburg (Germany), backed by national legislation and financial support, aims to show how the country's north-east can be supplied with 100% renewable energy by 2035. Greater digitalisation will facilitate decarbonisation and create possibilities for new players to emerge in the market, with potential to challenge the city's distribution company.

National governments are well placed to align climate and energy policies adopted at different governance levels (such as city, state and national) and to disentangle conflicting incentives that support the transition to a renewables-based energy system. Policy clarity and coherence is especially important for stimulating and shaping activity in the private sector. National and state governments also can go farther by empowering local governments to set more ambitious renewable energy targets – for example, by prohibiting the sale of fossil fuel vehicles, banning the use of fossil fuels to heat buildings and introducing renewable energy requirements in building codes and mandates. For example, the United Kingdom has banned sales of new petrol and diesel vehicles starting in 2030, which will have significant implications for the use of renewable fuels and electricity in urban transport. Such an approach ensures that emissions across all cities in a country fall steadily, while enabling ambitious city governments to advance faster.

National governments also play a role in financing low-carbon, resilient and inclusive cities, namely by fostering a fiscal system that generates the desired amount of public revenues and creates appropriate incentives for firms, households and sub-national governments. Responsible fiscal decentralisation can enhance the accountability of city governments for local service delivery and underpins their creditworthiness so that they can access capital markets. Local governments need the authority and capacity to control their own revenues, among others, to be able to provide grants, loans and subsidies to support the decarbonisation of urban systems. For example, the Marburg-Biedenkopf district (Germany) has built on its ability to subsidise the installation of electric vehicle charging stations to set the requirement that the electricity supplied to the stations must be renewable.

National governments can build a multilateral system that fosters inclusive, zero-carbon cities by setting a zero-carbon urban transition firmly on the global agenda, strengthening international frameworks that accelerate rather than undermine the transition, and using multilateral architecture – particularly the multilateral development banks – to support countries' own urban climate actions.

Source: See endnote 52 for this chapter.

i As of 2019, 108 countries out of 195 had a fully formulated national urban policy (termed a "National Urban Policy", "National Urbanisation Policy", "National Urban Strategy" or a similarly close variant).

RENEWABLES IN MUNICIPAL OPERATIONS

To increase the share of renewables in their own operations, municipal governments have used their assets to deploy distributed renewable energy generation capacity on and alongside public buildings (for example, schools, hospitals, sport centres and social housing), along city streets (including street lighting) and for municipal fleets. Most of these local projects have been solar PV systems, sometimes combined with battery storage or solar thermal systems. In some cities, municipal governments and other actors also have tapped into local wind, biomass and hydropower resources, either for electricity, direct thermal heat production and co- and tri-generation for power and heat, or to support the integration of renewables in district energy systems.

Some municipal governments have faced constraints to installing renewable energy within city limits – such as high land costs, land scarcity or building regulations. In many cases, they have opted instead to import renewables from outside of urban areas through procurement and strategic partnerships with third-party providers, including neighbouring communities. This has allowed them to use virtually any renewable energy source available, including bioenergy, hydropower, solar, wind, geothermal and ocean energy[i].[62] Some municipal governments also have bundled demand with neighbouring cities, building on economies of scale to develop their own renewable energy projects or to procure renewables in bulk; other cities with vast rural hinterlands have established partnerships with these surrounding territories.[63]

Some city governments have moved from single-sector planning to designing integrated (and circular) urban systems. This includes linking their energy supply with other urban activities to find cost-effective solutions to multiple challenges – for example, using urban waste and wastewater streams as feedstocks to produce biogas, biomethane and other renewable fuels.[64] The recycling of waste heat (also called waste heat recovery) has evolved, with some cities feeding the heat from industrial activity and data centres into district energy systems. While this is not in itself a renewable energy technology, such innovations have played an important role in creating integrated, efficient urban energy systems.[65]

By scaling up renewables in municipal operations, city governments also have led by example to help drive change city-wide and build up the local capacity. This has been an important first step to demonstrate the business case and raise awareness of the opportunities that renewables present.

LEVERAGING RENEWABLES CITY-WIDE

Achieving urban renewable energy targets depends not only on political commitment and municipal investment in renewables, but also on cities' ability to mobilise and enable the uptake of renewables city-wide, by other actors. To support this broader deployment of renewable energy, municipal governments have expanded their policy portfolios. By the end of 2020, at least 799 municipal governments had implemented regulatory policies, financial and fiscal incentives, and indirect support policies to enable the uptake of renewables in buildings and transport city-wide (→ *see Urban Policy Landscape chapter*).[66]

Policy trends for **buildings** include the rise of municipal building codes that mandate the use of renewable energy for electricity or heating (in addition to focusing on reducing energy demand and promoting nature-based solutions). These codes typically apply to new buildings, while renewables for existing buildings often are encouraged through financial and fiscal incentives such as grants, rebates and low-interest loans.[67] Most local government policy making has focused on growing the share of renewables in the **power** sector, mainly through solar PV systems, sometimes combined with battery storage or solar thermal systems. Momentum also has grown for electrifying space and water heating in buildings, resulting in more buildings using electricity generated from rising shares of variable renewables in the energy mix. In addition, the emergence of bans and restrictions on fossil fuels for **heating** in buildings, present in more than 53 cities worldwide, has contributed to rising electrification and the use of renewables (→ *see Figure 11 in Urban Policy Landscape chapter*).[68]

In the **transport** sector, city governments have made strides to decarbonise municipal transport fleets and mobility infrastructure to improve urban air pollution, protect public health and well-being, and mitigate congestion and noise.[69] Although some cities have continued to support the use of biofuels in fleets, urban policies and procurement increasingly have focused on the electrification of transport. However, only a few cities have taken e-mobility as an opportunity to increase the share of renewables in the sector, for example through direct investment in new renewable electricity capacity, via power purchase agreements, by setting obligations/requirements for procurement and by subsidising the use of renewable electricity to charge electric vehicles.

To support the decarbonisation of transport, cities have established low-emission zones and bans on certain fuels or vehicles, which are in place in 249 and 14 cities respectively.[70] In addition, to reduce the overall need for individual motorised transport, city governments have encouraged the transition to more efficient modes of transport – such as (renewables-based) public transit, including buses, metros and trams – and have improved walking and cycling infrastructure.[71]

i For an overview of the status of renewable energy technologies, see the Market and Industry Trends chapter in REN21's *Renewables 2020 Global Status Report*, available at www.ren21.net/gsr.

City governments also have shaped urban energy systems to better accommodate rising shares of renewables in the energy mix. They have expanded district energy networks and grid infrastructure, implemented efficient end-use technologies, expanded the electrification of transport and thermal demand (supported by technologies such as heat pumps and energy storage systems) and facilitated other demand-side flexibility. All of these measures provide the potential side-benefits of greater system efficiency, improved reliability of service and lower overall system costs.[72]

Trends in urban financing and investment for renewables generally depend on the availability of capital for funding projects, including the ability of municipal governments to mobilise their own fiscal revenue collection and borrow money. Many cities have limited funds at their disposal and/or depend on national governments to provide a significant amount of finance.[73] Despite context-specific challenges, the finance and investment trends related to renewables in cities closely mimic those at the global level, including divestment from fossil fuels and re-investment in renewables (→ *see Financing and Investment chapter*). As of 2020, more than 160 city governments and pension funds had divested from fossil fuels, including 12 members of the C40 Cities network that pledged[i], as part of their COVID-19 economic recovery plans, to divest city assets from fossil fuel companies and then re-invest the funds in climate solutions.[74]

Municipal governments are responsible for only part of the financing that occurs within a city. Businesses, households, communities and other urban actors also play a role, often encouraged by policies. In Europe and the United States, as well as elsewhere, more and more citizens have chosen to purchase energy from providers offering renewable electricity or heat, to increase self-consumption of renewables, and to join together to create community energy projects in cities. City governments also have used participatory governance to include citizens in urban planning, budgeting and policy development processes.[75]

Amsterdam, Netherlands

CITY LEADERSHIP: NETWORKS AND INITIATIVES

Local governments have worked together in global and regional networks to raise their voice, increase their advocacy capacity and sharpen their role in the climate, sustainable development and energy debates. Collectively, these networks have played an important role in encouraging cities to adopt renewable energy targets and implement local climate action, and they have offered a platform for effective information and resource exchange and inspiration.[76]

- In 2020, more than 1,750 cities were part of the network of **ICLEI – Local Governments for Sustainability**, committing to sustainable urban development.[77] ICLEI worked with CDP[ii] in 2019 to launch the CDP-ICLEI Unified Reporting System in an effort to streamline city climate and energy reporting. During 2020, 812 local governments from 93 countries reported their data to this system.[78]
- By mid-2020, 97 cities were part of the **C40 Cities** network (no change from 2019), representing more than 700 million citizens and one-quarter of the global economy.[79] C40 cities aim to collectively halve their local greenhouse gas emissions by 2030, and 88 of the cities have signed on to Deadline 2020, a commitment to develop a climate action plan compatible with the Paris Agreement.[80] During 2019 and 2020, C40 cities continued to be frontrunners in climate and energy ambition, including:
  - By 2019, 28 cities (including 5 non-C40 cities) had joined the Net Zero Carbon Buildings Declaration, committing to net-zero carbon for new buildings by 2030 and for all buildings by 2050.[81]
  - In 2019, 35 cities (including 7 non-C40 cities) pledged to procure only zero-emission buses starting in 2025 and to ensure that a major area of the city is zero-emission by 2030[iii].[82]
- **Energy Cities**, the European association of cities in the energy transition, brought together 1,000 local governments in 30 countries as of 2020, with the goal of transforming European governance and legal frameworks to enable cities to play their part in the energy transition.[83]
- As of 2020, the **ASEAN Smart City Network**, launched in 2018, brought together 26 pilot cities in member states of the Association of Southeast Asian Nations to work on smart, sustainable urban development. [84]

i These 12 cities are signatories of the Divesting from Fossil Fuels, Investing in a Sustainable Future Declaration.

ii CDP, previously the Carbon Disclosure Project, is a disclosure platform for companies, states, cities and regions; see www.cdp.net.

iii These initiatives are, respectively, the Green and Healthy Streets Declaration and the Fossil Fuel Free Streets Declaration.

Many city networks also exist at the regional level, often in collaboration with global partners. Some local governments have organised themselves in national networks (as in Austria).[85] In the United Kingdom, the UK 100 network brings together around 100 local governments that have pledged to shift to 100% clean energy by 2050; in 2020, some member cities committed to achieve net zero by 2045.[86]

Momentum also grew during 2019 and 2020 for specific initiatives and campaigns that engage local governments in energy and climate action, often in collaboration with city networks.

- The **Global Covenant of Mayors for Climate & Energy**[i] is the largest global coalition of cities and local governments. Signatories commit to reducing community-scale greenhouse gas emissions, adapting to climate change and improving access to sustainable energy (i.e., renewables and energy efficiency). As of mid-2020, more than 10,500 cities in 142 countries had committed to the Global Covenant of Mayors (232 new cities in 2019 and 177 as of mid-2020), with most of these cities (more than 9,600) in Europe, followed by Latin America and the Caribbean and North America.[87] Of the total signatories, 9,482 had climate change mitigation targets, and 5,460 of these also had mitigation plans; 1,870 cities had set adaptation goals, and 335 of these also had adaptation plans.[88]
- The **Covenant of Mayors for Sub-Saharan Africa** (CoM SSA) was established in 2015 as part of the Global Covenant of Mayors, and by 2020 it had been signed by 175 local governments from more than 35 countries across Sub-Saharan Africa.
- CC35, under the **Mayors for Climate** ("Alcaldes por el clima") initiative, brings together local governments in Latin America to pass binding decarbonisation legislation, and had 274 members as of mid-2020.[89]
- **Race to Zero**, a global campaign under the United Nations Framework Convention on Climate Change and supported by leading net-zero initiatives and city networks, brings together businesses, cities, regions and investors to facilitate the shift to a decarbonised economy. By the end of 2020, the campaign had 454 participating city governments, with the goal of mobilising 1,000 by the time of the United Nations Climate Change Conference in Glasgow (Scotland) in late 2021.[90]
- To demonstrate city action towards the Paris Agreement, in 2020 a record 255 cities from 53 countries participated in **WWF**'s One City Planet Challenge, a competition that was won by Mexico City.[91]
- By 2020, under the **Sierra Club's Ready for 100** campaign, 172 US cities had made commitments to 100% renewable energy by 2050 at the latest (up from 131 cities in mid-2019), and 48 cities had already achieved that goal.[92] Other initiatives in the United States include the We Are Still In campaign, the Climate Mayors network and the US Conference of Mayors Climate Protection Agreement.[93]

Although most countries' Nationally Determined Contributions[ii] towards reducing emissions under the Paris Agreement do not reference city-level renewable energy commitments (or specify the role of cities in achieving emission reductions), national governments will need to rely on urban actors to fulfil their obligations.[94] Many of the NDCs highlight urban adaptation and resilience and include targets that also apply to urban areas, such as the decarbonisation of buildings, energy, transport and waste.[95] By the end of 2020, 190 parties had submitted their first NDCs, and 8 had submitted their second.[96] Cities can contribute to attaining NDCs not only by reducing their own emissions, but also by participating in international initiatives.


Havana, Cuba

City networks have encouraged municipal governments to adopt renewable energy targets and implement local climate action.

i The initiative started as the European Union's Covenant of Mayors in 2008 but has since grown to cities in 140 countries by the end of 2020. The Global Covenant of Mayors for Climate & Energy combined the EU's Covenant of Mayors with the Compact of Mayors (launched in September 2014 by UN Secretary-General Ban Ki-moon). See European Commission, "EU Covenant of Mayors and Compact of Mayors launch largest global coalition of cities committed to fighting climate change", press release (Brussels: 22 June 2016), https://ec.europa.eu/commission/presscorner/detail/it/IP_16_2247.

ii NDCs include policies, targets and measures that serve as the basis for national climate plans. See World Resources Institute, "National Climate Action under the Paris Agreement", https://www.wri.org/ndcs, viewed 15 November 2020.

REGIONAL TRENDS

EUROPE

European cities have been global leaders on urban energy and climate issues, often driven by the push for greater climate action as well as a desire to improve the health of city residents.[97] For example, cities in Europe spearheaded the "climate emergency" movement and accounted for 45% (826) of the total 1,852 climate emergency declarations issued worldwide as of the end of 2020.[98] Additionally, at least 357 European cities had a renewable energy target in place by year's end.[99]

European cities were the most numerous participants in city networks and dominated local climate action in 2020: by the end of the year, more than 10,000 cities in 43 European countries had signed the Covenant of Mayors for Energy & Climate, and over 6,700 of these had submitted action plans as well, many of which specify a role for renewables.[100] In line with the European Green Deal, cities also have been committing to net-zero goals and developing more holistic strategies and integrated solutions to decarbonise activities in urban areas, including scaling up renewables on municipal buildings, using waste and wastewater as inputs to produce renewables, integrating solar and geothermal district heating, and shifting to renewable-based municipal vehicle fleets.[101]

In late 2020, the European Green City Accord was launched with the aim of speeding Europe's transition to sustainable development by getting different levels of government to work together and mobilise other stakeholders. The Accord will support city efforts towards achieving the following five goals by 2030: significant improvement in air quality; important progress in improving the quality of water bodies and the efficiency of water use; considerable progress in conserving and enhancing urban biodiversity; advancement towards the circular economy; and significant reduction in noise pollution.[102]

In contrast to many other regions, cities in Europe are shaped by infrastructure that extends back centuries, and they typically have a more settled urban form and low rates of new building construction. The focus is thus on renovating and retrofitting existing structures, often with dedicated funding from other levels of government, such as the EU's "renovation wave" strategy[i],[103] Cities and communities have taken on growing importance at the EU level, exemplified by targeted projects providing financing for innovative cities.[104] For example, so-called lighthouse cities have been selected as climate innovation leaders to set positive examples and lay the path for other cities to follow.[105] In contrast, only a few national governments have fully understood the key role of local authorities in the energy and climate transition.[106]

Hagafoss , Norway

Europe and North America remain leading regions for city-level renewable energy and climate action.

Milan, Italy

i The EU's renovation wave strategy focuses on the need to improve, retrofit and decarbonise existing buildings. See European Commission, "Renovation wave", https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en, updated 18 January 2021.

NORTH AMERICA

North America remained a leading region for city-level renewable energy action, driven by local ambition to decarbonise and diversify energy supplies while increasing economic competitiveness and boosting resiliency.[107] As of the end of 2020, at least 350 municipal governments in the United States and Canada had renewable energy targets, and several cities had made significant progress towards their 100% renewable electricity goals, with several cities achieving these during 2019 and 2020.[108] Key trends in the region included procurement of renewables for municipal operations, galvanised support for distributed renewable energy generation projects, diverse community solar models, and robust incentives or mandates for energy efficiency upgrades and building electrification. North American cities continued to leverage municipal green bonds, federal and state funding, clean-tech incubator support and other innovative financing mechanisms to support the development of renewables.[109]

In the United States, local government renewable energy transactions increased considerably after the federal government stated its intention in 2017 to withdraw from the Paris Agreement (the country rejoined in January 2021).[110] Cities accounted for most of the new renewable power capacity added by local governments during 2019 and 2020 – primarily through off-site power purchase agreements (PPAs) signed with developers of large-scale solar PV projects, mainly in California and Texas.[111] In Canada, a major policy focus in large cities – notably Montreal, Toronto and Vancouver – was increasing the share of renewable energy across not just the power sector but also heating, cooling and transport.[112]

Although North American cities have struggled to deploy renewables more widely in heating, cooling and transport, an increasing share of municipal governments partnered with legislative or regulatory bodies at higher levels of governance, as well as with community stakeholders and/or the private sector, to remove legal, technical and financial barriers restricting renewable energy deployment and use across all end-use sectors.[113]


Oak View, California, United States

ASIA

In Asia, growing concerns about air pollution and smog have driven public demand for renewable energy technologies and electric vehicles to improve public health.[114] Although national governments have tended to dominate city-level actions to promote renewables, municipal-level commitment has been growing. By the end of 2020, at least 51 municipal governments in Asia had set renewable energy targets, and 37 had implemented renewable energy policies, most of which were in buildings and transport.[115] In addition, local governments have been instrumental in pushing the national governments in Japan and the Republic of Korea to commit to carbon neutrality and/or adopt net-zero targets.[116] Cities in Asia increasingly have sought to develop and strengthen public-private partnerships and to take advantage of digitalisation and use smart technology to attract more foreign direct investments in renewables.

Chinese cities have actively promoted renewables, guided mainly by national and regional policies and action plans, many aimed at reducing air pollution.[117] In addition, several municipal governments have subsidised renewables in buildings and supported the phase-out of fossil fuels for heating purposes. China dominates the global e-mobility market, accounting for 98% of the world's electric buses and for the majority of electrified cars, two-/three-wheelers and trucks.[118] Green hydrogen for transport (and other uses) also is garnering interest in both China and the Republic of Korea, with several cities having ongoing or planned pilot projects.[119] Municipal governments in the Republic of Korea have dominated the number of climate emergency declarations issued in the region, representing 228 out of the 288 as of 2020.[120]

India launched a smart cities programme in 2015 to increase solar power generation capacity in urban areas, and some of these efforts have been coupled with the electrification of urban transport (part of the country's Faster Adoption and Manufacturing of Electric Vehicles (FAME)-II in 2019-2020).[121] Momentum is growing for the expansion of district cooling in the Indian cities of Amaravati, Gujarat International Finance Tec-City (GIFT City) and Rajkot, as well as elsewhere in Asia including in Bangkok (Thailand), Cyberjaya (Malaysia), Manila (Philippines) and Singapore.[122] Still, data on renewable energy progress in Asia remain limited, often due to language barriers and to low participation in international reporting.


Bacoor, Philippines

SUB-SAHARAN AFRICA

Due to rising urbanisation, population growth and energy demand[i], the opportunities around renewable energy use in cities are increasingly recognised in Sub-Saharan Africa. At least 19 cities, including Cape Town and Durban (both South Africa) and Kampala (Uganda) have in place renewable energy targets, and 34 cities have policies.[123] Common drivers for renewables in the region include reducing poverty and inequality (including by addressing energy access and energy poverty) and boosting the resilience and reliability of power systems.[124]

City governments play a key role in shaping the energy landscape of Sub-Saharan Africa. However, competing development priorities, weak fiscal decentralisation, limited municipal mandates across key sectors, and constraints in skilled capacity to execute municipal functions continue to hinder the wider adoption of renewables.[125] Nonetheless, cities have supported local renewable energy deployment in a variety of ways, including by facilitating collaborative projects led by national governments, development finance institutions and/or private actors.[126] Some Sub-Saharan local governments, especially in cities where transport is responsible for a large share of energy consumption, also have entered into public-private partnerships to advance e-mobility (sometimes linked to renewable electricity) at the city level.[127]

Still, the number of cities and towns in the region that have reported data on renewables remains low, due in part to poor or non-existent Internet access, lack of technical (information technology) equipment for local government staff, and the absence of systematic and robust data collection (a worldwide challenge) – all of which impact the availability of data necessary for analysis and trend identification over time.[128] This affects local decision making and resource allocation, and also is a barrier for private investors.[129] To address this challenge and to access technical guidance, many Sub-Saharan African cities have joined international city networks such as ICLEI and initiatives like the Covenant of Mayors in Sub-Saharan Africa, which support knowledge and internal capacity on renewable energy data collection and developing robust implementation projects (→ *see Feature chapter*).[130]

LATIN AMERICA AND THE CARIBBEAN

Despite facing many challenges, **city-level action** to support renewables is expanding, including in developing and emerging economies.

In Latin America and the Caribbean, concerns about traffic and congestion, inadequate infrastructure, air pollution and the effects of climate change have accelerated investment in renewables and the electrification of public transit.[131] By the end of 2020, several municipal governments had renewable energy targets (39 targets), and cities in the region were among the frontrunners in setting net-zero targets (212 targets).[132] Many cities already have high shares of renewable electricity in their energy mixes, including Bogotá (Colombia), Curitiba (Brazil) and Quito (Ecuador).[133] This has been facilitated by the large contribution of hydropower to national and regional grids, emerging national-level regulations for integrating distributed power generation, the growing penetration of wind and solar PV power (incentivised by national policies) and the emergence of renewable energy auctions.[134]

The liberalisation of electricity markets in Argentina, Brazil, Colombia, Mexico and Peru has made it possible for municipal governments and other large energy consumers in these countries to procure renewable electricity directly from local or nearby projects (although residential users remain excluded from choosing their supply companies).[135] Additional trends include the integration of solar PV and solar thermal systems in public buildings; the creation of public-private partnerships to implement larger decarbonisation projects (such as investments in public transit infrastructure); and growing momentum for the electrification of public bus fleets, with e-buses operating in cities in more than 10 countries.[136]

Cape Town, South Africa


Baños, Ecuador

i Despite rising energy use in the region, energy consumption in Sub-Saharan Africa remains among the lowest in the world and relies heavily on traditional biomass, mainly wood and charcoal. See International Energy Agency (IEA), *Africa Energy Outlook 2019 – Analysis Scenarios* (Paris: 2019), and IEA, *World Energy Outlook 2020* (Paris: 2020).

OCEANIA

Renewable energy deployment varies widely across Oceania. Many Pacific island nations have turned to renewables to decrease their dependence on fossil fuel imports, reduce energy costs, and increase energy security and resilience, with most of these efforts being dominated by national and/or sub-national governments.[137] In Australia and New Zealand, momentum is growing for renewable energy in cities, also facilitated by rising concerns about climate change and energy insecurity. By the end of 2020, 114 municipal governments in Australia and New Zealand had declared a climate emergency[i], and 16 cities had a renewable energy target in place, including several cities that have committed to (or already achieved) 100% renewable energy targets, including Adelaide, Melbourne and Sydney (all Australia).[138]

Renewable power purchase agreements gained momentum in Australia, with several major cities, including Melbourne and Sydney, negotiating PPAs in 2019 and 2020 to help achieve their ambitious renewable electricity goals.[139] Australian cities also continued efforts to decarbonise transport, with electric refuse trucks starting operation in Adelaide, Casey and Yarra.[140] Investment in renewable energy projects in Australia has increased in recent years, mainly in the private sector and supplied by domestic banks. In the wake of the widespread 2019 wildfires, municipal governments created several recovery and reconstruction funds to support the installation of solar PV systems in cities and towns.[141]

MIDDLE EAST AND NORTH AFRICA

Across the Middle East and North Africa, concerns about air pollution and health have risen, and energy security challenges remain. Generally, municipal-led renewable energy developments have progressed slowly, due to lack of financial and human resources and strong centralisation of the energy system.[142]

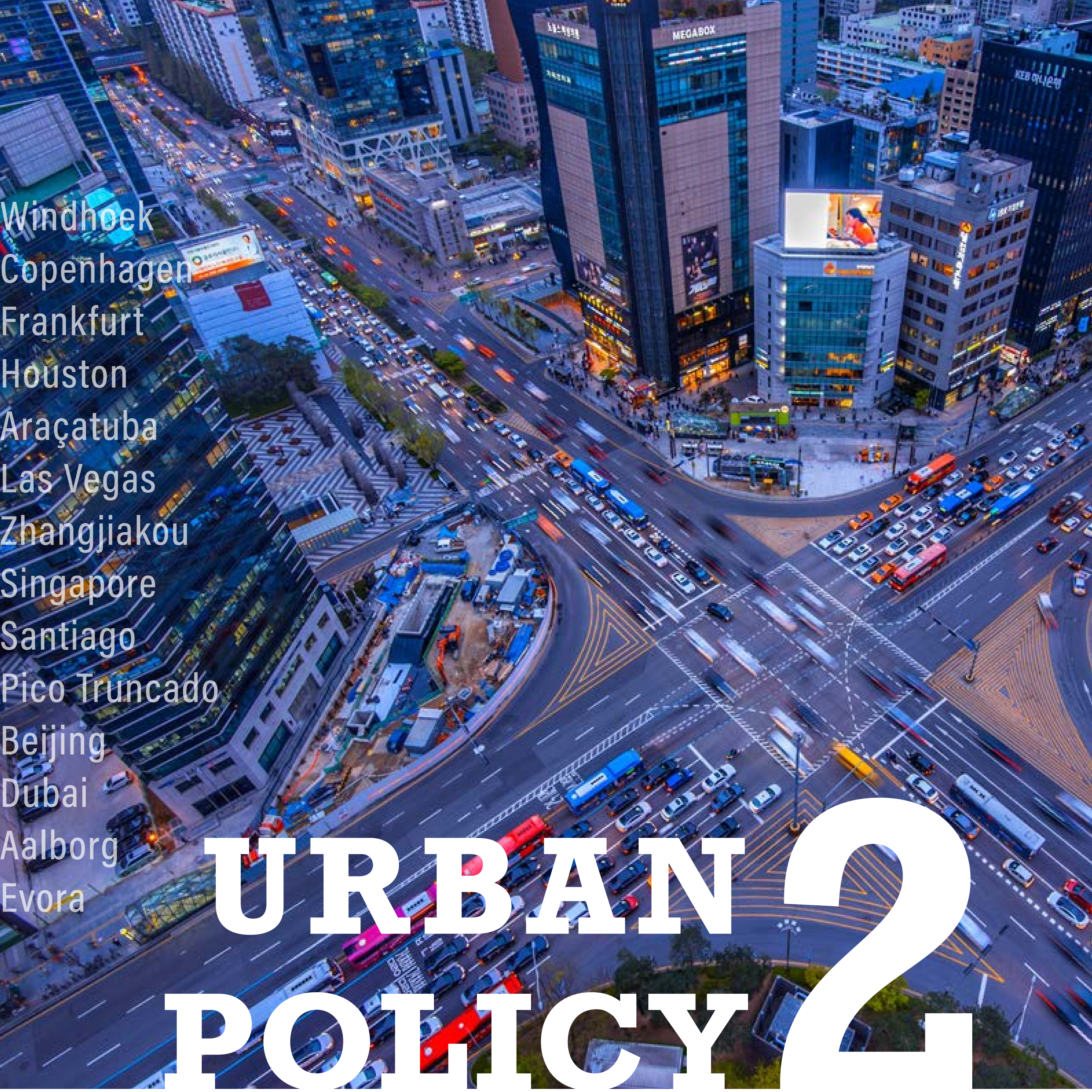
City governments tend to have comparatively little political autonomy, and thus national rather than municipal governments have largely driven efforts to deploy renewables (exceptions include Abu Dhabi, Dubai and Ras Al Khaimah in the United Arab Emirates).[143] Some renewable energy projects in cities have been funded by national governments, whereas in less affluent regions investment has been supported by foreign development aid as well as rising involvement from the private sector and civil society.

The key drivers for renewables vary across world regions, but concerns about **air pollution** are global.

Taupo Volcanic Zone, New Zealand

Dubai, United Arab Emirates

i At the end of 2020, New Zealand's national government also declared a climate emergency and set a goal to be carbon neutral by 2025.



Windhoek
Copenhagen
Frankfurt
Houston
Araçatuba
Las Vegas
Zhangjiakou
Singapore
Santiago
Pico Truncado
Beijing
Dubai
Aalborg
Evora

URBAN POLICY 2

LANDSCAPE

Orlando
Adelaide
Rajkot
Seoul

URBAN POLICY LANDSCAPE

Around
260 cities
set new targets or passed new policies in 2020.

Municipal governments around the world have been moving renewable energy up the policy and planning agenda, driven by the desire to improve public health and well-being, alleviate poverty, tackle climate change and improve local resilience, among other goals, and supported by the falling prices of renewables; overall, more than 1 billion people – around a quarter of the global urban population – lived in a city with a renewable energy target and/or policy (for a total of over 1,300 cities), and around 260 cities set new targets or passed new policies in 2020.[1] In many cases, municipal targets and policies are far more ambitious than those in place at higher levels of government.[2]

Municipalities have numerous policy options to stimulate renewable energy deployment. They can set targets and scale up the use of renewables for their own **municipal operations** (whether in buildings or transport fleets) through on-site generation and procurement policies. They also can use their role as regulators and policy makers to implement direct regulatory policies, financial and fiscal incentives as well as indirect support policies to encourage the **city-wide** adoption of renewable technologies.[3] In addition, municipal governments can raise awareness about the benefits of renewables, facilitate dialogue, and engage local residents, businesses and other stakeholders in the energy transition[i],[4]

Municipal governments have been advancing the production and use of renewable energy through various measures, including integrating renewables directly into near- and long-term energy and resource planning (→ *see City Snapshot: Orlando*).[5] For example, mandating the inclusion of renewable technologies and/or electric vehicle charging infrastructure in new construction can enable higher renewable energy shares while helping to achieve other city-wide goals. Governments also can advance renewables by planning infrastructure and the built environment in more efficient ways, considering urban density, building orientation and related effects on mobility to enable greater renewable energy use in key sectors such as buildings, industry and transport.[6]

i For more on the multiple roles of municipal governments in the energy transition, see Chapter 1, "Cities in the Renewable Energy Transition", in the REN21, *Renewables in Cities 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wpcontent/uploads/2019/05/REC-2019-GSR_Full_Report_web.pdf.

ORLANDO

FLORIDA (UNITED STATES)

Land area (km^2)	Population size (2019)	Greenhouse gas emissions (CO_2 equivalent)
295	over 280,000	6,994,170 tonnes

The City of Orlando has a strong reputation for its city-wide achievements in sustainability and resilience. Over the last decade, the Green Works Orlando initiative has revolutionised the city by adding a sustainability chapter to the local municipal code. The implementation of sustainability policies and plans has made the city a leader in developing environmentally friendly communities.

In 2020, the Orlando Utilities Commission (OUC) began developing its Electric Integrated Resource Plan, with the aim of becoming carbon neutral by 2050 (with interim CO_2 emission reduction targets of 50% by 2030 and 75% by 2040). The plan also acts as a pillar to achieve the mayor's ambitious goal of 100% renewable electricity generation[i] in the city by 2050. It supports the phase-out of coal by 2027 and provides a roadmap to diversify the city's existing electricity mix. Although solar PV will remain the main source of new energy, Orlando will invest in energy storage and other related technologies to ensure reliability and resilience.

The OUC has a major role in making solar energy affordable and accessible in the city and has found innovative ways to harness power from the sun. In 2017, it established long-term power purchase agreements to buy power from the 12.6 megawatt (MW) Kenneth P. Ksionek Community Solar Farm, the first in the country to include a solar PV array that sits atop a by-product landfill. In 2020, the OUC backed the construction of two new solar PV farms – the Harmony Solar Energy Center in St. Cloud and the Taylor Creek Solar Energy Center in east Orange County[ii], together capable of powering 30,000 homes – and started purchasing power from them.

Orlando also is home to more than 1 MW peak of floating solar PV and has been a pioneer in this new application since 2017. The OUC will to continue to study the performance and scalability of floating solar PV in collaboration with the National Renewable Energy Laboratory thanks to a USD 1 million grant from the US Department of Energy. In 2020, the City of Orlando unveiled the new "floatovoltaics" at its international airport, showcasing this unique solar application. The local government has installed several "solar sculptures" and "solar trees" in the city to generate electricity and educate customers on the benefits of solar power.

Source: See endnote 5 for this chapter.

i According to the CDP-ICLEI Unified Reporting System, the share of renewables in electricity generation in Orlando was 2% (no date specified).

ii These are two of five projects being developed in the context of the Florida Municipal Solar Project, a partnership between the Florida Municipal Power Agency and 16 Florida public power utilities, including the OUC.

TARGETS

RENEWABLE ENERGY

Globally, at least 834 cities in 72 countries had a renewable energy target in at least one sector[i] by the end of 2020.[7] This means that an estimated 558 million people worldwide are living in a city with at least one renewable energy target.[8] Altogether, these cities have a combined total of 1,088 targets, as several cities have adopted more than one renewable energy target (whether for municipal operations and/or city-wide energy use) (→ *see Figures 3 and 4 and **Reference Table R1***).[9] Although most municipal targets are aimed exclusively at the power sector (62%), several municipalities have enacted targets specifically for heating and cooling or for transport, and some have committed to cross-sector or economy-wide targets.[10]

Geographically, the number of municipal renewable energy targets has increased in all regions of the world, although most targets are in North America and Europe (a combined 81%) followed by Asia (8%).[11] In Europe, targets are especially prevalent in Germany and Italy, facilitated by rising awareness of the influence of cities within the EU as well as by governance structures that allow local participation in energy issues.[12] In North America, targets are most common in the United States, which is home to 419 targets (39% of the global total), demonstrating the long-term commitment of municipal authorities despite the temporary US withdrawal from the Paris Agreement.[13] Overall, more than 80% of renewable energy targets globally are in regions that have higher income per capita, and are predominantly in countries with colder climates.[14] Generally, small and medium-sized cities in the population range of up to 500,000 inhabitants have emerged as frontrunners in target-setting, home to 74% of all targets (→ *see Figure 5*).[15] However, some larger cities and megacities – such as Beijing (China), Cape Town (South Africa), Copenhagen (Denmark) and Frankfurt (Germany) – also have targets.[16]

Municipal renewable energy targets differ in several ways[ii]. Although many targets are aspirational goals, taking the form of pledges, some cities have enacted legally binding targets.[17] The scope of targets ranges from municipal operations to city-wide energy production or use, and timelines vary widely (→ *see Figure 6*).[18] Some cities also break down their targets into interim, shorter-term targets to facilitate the tracking of progress, and align their action plans accordingly.[19] The majority of cities aim their targets at increasing the overall share of energy from renewables, although many also apply specific capacity or generation goals.[20]

Despite the momentum at the municipal level to establish renewable energy targets, city reporting on actual progress towards achieving these targets has lagged.[21] Many cities are either not gathering or not providing sufficient data to enable adequate monitoring and benchmarking. As a result, it remains difficult to determine the extent to which cities are on track to reach their targets (→ *see Box 1 in Global Overview chapter*).[22]

Hong Kong, China

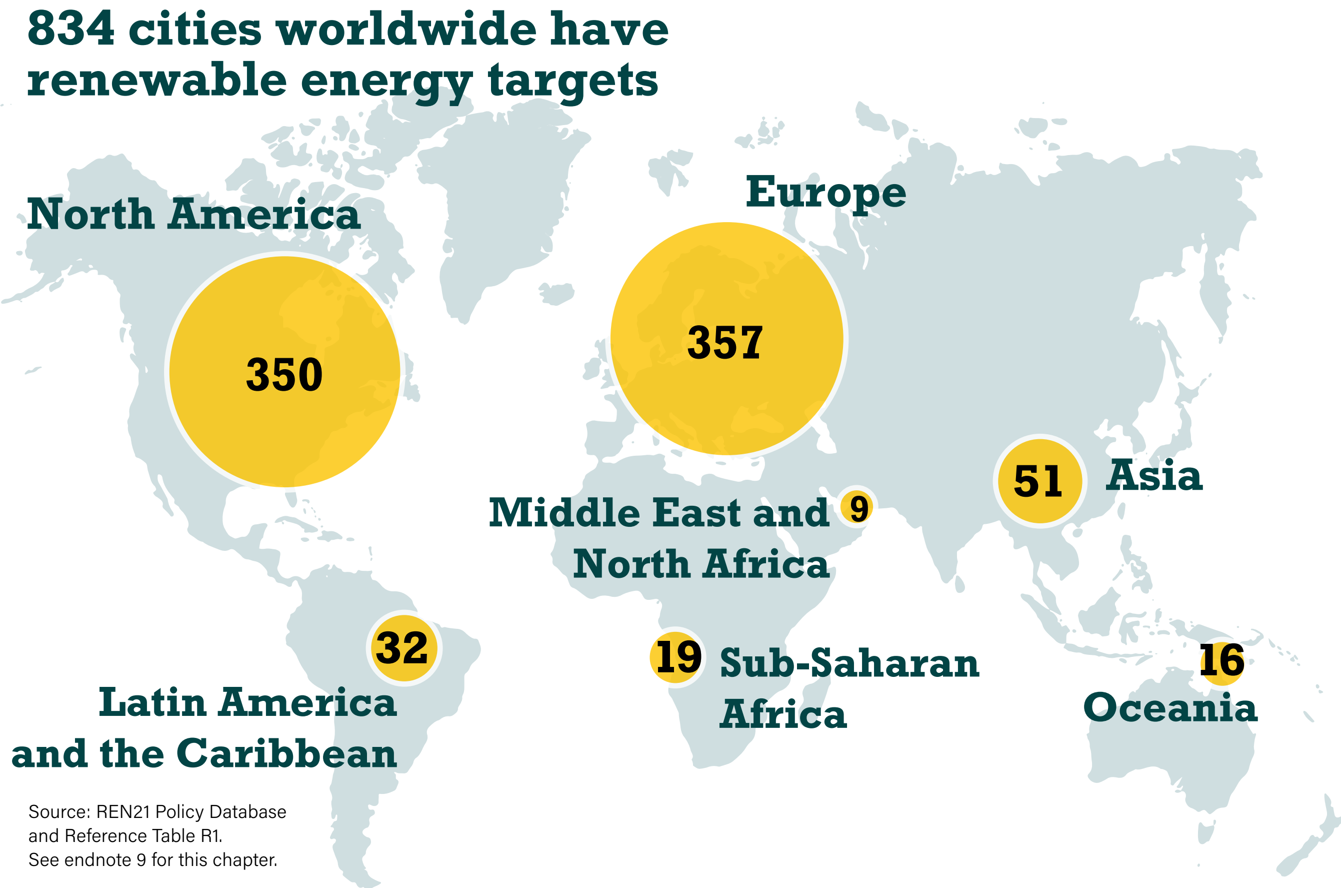
Small and medium-sized cities have emerged as **frontrunners** in renewable energy target-setting.

2

i This total includes multiple targets for the same city. It covers renewable targets for consumption of all energy as well as for energy specifically in the power, heating and cooling, and transport sectors, as well as targets for specific installed capacity. It excludes targets for enabling technologies such as e-mobility and energy efficiency targets. In some cases, city governments have passed renewable energy targets but it remains unclear whether they are for renewable electricity or economic-wide targets (→ *see Box 1 in Global Overview chapter*).

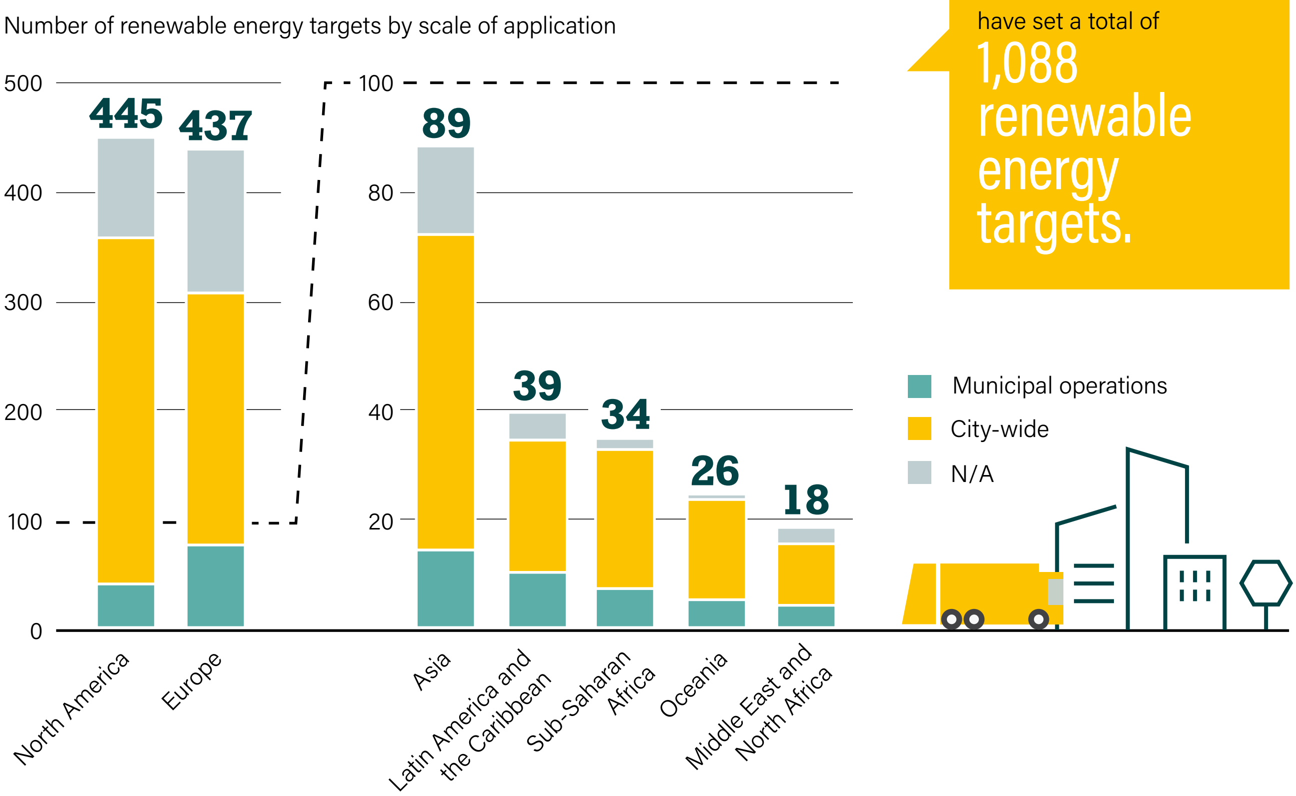
ii For more on the nature of renewable energy targets in cities, see REN21, *Renewables in Cities 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wpcontent/uploads/2019/05/REC-2019-GSR_Full_Report_web.pdf.

Figure 3. Renewable Energy Targets in Cities, 2020



Source: REN21 Policy Database and Reference Table R1. See endnote 9 for this chapter.

Figure 4. Renewable Energy Targets in Cities, by Scale of Application and Region, 2020



Note: The figure includes cities with renewable energy targets either for municipal operations or for city-wide energy use, or for both. Some cities have more than one renewable energy target. N/A = scale of application not available.

Source: REN21 Policy Database and Reference Table R1. See endnote 9 for this chapter.

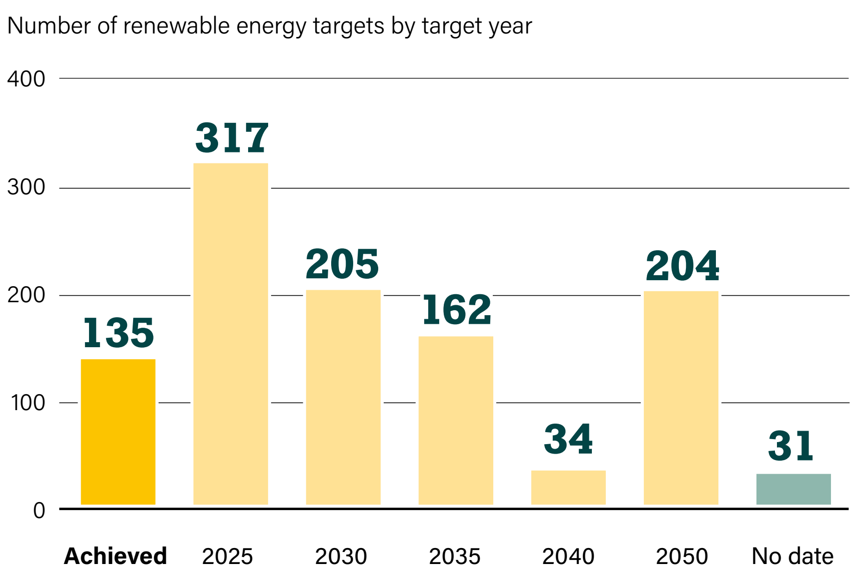
Figure 5. Renewable Energy Targets in Cities, by City Size and Region, 2020

Note: Some cities have multiple renewable energy targets.
Source: REN21 Policy Database and Reference Table R1. See endnote 15 for this chapter.

Cities with less than 500,000 people are home to

74% of all renewable energy targets.

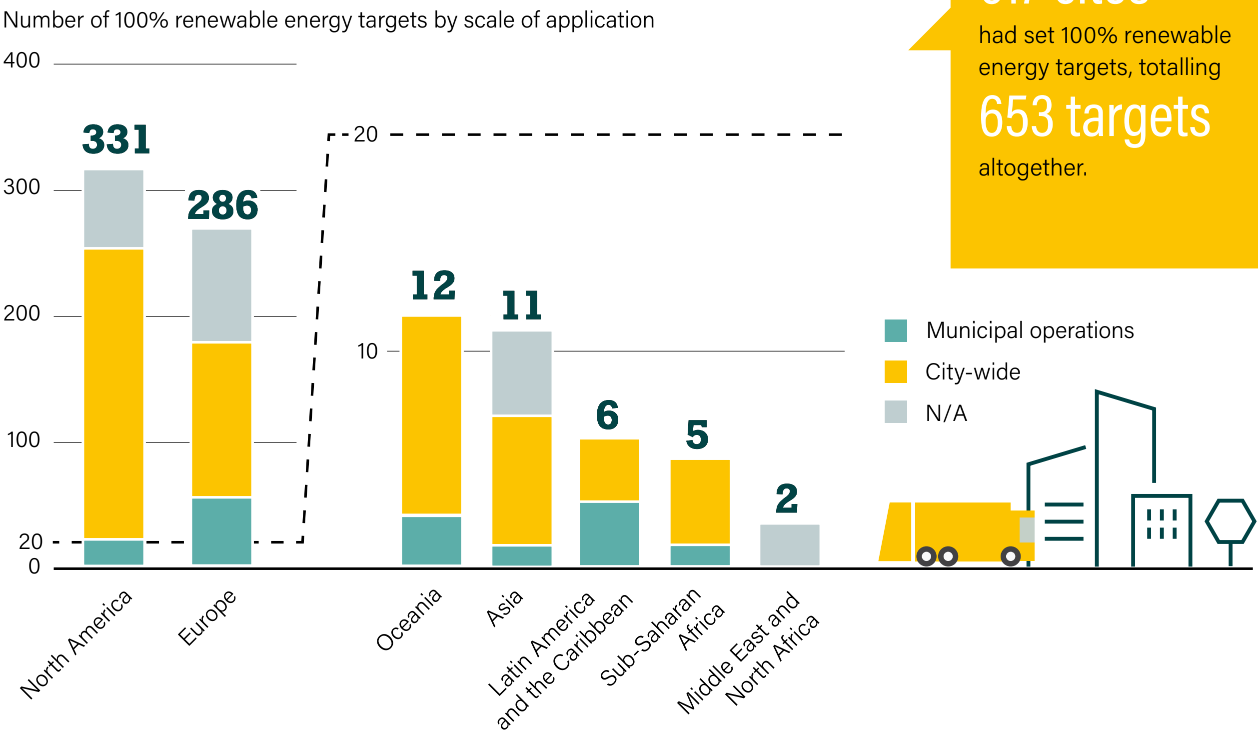
Figure 6. Renewable Energy Targets in Cities, by Target Year, 2020



Note: Data for target years also include targets within the span of years prior to those specified (e.g., 2026-2029 for the 2030 target year).
Source: REN21 Policy Database and Reference Table R1. See endnote 18 for this chapter.

The movement towards 100% renewable energy – particularly 100% renewable electricity – has continued to gain traction. Globally, 617 cities had set 100% targets for either municipal operations or city-wide energy use as of 2020, together totalling 653 targets (→ *see Figure 7*).[23] Most of these commitments are for the power sector only. Although most such targets aim for years in the 2030 to 2050 period, at least 125 cities (including 47 in the United States alone) already had achieved their 100% renewable electricity targets by the end of 2020 (→ *see City Snapshot: Adelaide*).[24] For example, Houston (Texas) has met its target of powering its municipal operations – including its wastewater treatment plants, zoo and three airports – with 100% renewable electricity, making it the largest US city to power its operations entirely by renewables.[25]

Figure 7. 100% Renewable Energy Targets in Cities, by Scale of Application and Region, 2020



617 cites had set 100% renewable energy targets, totalling **653 targets** altogether.

Note: The figure includes cities with 100% renewable energy targets either for municipal operations or for city-wide energy use, or for both. Some cities have more than one 100% renewable energy target. N/A = scale of application not available.

Source: REN21 Policy Database and Reference Table R1. See endnote 23 for this chapter.

ADELAIDE

AUSTRALIA

Land area (km^2)
15.6

Population size (2019)
1.3 million

GHG
Greenhouse gas emissions (CO_2 equivalent)
360,759 tonnes

As part of a power purchase agreement, the City of Adelaide's municipal operations have been powered by 100% renewables since July 2020, using electricity generated from wind farms in mid-north South Australia and new solar PV farms on Eyre Peninsula and in the South East. This long-term commitment supports the Adelaide Carbon Neutral Strategy 2015-2025, which sets a target for carbon neutrality by 2025.

As a step towards achieving this goal, the City adopted the Carbon Neutral Adelaide Action Plan 2016-2021 to reduce greenhouse gas emissions. The plan sets out 104 actions for council and local government under several low-emission pathways: energy-efficient built form, promoting walking and cycling, hybrid and electric vehicles for individuals and businesses, "zero-emission" transport, towards 100% renewables with solar PV and solar hot water, reducing emissions from waste and water use, and offsetting carbon emissions. The projects under the 100% renewable pathway generate cost savings for residents and businesses along with reducing emissions. In total, the city had installed 8.3 MW-peak of solar PV capacity as of 2019, including 2,362 kilowatts (kW) at city-owned and -operated sites.

Local government investments in energy storage support the deployment of new affordable storage technologies. For example, the Hornsdale Power Reserve, referred to as South Australia's Big Battery, was established in 2017 with 100 MW-peak, and another 50 MW-peak had been added in early 2020. Located next to the 316 MW Hornsdale Wind Farm, the Power Reserve is one of the world's largest lithium-ion batteries, providing grid services that enable the penetration of variable renewable energy sources like wind and solar power.

In addition, the Carbon Neutral Adelaide Action Plan provides incentives to create new economic opportunities and to support the business sector. Building upgrade finance provided by private financiers in partnership with the local council helps to improve the energy, water and environmental efficiency of non-residential buildings and infrastructure. This mechanism offers loans from the financier to building owners, which are repaid by the local council. Upgrading the infrastructure provides financial returns and has the potential to reduce electricity use 43% by 2030.

The Sustainability Incentive Scheme and the CitySwitch Green Office support city residents with financial incentives for the uptake of sustainability practices, technology and trends for low-carbon living. Rebates of up to AUD 5,000 (USD 3,831) are available for households, businesses and car parks for the installation of energy-saving technologies, solar PV systems, EV charging, solar hot water systems and energy storage systems.

The City of Adelaide also is assessing adaptation actions to increase the energy self-sufficiency of its wastewater treatment plants by harnessing biogas to generate renewable electricity. A total of 39,000 megawatt-hours (MWh) was generated from wastewater biogas in 2018-19. In parallel, the local government has been exploring the potential of carbon offset projects. In 2017, a demonstration carbon sequestration site was established near Adelaide High School to provide the community with a practical example of a carbon sink.

Source: See endnote 24 for this chapter.

City governments continued reporting on renewable energy targets, with 812 cities providing data to the CDP-ICLEI Unified Reporting System by the end of 2020.[26] Of these, 95 were in the progress of developing a renewable energy target in 2020 and 152 intended to pass one in the next two years.[27]

Targets in the **power** sector have continued to receive most of the attention. As of 2020, at least 612 cities had renewable energy targets focused on the power sector (678 targets altogether), including targets to switch to renewable electricity consumption or targets for a specific amount of renewable generation.[28] Cities with new renewable power targets in 2020 included Araçatuba (Brazil); Blacksburg, Houston, Las Vegas and Louisville (all US); Evora (Portugal); Murcia (Spain); and Singapore.[29]

A growing number of cities have set targets for renewable **heating and cooling**, particularly in Europe and the United States. This trend is especially pronounced in cities that have adopted net-zero or other climate targets, as recognition grows of the critical role that the heating and cooling sector plays in achieving decarbonisation.[30] In Scandinavia, Baerum (Norway) and Helsingör (Denmark) have targets for the use of 100% renewables in district heating, and Helsingör has specified that its district system will rely entirely on bioenergy.[31] Momentum also has grown for the adoption of solar water heater targets, particularly in developing countries. Mexico City committed in 2019 to retrofitting eight public buildings with solar water heating, and similar targets also exist in Alheim (Germany) and Antofagasta (Chile).[32]

In the **transport** sector, most city-level targets focus on electric vehicles, with some linked directly to renewable power (→ *see E-mobility and Hydrogen section*).[33] Although most **biofuel targets** for transport are set at higher levels of government, a few examples exist in cities, including in Auckland (New Zealand) since 2014, and in Helsingborg (Sweden) and Mexico City (Mexico) since 2019.[34] Some municipal governments also have worked with ports and port authorities to develop decarbonisation targets and strategies, including for increasing the production and use of renewables (→ *see Box 1*).[35]

At least
67 cities
have e-mobility targets.

E-MOBILITY AND HYDROGEN

E-mobility targets dominate urban transport-related targets and increasingly are being adopted in cities worldwide. Overall, at least 67 cities had e-mobility targets as of the end of 2020, up from 54 in mid-2019.[36]

Electrification offers the potential to increase the use of renewable energy in transport[i],[37] Although most cities with e-mobility targets do not link them directly to renewable electricity, several cities have adopted separate targets for e-mobility and renewable electricity – including Amsterdam (Netherlands), Cape Town (South Africa), Dubai (United Arab Emirates), Hamburg (Germany), Portland (Oregon, US) and Toronto (Canada) (→ *see Figure 8 and* ***Reference Tables R2 and R3***).[38]

E-mobility targets often aim for a certain number or percentage of EVs either sold, in circulation or registered in a city by a certain year. In 2019 and 2020, at least four cities – Delhi (India), Los Angeles (California, US), Santiago (Chile) and Seoul (Republic of Korea) added to their existing e-mobility targets, and at least three additional cities – Hamburg (Germany), Singapore and Tallinn (Estonia) – announced their first e-mobility targets.[39] To reduce local air pollution, the government of Delhi (India) set targets in 2019 for at least 500,000 EV registrations by 2024, and for delivery companies in the city to electrify 50% of their fleet by 2023 and 100% by 2025.[40] Also in 2019, Los Angeles (California, US) announced plans to increase the city's share of zero-emission vehicles[ii] in operation to 25% by 2025, 80% by 2035 and 100% by 2050.[41] In 2020, Santiago (Chile) announced a target to electrify 4,250 of its 6,600 buses by the end of 2021.[42]

Hamburg, Germany

i Researchers and policy makers increasingly recognise that to truly decarbonise the transport sector, e-mobility targets need to be linked directly with or at least complemented by renewable electricity targets. See REN21 and FIA Foundation, *Renewable Energy Pathways in Road Transport* (London: November 2020), https://www.ren21.net/wpcontent/uploads/2019/05/REN21_FIA-Fdn_Renewable-Energy-Pathways_FINAL.pdf.

ii Zero-emission vehicles do not produce tailpipe emissions. These air pollutants, emitted during the operation of a vehicle, often include greenhouse gases, particulate matter, volatile organic compounds, nitrogen oxides, carbon monoxide and sulphur dioxide.

BOX 1. Renewable Energy in Urban Ports and Port Authorities

Since most ports are located in cities, many interlinkages exist between ports and the urban environment. These linkages often have negative consequences at the local level: for example, in Hong Kong (China) more than half of the city's sulphur dioxide emissions are related to shipping. To address these concerns, both municipal policies and port development strategies increasingly have included measures to reduce emissions, mitigate the environmental impacts of port activities (including loading and unloading) and scale up renewable energy.

Nearly 90% of Europe's port authorities are publicly owned, meaning that local and other governments have a key role to play in the uptake of renewables at these ports. For example, the Climate Neutral Roadmap 2050 of Amsterdam (Netherlands), published in 2020, includes plans to transform the city's port into a "battery" to store and distribute renewable electricity and produce renewable hydrogen. In general, on-site hydrogen production via electrolysis using renewable energy sources (mainly solar PV and wind power) has begun attracting the attention of city ports around the world (→ *see Markets and Infrastructure chapter*).

Several city ports have adopted decarbonisation targets and strategies that affect not only port activities but also the diverse industries often hosted by ports, including shipping, cruise tourism, heavy transport and power generation. In 2019, in partnership with the municipal government, the Port of Oslo (Norway) set a target for an 85% reduction in its greenhouse gas emissions by 2030, with the goal of eventually becoming the world's first zero-emission port. Strategies to achieve this include working with operators to electrify ferries and building shore power[i] connections that allow boats to cut their engines and plug in to the grid when docked.

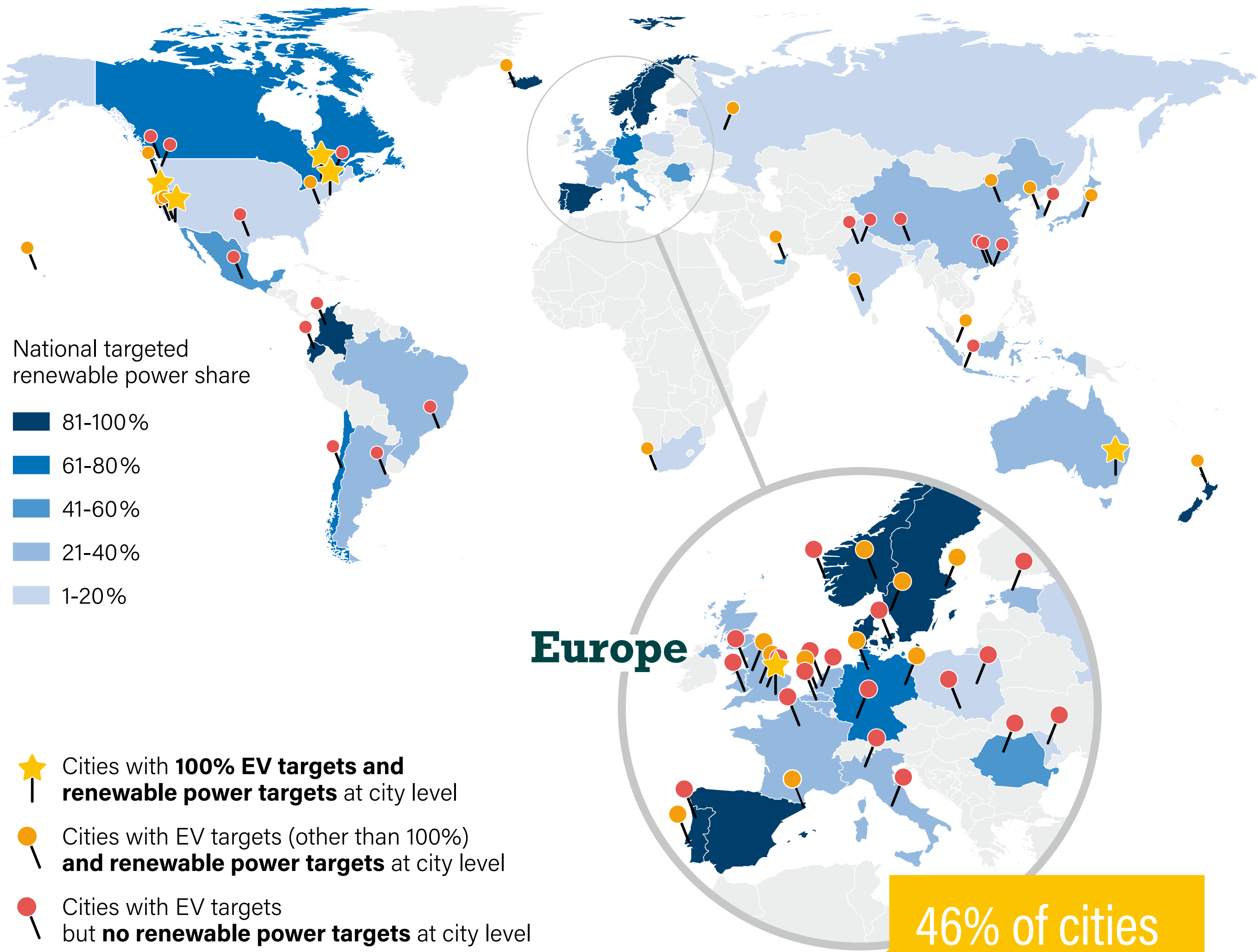
In 2020, the Port of Esbjerg (Denmark) and the Port of Rotterdam (Netherlands) announced plans to build on-site facilities to supply renewable power to ships. The first shore power supply plant at the Port of Kiel (Germany) has been in operation since 2019, supplying ferries with renewable electricity. In North America, the use of shore power is mandatory under state regulation at ports in California (US), including Los Angeles, Oakland, San Diego and San Francisco. Shore power connections also are available in Halifax (Nova Scotia, Canada), Seattle (Washington, US) and Vancouver (British Columbia, Canada). Starting in 2020, the Port of Houston became the first US port to agree to purchase renewable electricity for port-wide activities.

Source: See endnote 35 for this chapter.

Rotterdam, Netherlands

i Shore power is the process of providing electrical power from the shore to a ship while it is docked. The provision of shore power offers the potential to increase the use of renewable electricity when ships are at berth, depending on the share of renewables in the port's electricity mix. By the end of 2019, nearly 80 ports, three-quarters of them in Europe, had shore power capability.

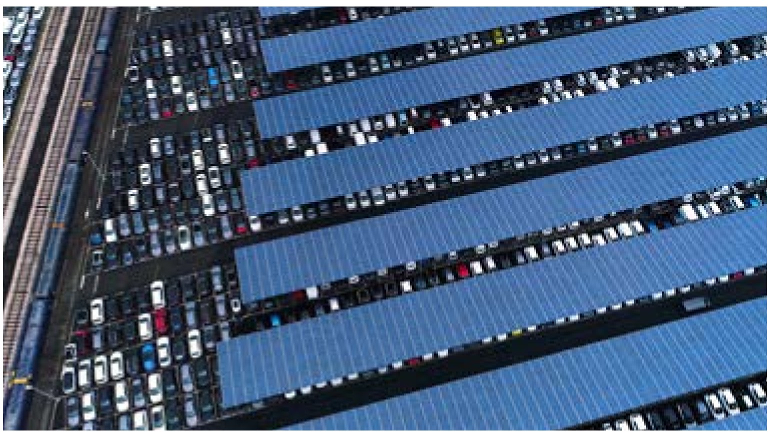
Figure 8. National Renewable Power and Electric Vehicle Targets in Cities, 2020



46% of cities with EV targets

also have a city-wide renewable electricity target.

Source: REN21 Policy Database and Reference Tables R2 and R3. See endnote 38 for this chapter.



Feletto Umberto, Italy

Some cities have committed to phasing out fossil fuel vehicles in certain fleets (typically public transport fleets such as buses and ferries) and to procuring only "carbon-neutral", "zero-emission" or "clean"[i] vehicles. In 2019, Turku (Finland) committed to 100% carbon-neutral public transport by 2029.[43] Hamburg (Germany) has pledged to procure only zero-emission buses from 2020.[44] Also in 2020, Singapore set a target to transition its entire bus fleet to clean energy by 2040, and Seoul (Republic of Korea) announced plans to phase out diesel vehicles in public fleets by 2025 and replace them with battery electric and hydrogen-powered vehicles.[45]

Targets for the use of **renewable hydrogen**[ii] in transport are not common[iii], but policy attention and interest in fuel cell vehicles are emerging in some cities, especially in East Asia, Australia, California (US) and Europe (although typically without requirements for renewable hydrogen).[46] In 2020, the municipal government of Zhangjiakou (Hebei Province, China) announced a target to have more than 2,000 fuel cell vehicles and 16 hydrogen refuelling stations in operation by 2022.[47] (→ *see Policies section in this chapter, and Markets and Infrastructure chapter.*)

Seoul, Republic of Korea

EMISSION REDUCTION AND NET-ZERO TARGETS

Several cities have adopted climate-related targets, focusing on reductions in carbon and/or broader greenhouse gas emissions. Although such targets do not necessarily specify a role for renewable energy, renewables are expected to be instrumental in efforts to achieve them, alongside promoting energy efficiency and other actions.[48] Globally, by the end of 2020, around 10,500 municipal governments, representing some 946 million inhabitants[iv], had committed to reducing their carbon emissions by a specific date; most of these cities are in Europe, but targets are emerging elsewhere as well.[49]

Momentum also has grown for the adoption of net-zero[v] commitments – achieving a balance between CO_2 emissions and removals. Overall, the number of net-zero targets in cities has increased roughly eight-fold from 2019 (even growing amid the COVID-19 crisis), and by the end of 2020 a total of 796 municipal governments in 63 countries had adopted such targets.[50] This means that around 700 million people (9% of the global population) live in a city with a net-zero target (excluding targets set at the state, national or other levels of government).[51] Net-zero targets are most prevalent in Europe and in Latin America and the Caribbean, followed by East Asia and the Pacific and North America.[52]

Some municipal governments are making net-zero pledges on their own, and many are joining networks of like-minded actors. For example, the Carbon Neutral Cities Alliance as well as 88 members of C40 Cities have signed on to Deadline 2020, committing them to being greenhouse gas emissions neutral and climate-resilient by 2050.[53] Municipal interest in becoming net-zero also was catalysed by the launch of the Climate Ambition Alliance at the United Nations Climate Conference in December 2019 and by the launch of Race to Zero[vi] in early 2020.[54]

It remains to be seen how municipal governments will implement their net-zero targets in their policy documents and specify a role for renewables. Of the 796 municipal governments with net-zero targets, 222 had passed a renewable energy target as of the end of 2020, either specified as part of their net-zero commitment or as an independent target (→ *see Figure 9 and* ***Reference Table R4***).[55] For example, Adelaide (Australia) plans to achieve net zero through a variety of energy efficiency measures as well as 100% renewable energy.[56]

i The terminology used in this chapter mimics the terminology that cities generally use in setting targets and policies to decarbonise transport. Different cities adopt different concepts, such as "carbon-neutral", "zero-emission" or "clean" vehicles, which typically refer to electric vehicles and are not necessarily linked with renewable energy.

ii Also referred to as green hydrogen. See Glossary for definition.

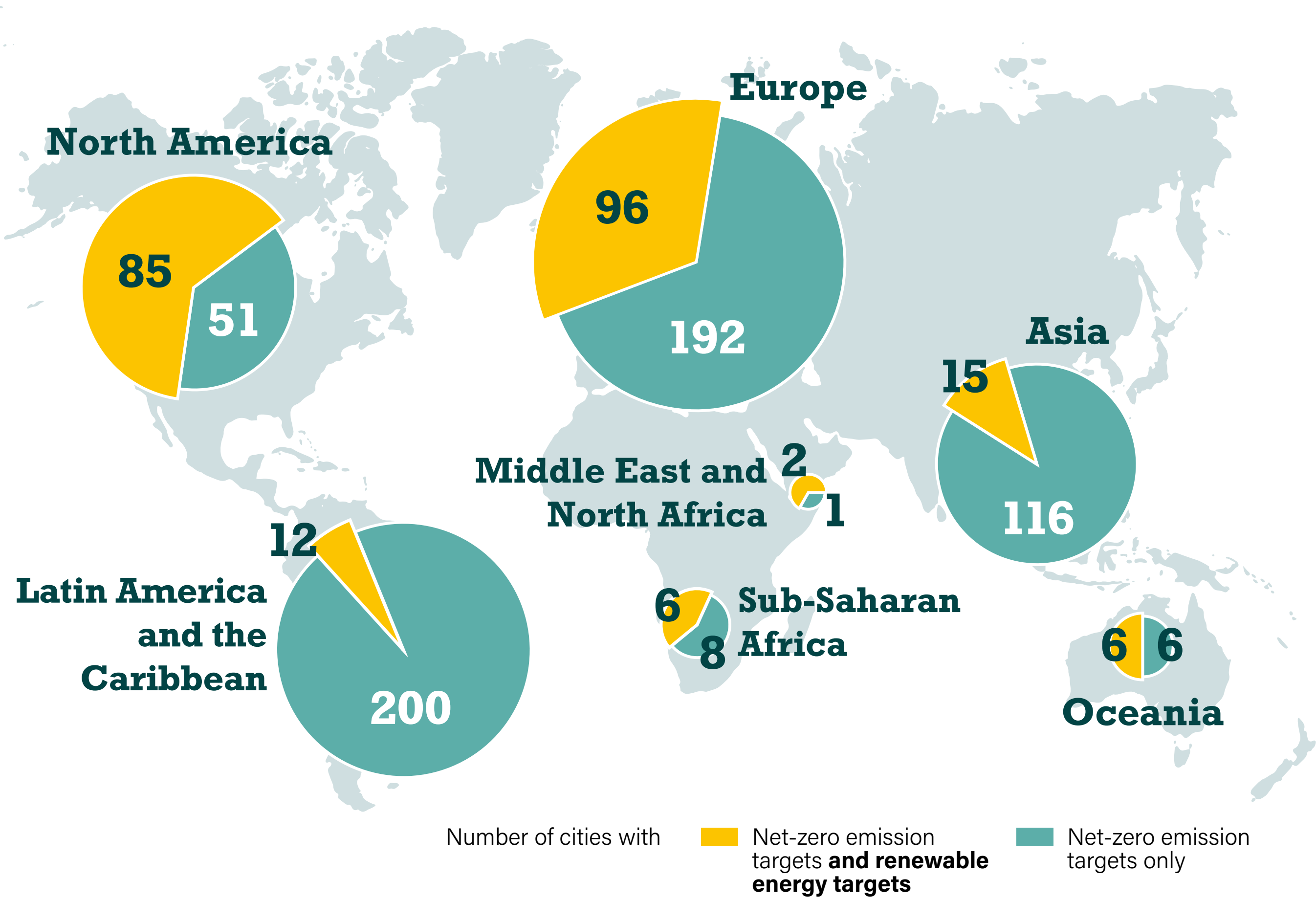
iii A few countries have targets for renewable hydrogen at the national level that could be complementary to city-level hydrogen targets. See REN21, *Renewables 2021 Global Status Report* (forthcoming).

iv As stipulated under the Global Covenant of Mayors for Climate & Energy.

v This can be achieved, for example, by using natural sinks, such as reforesting land or adopting agricultural best practices, or through a technological solution, such as carbon capture and storage. Net-zero targets also are referred to commonly as "climate-neutral", "carbon-neutral" or "zero-emission" targets, although technically these are not the same. Carbon neutrality refers to net-zero emissions of only CO_2, whereas climate neutrality indicates a broader focus on net-zero emissions of all greenhouse gases. There is no agreed-upon definition, and implementation of these targets also varies broadly. See endnote 48 for this chapter.

vi Race to Zero is mobilising a coalition of leading net-zero initiatives, bringing together businesses, cities, regions and investors to facilitate the shift to a decarbonised economy ahead of the 2021 United Nations Climate Change Conference. See https://racetozero.unfccc.int.

Figure 9. Net-Zero Emission Targets and Renewable Energy Targets in Cities, by Region, 2020



Source: REN21 Policy Database and Reference Table R4. See endnote 55 for this chapter.

As with renewable energy targets, net-zero targets vary in the scope of emissions covered (CO_2 only or also other greenhouse gas emissions), the scale of application (municipal only or city-wide) and the timeline.[57] While some cities, such as Adelaide (Australia) and Copenhagen (Denmark), aim to become net zero by 2025, most cities have targeted 2050, and others (including 21 of the 454 cities in Race to Zero) aim for various years before 2050.[58] As of 2020, only a few municipal governments (including 25 of the 454 cities in Race to Zero) had created action plans or binding legislation to achieve their net-zero targets.[59] Thus, how cities will implement and report on action in this area remains to be seen.

MUNICIPAL OPERATIONS

To achieve their renewable energy targets, municipal governments have adopted various policy measures to advance renewables in the power, heating and cooling, and transport sectors. Some cities have implemented policies to increase renewables across municipally owned operations (→ *see Markets and Infrastructure chapter* for more on renewable energy installations in cities and on the procurement of renewables in the buildings and transport sectors). Other municipal governments have used their role as policy makers and regulators to pass comprehensive (city-wide) policies to encourage the uptake of renewables among residents, businesses and other urban actors. (→ *see Policies section in this chapter*).

MUNICIPAL BUILDINGS

In jurisdictions where it is possible, municipal governments have increased their investments in renewables for their own-use in municipal buildings, whether through direct investment in on-site generation, procurement processes or strategic purchasing of renewable energy directly from third-party providers.[60]

Municipal governments have implemented policies to install renewable **power** capacity on or near municipally owned buildings such as city halls, sport facilities and schools. In Dublin (Ireland), the city council issued a contract in 2019 to equip seven sports centres with solar PV, saving EUR 129,000 (around USD 158,400) in energy costs and reducing 321 tonnes of carbon emissions annually.[61]

In some cases, cities have installed renewable power specifically to boost their resilience and energy security, particularly during extreme weather events.[62] In 2020, Portland (Oregon, US) installed a solar PV system with battery storage at its main fire station to provide sustained, reliable power in the event of prolonged grid outages.[63] Adelaide (Australia) completed a 12 MW ground-mounted solar PV project at its main drinking water pumping station in 2020 as part of its plan to meet its electricity needs with 100% renewables.[64] Boston and Los Angeles (both US) as well as Quezon City (Philippines) have begun incorporating renewable energy infrastructure directly into their resilience planning.[65]

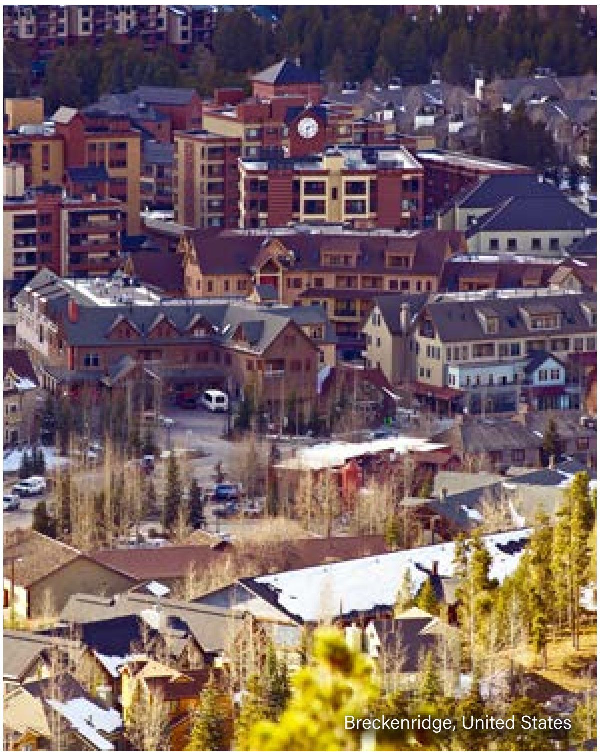
For municipal governments that face constraints to installing renewables within city limits (such as high land costs or land scarcity), among the only ways to achieve renewable energy targets are to increase their procurement of renewable electricity or to partner with third-party operators to develop projects outside of city boundaries. Municipal procurement of renewables has spread rapidly in cities around the world, including Chennai (India), Karak (Jordan), Pico Truncado (Argentina) and Windhoek (Namibia).[66]

Between 2015 and mid-2020, cities in the United States supported a total of 433 renewable power procurement deals for a combined 9,188 GW of capacity.[67] Partly as a result of these arrangements, the total renewable energy capacity installed annually in US cities nearly tripled from 1,042 MW in 2017 to 2,716 MW in 2019.[68] Most of these deals consisted of community solar initiatives and power purchase agreements signed with developers beyond city borders, although they also included efforts to procure renewable power directly for municipal operations (such as projects sited at municipal buildings).[69]

Officials in Breckenridge (Colorado, US) explored several options to develop or procure as much renewable energy as possible within the city to achieve its goal of 100% renewable electricity in municipal use by 2025.[70] However, developing projects within city limits was deemed uneconomical due to the high cost of land, and it was more financially attractive to purchase power from off-site "solar gardens" (community solar projects) in surrounding areas.[71] Upon completion of these projects, Breckenridge will have met its 100% goal five years early.[72]

Municipal governments have increased their investments in renewables for municipal buildings.

Quezon City, Philippines



Breckenridge, United States

Compared to the power sector, policies to increase the share of renewables directly in the **heating and cooling** of municipal operations are less widespread, due to the decentralised character of this demand and the limited awareness of available options. However, the importance of heating and cooling has moved up the policy agenda in some areas, notably among local energy suppliers and at the EU level.[73] To reduce CO_2 emissions and improve air quality, the municipal government of Gdynia (Poland) has called for replacing solid fuel stoves with renewable energy sources (or gas boilers) in all municipally owned buildings by 2023.[74] Some municipal governments also have implemented bans and restrictions on fossil fuels for city-owned buildings. For example, the new public hospital in Canberra (Australia) will ban the use of natural gas and be powered 100% by renewables.[75]

Increasingly, municipal governments are facilitating the integration of renewables into their district energy networks, often in co-operation with public or private partners. In Temuco (Chile), the municipal government is developing district heating infrastructure (using biomass) through public-private financing and with the support of the National District Energy Office.[76]

Most public procurement of **zero-emission vehicles** focuses on electric vehicles.

MUNICIPAL TRANSPORT

City governments have made strides to decarbonise transport fleets and mobility infrastructure to improve local air pollution and mitigate other impacts of urbanisation such as congestion and noise.[77] In most cases, cities rely on public procurement or direct investment to source renewable fuels for public and municipal fleets, to replace internal combustion engine vehicles with electric vehicles that can be renewably powered, and/or to build associated infrastructure.

Although most **biofuel** policies are enacted at the national or regional levels, some cities have sought to increase the use of biofuels in public fleets.[78] Santa Barbara (California, US), stimulated by state and national mandates and building on its local feedstocks, announced in 2019 that it would replace petroleum diesel with biodiesel to fuel its municipal bus fleet.[79] Also in 2019, Longmont (Colorado, US) started sourcing locally produced biogas to fuel new refuse trucks.[80] In 2020, the Liverpool City Council (UK) commissioned a fleet of 20 refuse trucks that run on biogas.[81]

Still, most public procurement of zero-emission vehicles focuses on **electric vehicles**, with electric buses garnering the most attention from city governments worldwide. Although Chinese cities continued to dominate the global electric bus market during 2019 and 2020, interest in electrified bus transport also expanded to cities in North America, Latin America, Europe and elsewhere.[82]

Policies that promote electric vehicles are not in themselves renewable energy policies; however, they provide a critical entry point for higher uptake of renewables in transport, especially if combined with renewable electricity policies set by municipal, state and/or national governments.[83] A few cities require the use of renewables to charge electric buses: in 2019, São Paulo (Brazil) integrated 15 electric buses into its fleet that must be


China

charged using solar power, and new electric buses in Portland (Oregon, US) will be 100% wind-powered as part of the city's aim for a non-diesel fleet by 2040.[84]

Electric vehicles also are being procured for municipal delivery and refuse fleets, including in cities bound by renewable energy targets and policies.[85] In 2020, Leeds City Council (UK) took delivery of 122 electric vans to be used for services ranging from property maintenance to civil enforcement.[86] That same year, several cities started testing and integrating electric refuse trucks in their municipal fleets – including Blue Mountains (New South Wales, Australia) and Jersey City and New York City (both US).[87]

In some cases, EV procurement programmes are the result of public authorities increasingly adopting related purchasing obligations.[88] For example, the Supreme Council of Energy of Dubai (United Arab Emirates) has directed government organisations to increase the share of electric and hybrid vehicles they procure annually to at least 10% by the end of 2024, 20% by the end of 2029 and 30% from 2030 onwards.[89] Under Dubai's Clean Energy Strategy, in force since 2015, the share of renewable electricity used to charge EVs is targeted to grow from 7% in 2020 to 25% in 2030 and 75% by 2050.[90]

Several cities in East Asia, particularly in China, have procured **hydrogen** fuel cell buses. However, since nearly all of the hydrogen produced globally today is based on fossil fuels, only a few of the buses operate on hydrogen produced with renewable electricity.[91] In 2019, Zhangjiakou (Hebei Province, China) added 174 fuel cell electric buses to its expanding hydrogen fleet, which is fuelled with renewable hydrogen.[92] The municipality of Aalborg (Denmark) purchased three fuel cell buses that begun circulating in 2020 and rely on renewable hydrogen.[93]

Oregon, United States

Tigard, Oregon, United States

CITY-WIDE POLICIES

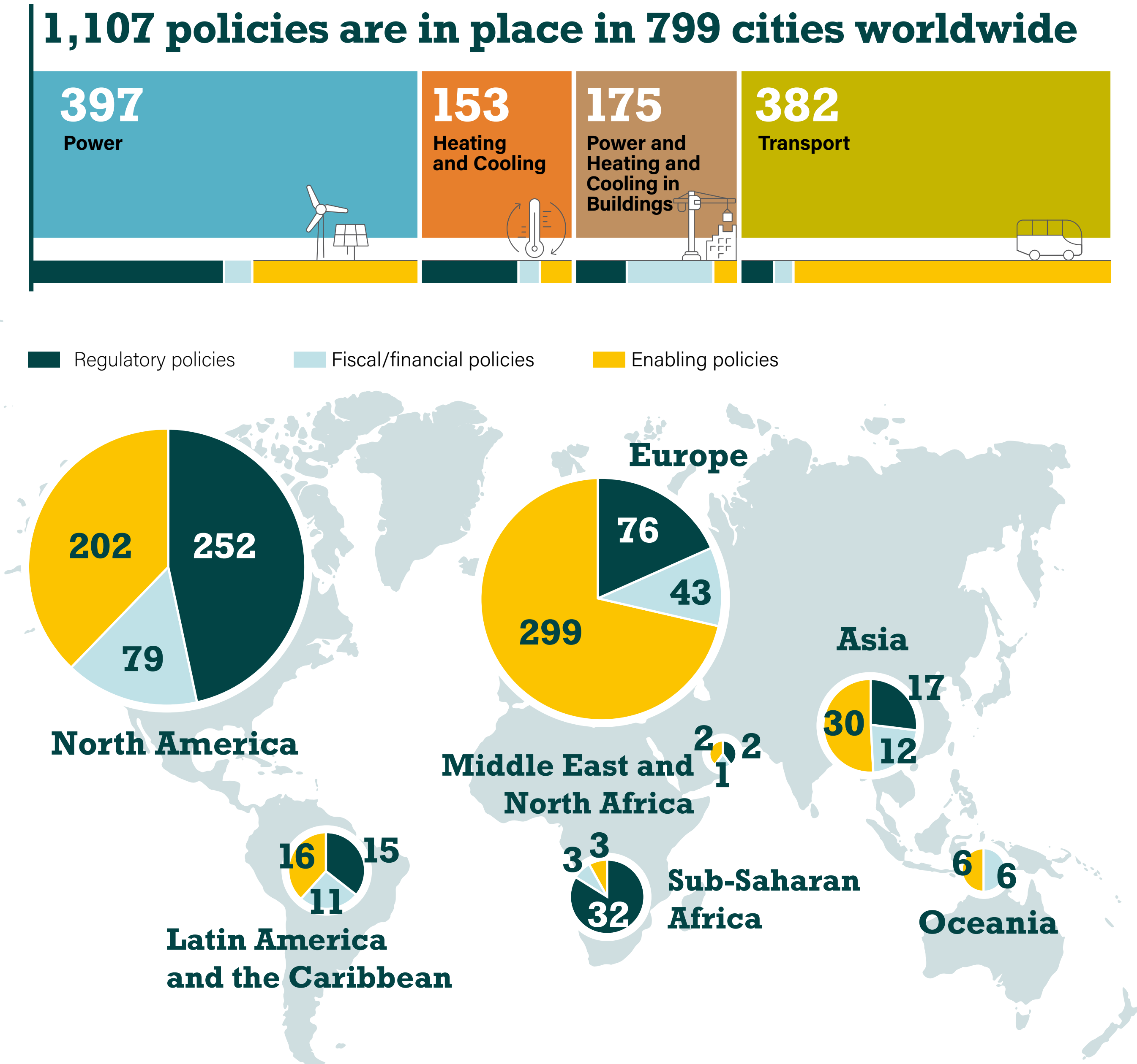
At least
799 municipal governments
had in place renewable energy policies.

Municipal operations often account for only a small portion of urban energy use. Thus, the success of cities in meeting their energy and climate goals relies not only on municipal investments in city facilities and fleets, but also on the decisions made by citizens, businesses and other urban actors regarding how to heat and cool their buildings, move around goods and people, and power their lights, appliances and activities.

To encourage the uptake of renewables city-wide, municipal governments have adopted a range of comprehensive policies.[94] By the end of 2020, at least 799 municipal governments had in place either renewable energy policies or policies supporting the scale-up of renewables across buildings and transport (for a combined total of 1,107 policies, with some cities having more than one policy).[95] These included regulatory policies (394 policies), fiscal and financial incentives (155 policies) and indirect policies that support the overall enabling environment for renewables (558 policies).[96] Most of the cities with policies were in the United States (532 policies) and Europe (418 policies), followed by Asia and Latin America and the Caribbean (→ *see Figure 10 and* ***Reference Table R5***).[97]

2

Figure 10. Renewable Energy Policies in Cities, by Type and Region, 2020



Source: REN21 Policy Database and Reference Table R5. See endnote 97 for this chapter.

Note: Some city governments have more than one renewable energy policy. Policies in buildings apply in the buildings sector and can include power, heating and cooling and/or transport elements.

City-level policy portfolios have expanded beyond power to sectors that are lagging at the national level.

The most successful city-level efforts have made use of different policy approaches in creative and synergistic ways. For example, a wide variety of city-led solar gardens (community solar projects) are starting to emerge around the world, creating new ways for the city government to partner with local citizens and businesses on accelerating the urban energy transition. Local governments are engaging either by investing the city's own resources or by making available municipal land for the development of local solar power projects. By doing so, the city government, individual citizens, as well as local businesses can purchase a portion of the project's output to meet all or part of their electricity needs.

Other city policies encourage investments in EV charging infrastructure, including by making it easier to lease municipal land to build charging stations. In turn, this infrastructure can help meet the growing charging needs of both municipal fleets and the wider community. In addition, some municipal governments are using renewable technologies specifically to alleviate energy poverty at the household level (→ *see Box 2*).[98]

Such policies have a direct impact on the adoption of renewable energy technologies and help expand the market. In turn, in jurisdictions with higher annual installations and more market activity, installers tend to find more ways to improve installation times and reduce overall costs to stay competitive.[99] Such reductions in "soft costs"[i] can bring down overall costs for end-users, helping to increase demand.[100]

i Soft costs consist of all non-hardware costs associated with renewable energy development, including permitting, installation, customer acquisition and supply chain costs. In the United States, soft costs make up an estimated 64% of the cost of a solar PV system. See US Department of Energy, Office of Energy Efficiency and Renewable Energy, "Soft costs 101: The key to achieving cheaper solar energy", https://www.energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy, updated 25 February 2016.

BOX 2. Municipal Policies Using Renewables to Reduce Energy Poverty

A growing number of cities have recognised the potential of renewable energy technologies to alleviate energy poverty[i]. In developing countries, renewable energy can help improve access to modern energy services, while in developed countries it can reduce the share of urban household energy spending, including for electricity, heating and cooling, and transport fuels.

A few cities have developed policy strategies to deploy solar systems to fight energy poverty. In major urban and peri-urban areas in Sub-Saharan Africa, such as Arusha (Tanzania) and Lagos (Nigeria), solar home systems – small solar arrays connected to a battery bank – have driven access to direct, local renewable energy supply. In Seoul (Republic of Korea), solar PV systems have been deployed on low-income housing as part of the city's target to install more than 1 million individual solar PV systems on city rooftops (including all government buildings) by 2022. Solar PV systems also have been installed on low-income housing in a growing number of US cities, including on senior housing as a means to reduce monthly energy costs for residents.

Such projects can be supported by municipal financial incentives. For example, in Honolulu (Hawaii, US), the municipal government provides loans for low-income homeowners to install solar water heating systems. In 2017, the municipality of Porto Torres (Italy) created a revolving fund of EUR 250,000 (USD 307,061) to support rooftop solar installations for families in need.

In some cases, municipal governments have partnered with energy suppliers to alleviate energy poverty. Vienna (Austria) has worked with the country's largest energy provider, Wien Energie, to safeguard the supply of energy to people in precarious living situations – for example, by cancelling so-called dunning costs[ii] and interest. In Spain, Martorelles and other municipalities have collaborated with Som Energi, a green energy co-operative, to cover the electricity bills of households in need. Hackney (UK) is implementing a Green Homes programme through the publicly owned energy company Hackney Light and Power that provides free insulation and trials renewable heating upgrades to help residents save on energy bills while reducing greenhouse gas emissions. Also in the UK, the Mayor of London and Octopus Energy formed London Energy in 2019, a renewable energy company that aims to fight the fuel poverty affecting 1 million Londoners.

Source: See endnote 98 for this chapter.

Maloti hills, Lesotho

i See Glossary for definition.

ii Dunning involves any communication between the utility and the customer such as phone calls or letters to ensure the collection of payment on outstanding invoices. Dunning costs refer to any additional expenses associated with this process.

CITY-WIDE BUILDINGS

In the buildings sector, some municipal governments differentiate their policy approaches between new and existing buildings, as well as by building type (residential, commercial, industrial, public).[101] Especially in regions with high rates of urbanisation and population growth, such as Sub-Saharan Africa and parts of Asia, the distinction between new and existing buildings can be critical, as much of the building stock that is projected to be in place in 2050 has not yet been built.[102] Even in Vancouver (Canada), 40% of the floor space expected to exist in 2050 has yet to be built, underscoring the importance of policies and regulations specifically for new construction, such as the introduction of more stringent energy performance standards and renewable energy mandates for such construction.[103]

Large swaths of Europe and North America are home to structures built before the introduction of energy performance standards or energy-related building codes. In Europe, the rate at which new construction is added relative to existing construction is only 1-2%.[104] For regions with slow building replacement rates, the focus on retrofitting initiatives has grown, often with dedicated funding support from other levels of government, such as the EU's recent renovation wave[i].[105]

However, developing and implementing policies for existing buildings has faced resistance, fuelled by factors such as high upfront costs, inertia and split incentives due to the ownership structure of buildings. Rather than using mandates, municipal governments often offer financial incentives such as grants, rebates and low-interest loans to encourage changes to existing structures. In Paris (France), regulations banning the installation of oil-based heating systems as of 2022 are limited to new buildings, whereas grants are being used to encourage the substitution of existing heating systems with cleaner and renewable options.[106]

In the buildings sector, by the end of 2020, around 150 cities had a total of around 180 policies aimed at decarbonising buildings through renewable power and/or renewable heating (typically for solar PV and solar thermal). In addition, some of the around 400 policies aimed exclusively at the electricity sector and some of the around 150 policies focused on heating and cooling more broadly also apply to buildings.[107] That said, electricity accounts for most cooling needs, as well as for a growing share of heating needs and for a small but growing share of transport needs.[108] This highlights the importance of cross-sectoral and integrated policy making, which some municipal governments have started to pursue as part of efforts to scale up renewables. In addition, municipal governments are taking advantage of synergies between energy efficiency and renewable energy by improving the efficiency of energy use in urban infrastructure (→ *see Sidebar 3*).[109]

i The EU's "renovation wave" strategy focuses in large part on the need to improve, retrofit and decarbonise existing buildings. See European Commission, "Renovation wave", https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en, updated 18 January 2021.

Helsinki, Finland

Around
150 cities
have policies in place to support both renewables-based power and heating in buildings.

SIDEBAR 3. Linking Renewable Energy and Energy Efficiency in Buildings

Energy efficiency is fundamental to achieving higher shares of renewable energy in a timely and cost-effective manner. All things equal, energy efficiency reduces the amount of energy required to deliver a product or service. It offers benefits including energy security and improved economic performance and competitiveness. As such, cities increasingly are linking energy efficiency and renewable energy efforts in buildings.

Higher efficiency in urban buildings can make renewable energy technologies – such as renewable heating and cooling systems – more cost-effective compared to fossil fuel options. The US cities of Boulder (Colorado), New York City and Washington, D.C. have partnered with manufacturers, distributors, utilities and government agencies to decarbonise heating and cooling systems in buildings by supporting the installation of high-efficiency heat pumps that are increasingly powered by renewable electricity sources.

Cities – in their roles as energy consumers, managers of energy networks and potential energy producers – are uniquely positioned to harness the synergies between renewable energy and energy efficiency to curb energy use and related emissions from buildings. In 2020, three Albanian cities – Georgios Karaiskakis, Nikolaos Skoufa and Vlora – participated in a demonstration project to reduce energy consumption and CO_2 emissions from schools and other public buildings, using a combination of smart building, energy efficiency and renewable energy technologies to improve heating and cooling.

To stimulate such projects, municipal governments have implemented policy tools including building energy codes and standards, local ordinances, and combined targets for energy efficiency and renewable energy. Building codes[i] for energy efficiency typically are enacted at the national level, and as of 2019 some 73 countries had in place mandatory or voluntary building energy codes, with 4 more countries developing them for 2021 onward. However, national building codes for energy efficiency often are insufficient (either because they are outdated, voluntary or lack enforcement).

In some cases, municipal governments can adopt stricter "reach" codes or requirements that strive to achieve a standard of energy performance above and beyond the minimum set at the state or national level for new municipal, residential and/or commercial buildings. Since 2012, Stockholm (Sweden) has allowed a maximum of 55 kilowatt-hours (kWh) per square metre (m^2) of energy consumption (including electricity and heating and cooling) for new buildings on municipally allocated land, with a view to reduce this to 45 kWh per m^2. As a result, energy use by the city's new buildings is on average 30% below the values set at the national level.

Some jurisdictions have leveraged their building energy codes to require on-site or off-site renewable energy generation in combination with energy efficiency. In California (US), the city councils of San Jose and Palo Alto approved new reach codes in 2019 mandating that new construction be electric-only (meaning that it does not include natural gas to meet on-site cooking or heating and cooling needs) and that it integrates solar readiness[ii] and energy efficiency. San Francisco has mandated that all commercial buildings over 50,000 square feet (4,645 m^2) be powered with renewable electricity by 2030. This policy, combined with a new reach code for all-electric new construction, will ensure that these buildings are 100% renewables-based for power, heating and cooling.

As of 2020, 475[iii] local governments within the CDP-ICLEI Unified Reporting System had set or planned energy efficiency targets to reduce energy and/or electricity demand, as a means to cut greenhouse gas emissions and energy imports or to trim budgets. Of the 200 local governments that had in place energy efficiency targets, at least 150 also had a renewable energy target, another 16 had a target in progress, and 13 were planning to enact a target in the next two years. For example, Leuven (Belgium) has linked its efficiency and renewables targets, aiming for 60% of the existing building stock to reduce energy use to the "lowest possible level" through retrofits, and the remaining 40% to reduce energy use and also to shift to renewable energy.

Source: See endnote 109 for this chapter.


Stockholm, Sweden

i Building energy codes are integral in setting construction standards to reduce the long-term energy demand of buildings.

ii Solar readiness refers to a requirement that new buildings include the wiring required to facilitate the addition of a solar PV system in the future.

iii Of the 812 local governments reporting to the CDP-ICLEI Unified Reporting System in 2020, 185 indicated that they already had an energy efficiency target in place, another 110 had a target in progress, and 93 were planning to enact a target in the next two years.

CITY-WIDE POWER

Regulatory policies

While many cities benefit from renewable energy regulatory policies introduced at other levels of government – such as state or national feed-in tariffs or feed-in premiums – around 190 cities had in place their own regulatory policies for renewable power capacity by the end of 2020, particularly in North America.[110] In addition, some cities also have regulatory policies to support either renewable power and/or heating and cooling in buildings more broadly.

Municipal-level **feed-in tariffs** (FITs) are present in numerous cities, including Canberra (Australia), Fukushima (Japan), Gainesville (Florida, US), Harare (Zimbabwe), Hong Kong (China), Rajkot (India) and Recoleta (Chile).[111] In South Africa, 28 municipalities have in place either net FIT or net billing policies that define the price that (typically) municipal utilities must pay for buying or compensating surplus electricity from solar PV systems in the city (→ *see Feature chapter*); this has been driven by efforts to reduce reliance on predominantly coal-fired generation from the national utility.[112] Similar mandates requiring municipal utilities to purchase power from citizens and local businesses exist in Dubai (United Arab Emirates), Los Angeles (US) and cities throughout Australia.[113]

Several municipal governments have adopted **net metering**[i] policies, which enable electricity customers to supply their own power on-site and then export any surplus generation to the grid in exchange for a one-to-one credit on their bill for every surplus kWh produced.[114] Although most net metering policies worldwide have been adopted at the national or state levels, municipal-level policies are gaining ground, mainly in the United States (including in San Antonio, Texas).[115] Although net metering has come under pressure at all levels in recent years, some municipal governments reaffirmed their policies. The city council of Springfield (Illinois, US) voted in early 2020 to continue net metering, rejecting the municipal utility's proposal to lower the compensation rate for surplus electricity.[116]

A growing number of utilities (including municipal utilities) have started to tighten the rules, offering customers with solar PV systems a separate compensation rate for their net surplus generation that is below the retail rate and that is often linked either directly or indirectly to market prices or to the utility's avoided costs[ii] (as in San Antonio).[117] In other instances, the compensation rate differs depending on whether the solar system is owned by a residential or a commercial customer. Georgetown (Texas, US) offers residential customers one-to-one net metering at the retail rate, whereas commercial customers are compensated at the lower avoided fuel cost rate.[118]

Some municipal regulations are specific only to new construction – or are more stringent for new construction than for existing buildings – allowing municipalities to raise the bar for all future construction city-wide. A growing number of cities have introduced **building codes and/or ordinances** specifically requiring solar PV on new construction (some also require either solar PV and/or solar thermal). Such mandates typically apply to buildings above a certain size (in square metres of total building footprint) or, in the case of the residential sector, to buildings above a certain number of storeys[iii].[119]

In 2014, Davis (California, US) adopted an ordinance requiring solar PV on all new single-family construction; in 2019, it expanded the ruling to require all non-residential construction to feature solar PV systems large enough to supply 80% of the electricity used on-site, or to integrate a certain amount of solar capacity per square metre of suitable roof space[iv].[120] In Sacramento (California, US), all new residential buildings are required as of 2020 to meet their on-site needs with solar PV, either through the installation of on-site systems or by buying into the local utility's "solar shares" programme, which enables households to own shares in larger community solar projects located outside of the city.[121]

In India, the municipal government of Karimnagar passed a regulation in 2019 making it mandatory for new buildings to install rooftop solar PV if the building area exceeds 2,700 square feet (251 m^2).[122] The city offers end-users a 30% subsidy for such installations, and the buildings connect to the grid via a net metering mechanism.[123] Rajkot (India) also has a mandate requiring solar PV rooftop systems on new buildings (→ *see City Snapshot: Rajkot*).[124] In Lahore (Pakistan), the local development authority adopted a regulation in 2019 mandating new commercial buildings to install rooftop solar PV systems to cover at least 20% of a building's total power requirement.[125] In Germany, the municipal government of Amberg passed a mandate in 2019 requiring solar PV in future developments, and similar mandates exist in Freiburg, Hamburg, Heidelberg, Konstanz and Waiblingen (→ *see City Snapshot: Heidelberg*)[v].[126]


India

i See Glossary for definition.

ii There are many different ways of determining a utility's avoided costs, with varying outcomes depending on the methodology employed.

iii Such mandates also exist at the national level such as in France as well as at the state level in countries such as Australia and the United States. However, efforts to introduce state-level mandates have encountered push back, leading to a search for local solutions. For instance, after lawmakers in California (US) introduced a solar mandate on all new construction that was scheduled to begin in 2020, challenges to the mandate led some city governments and local utilities to develop their own policies.

iv In Davis, California, the regulations stipulate 161 watts (direct current) per square metre of rooftop area that is deemed suitable for the installation of solar PV.

v See City Snapshot: Heidelberg online at www.ren21.net/cities

RAJKOT

INDIA

Land area (km²/2015)
129.2

Population size (2018)
1.8 million

GHG

Greenhouse gas emissions (CO_2 equivalent)
1,887,684 tonnes

Rajkot, the fourth largest city in the western Indian state of Gujarat, has committed to reducing its greenhouse gas emissions 14% by 2022-23 (from 2015-16 levels). Energy consumption in residential buildings totalled 606 million kWh in 2015-16, accounting for around half of all electricity consumption and contributing 35% of greenhouse gas emissions from economy-wide activities in the city. Recent efforts have focused on reducing energy consumption and enhancing energy efficiency in residential buildings. The Capacity Building for Low Carbon and Climate Resilient City Development project (CapaCITIES) has helped maximise the use of renewables in the city, reducing the need to tap into the predominantly coal-based national grid.

The Krantiveer Khudiram Bose social housing complex (known as 11A) consists of five buildings with a total of 140 dwelling units. At full occupancy, common amenities (lifts, lights, pumps, etc.) consume 3,000 kWh of electricity per month. To encourage the adoption of solar PV, a 31.5 kW-peak grid-connected solar PV system is being installed on-site and will be operated and maintained by the contractor/developer for a period of 10 years. The system consists of 100 polycrystalline solar PV panels of 315 watt-peak capacity each, mounted on a frame at a 21-degree panel tilt. It will generate around 3,780 units of electricity per month (45,360 kWh per year) and has the potential to reduce 37 tonnes of CO_2-equivalent greenhouse gas emissions annually. Overall responsibility for the safety, security and periodic cleaning of the panels will lie with the township's Residential Welfare Association, which has been trained on panel maintenance.

Because of its efforts in low-carbon action and community engagement, Rajkot Smart City was selected as the national winner of WWF's Global One Planet City Challenge in 2020. Other noteworthy initiatives in Rajkot that support this award include: the installation of 9,629 kWh of grid-connected solar PV systems on residential buildings (with a further proposed 500 kWh on municipal buildings); retrofitting of 63,178 public street lights with light-emitting diodes (LEDs), resulting in annual energy savings of 11.5 million kWh; the implementation of Smart Ghar III, an affordable green home concept aimed at maintaining indoor thermal comfort with minimal climate impact; and plans to replace diesel buses with electric ones, along with the provision of solar PV charging.

Source: See endnote 124 for this chapter.


India

Some municipal governments have developed building energy codes with performance standards that aim to achieve higher energy efficiency levels and support the adoption of renewable technologies. As of mid-2020, at least 35 cities in California (US) had adopted building codes specifically to reduce their reliance on natural gas in new construction (→ *see Overall enabling environment section*).[127] In some cases, the code is coupled with a renewable energy requirement: for example, Richmond (California) requires new residential buildings under three storeys to be all-electric, and new residential buildings of any size must install a minimum amount of on-site solar (thermal or PV)[i] (→ *see Sidebar 4*).[128] By October 2020, roughly 10% of California's population was living in a city that had building codes requiring solar readiness and/or EV charging readiness (the wiring required to enable the rapid addition of solar PV or EV charging) or the addition of solar PV or solar thermal (→ *see also City-level Transport section*).[129]

Fiscal and financial incentives

Globally, municipal governments were providing fiscal and/or financial incentives such as rebates and grants, low-interest loans, and tax credits and deductions to increase renewable power.[130] Generally, these support mechanisms do not differentiate between new and existing buildings.

Municipal governments offer **investment subsidies** such as **rebates and grants** to encourage the installation of renewable power capacity. For example, the municipal utility serving San Antonio (Texas, US) offers residential rebates of USD 2,500 per solar installation, as well as commercial rebates of 60 US cents per watt (for systems up to 25 kW) and 40 US cents per watt (for systems above 25 kW).[131] Philadelphia (Pennsylvania, US) provides rebates totalling up to USD 500,000 per fiscal year to commercial and residential solar PV installations completed after 1 July 2019.[132]

In 2020, Beijing, Guangzhou, Shanghai and Xian (all China) announced financial support policies for distributed solar PV through 2025, providing a subsidy per kWh produced.[133] In Gdynia (Poland), the municipal government provides one-off subsidies for renewable electricity production that uses solar PV and micro power plants, offering PLN 2,500 (around USD 674) for single-family buildings and PLN 5,000 (over USD 1,348) for multi-family buildings.[134] In Freiburg (Germany), where a subsidy to fund new energy storage systems went into force in 2019, the city provides EUR 150 (USD 184) per kWh of storage capacity (provided the solar PV system has at least 1.25 kW of output per kWh of storage capacity).[135] Similar municipal support for customer-sited solar PV exists in Berlin, Braunschweig, Jena, Stuttgart and Wallenhorst (all Germany), Los Angeles and San Francisco (both US), Tokyo (Japan) and Vienna (Austria).[136]

Some municipal governments provide direct investments in the community for the installation of renewables (→ *see City Snapshot: Seoul*).[137] As part of Australia's efforts to help communities recover from the devastating wildfires of 2019, several local municipalities in Victoria state dedicated recovery and reconstruction funds specifically for renewable energy and storage projects.[138] The initiative will fund the installation of roughly 50 solar PV systems (of 6.5 kW each) at not-for-profit community organisations in several cities and towns, including at schools, emergency service buildings, sporting clubs and community centres that need to be rebuilt.[139]

Municipal governments are providing fiscal and/ or financial incentives to increase renewable power.

i The minimum required share of energy provided by solar PV or solar thermal systems is calculated based on the total square footing of the building.

SEOUL

REPUBLIC OF KOREA

Land area (km²)
605

Population size (2020)
9.9 million

GHG

Greenhouse gas emissions (CO_2 equivalent)
46,685,000 tonnes

In July 2020, Seoul, the capital of the Republic of Korea, responded to the country's commitment to achieve climate neutrality by 2050 by developing an integrated policy approach focused on five key areas: buildings, mobility, forestry, clean energy and waste management. Seoul's vision is to be a sustainable city where "human, nature and future co-exist".

The Republic of Korea's policy approach towards climate neutrality mirrors the EU's Green Deal to achieve net-zero emissions and respond to climate change. By 2025, the Korean government will invest around USD 37 billion in Green New Deal policies and a further USD 7 billion in carbon-cutting measures. Seoul has put forward two intermediate goals ahead of the 2050 climate-neutrality goal: to achieve 40% emission reduction by 2030 and 70% emission reduction by 2040 (compared to 2005 levels).

Since 2012, Seoul has adopted policies to reduce its dependency on nuclear energy through two phases of the One Less Nuclear Power Plant Project. In 2017, Solar City Seoul was launched with the goal of adding 1 GW-peak of solar power capacity by supplying PV panels to 1 million households by 2022. The programme, which has a budget of around USD 1.46 billion (funded mostly by public investment), aims to reduce CO_2 emissions by 544,000 tonnes annually and to add 4,500 new jobs by 2022. The programme exceeded its intermediate goal by installing a total of 357.1 MW of solar panels for 285,000 households by 2019.

One of the challenges facing the Solar City Seoul programme is securing enough space at buildings and public facilities to install solar panels. As part of the green energy initiative of the Seoul 2050 climate neutrality plan, Seoul is identifying new installation sites (including urban infrastructure); increasing the standards for solar generation in zero-energy buildings; providing subsidies for building-integrated PV; extending the feed-in tariff system to on-site solar power generators and supporting new solar PV technology.

Source: See endnote 137 for this chapter.

In an innovative policy that focuses on adjusting the electricity rates that customers *pay*, rather than the payment levels they *receive* when exporting their net surplus generation, Newstead (Australia) has set out, in partnership with the local utility, to introduce "solar sponge" tariffs that offer much lower rates to customers during the daytime hours when solar power is abundant.[140] The reduced tariffs are available to all customers that have suitable metering infrastructure, in particular meters that support time-of-use tariff structures.[141] The regional distributor, South Australia Power Networks, started offering the solar sponge tariffs in July 2020, in part to help stabilise the grid during the daytime surge in solar power and to mitigate challenges associated with the "duck curve"[i].[142]

Some municipal governments offer

tax credits and deductions

for producing on-site renewable electricity.

Low-interest loans have remained an important tool for municipal governments. In Milwaukee (Wisconsin, US), the city partnered with a local credit union to offer low-interest loans of up to USD 20,000 for homeowners to finance rooftop solar PV; similar incentives exist for households in Boulder (Colorado, US) and Honolulu (Hawaii, US) and for commercial and non-profit entities in Baltimore (Maryland, US).[143] Since 2018, the municipal bank of Godoy Cruz (Argentina) has provided citizens low-interest loans to finance solar PV systems, and the municipality facilitates approvals and installation.[144]

An increasingly popular financial tool is Property Assessed Clean Energy (PACE) financing, which enables citizens and businesses to repay their solar loans to the municipality through an annual surcharge on the yearly property tax assessment. As of 2020, PACE programmes were available in at least 62 US cities and were starting to be deployed across Europe, including in Olot (Spain) and with plans under way in cities in Austria, Belgium, Italy, Poland and Romania.[145] Frisco (Texas, US), a local PACE administrator, partnered with national banks and the municipality in 2019 to provide long-term, low-interest loans to finance renewable energy projects in the community.[146]

Some municipal governments offer **tax credits and deductions** for producing on-site renewable electricity. Rio de Janeiro (Brazil) passed a tax exemption in 2020 for renewable power produced by distributed generation projects.[147] In Salvador (Brazil), the municipal government offers property tax discounts for installing solar PV; the system must correspond to a minimum percentage consumed by the property.[148] A solar rebate programme in Boulder (Colorado, US), launched in 2019, offers a sales and use tax rebate of around 15% on qualifying solar PV and solar thermal installations.[149] Municipal tax exemptions also are available in US cities such as Chicago, New York and Washington, D.C.[150]

Overall enabling environment

In addition to enacting direct policy measures for renewables, municipal governments are putting in place indirect support policies and improving their permitting and administrative procedures for renewable power projects developed within city limits.[151]

Even residents with sufficient disposable income to invest in on-site renewable power projects may be held back by a lack of suitable roof space, as many live in multi-unit buildings, are tenants rather than owners or face heritage-related restrictions that make installing their own solar system difficult.[152] To overcome this, cities and local governments have embraced a variety of approaches, including developing solar gardens (community solar projects). Many such projects rely on **virtual net metering**, an important enabling policy that allows users to offset their on-site electricity consumption by using electricity generated elsewhere on the grid. Under such models, consumers that participate in community solar projects receive credits on their electricity bills on a pro-rata basis according to their individual share of investment in the project as a whole. When Delhi (India) revised its solar policy in 2019, it introduced virtual net metering to allow residents and businesses without suitable roof space to invest in solar energy systems, overcoming a key barrier to solar uptake in the densely populated city.[153]

Another barrier for some is the inability to conduct maintenance on their solar PV system, whether because of age or mobility, lack of training in the community, the time and cost for maintenance, or other factors. Several approaches have gained momentum to overcome such barriers. In Haystacks (New South Wales, Australia), construction began in 2020 on a community-owned solar garden project that offers members the opportunity to buy one or more of the 300 "plots" of roughly 3 kW each.[154] The approach removes the need for individuals or businesses to engage in operations and maintenance, while the power generated by each member's share of the garden is then credited on their electricity bill.[155]

Another policy option that has rapidly gained ground in the United States and is starting to emerge in Australia and the United Kingdom is **community choice aggregation** (CCA).[156] Under a CCA, municipalities (independently or in partnership with an agency running the CCA) aggregate the electricity demand of residents and businesses and set out to procure electricity for all participating customers city-wide, either through direct contracts with energy producers or via third-party agreements.[157] By enabling local communities to procure their own electricity, CCAs can be an attractive option for cities that want more local control over their electricity mix. The aggregation of demand also helps cities and local governments negotiate better rates with suppliers and lock in contracts for higher shares of renewables, including 100%.[158]

i The "duck curve" refers to the duck-shaped curve of electricity demand in a given jurisdiction that arises as the share of daytime solar PV increases in the system. See J. St. John, "The California duck curve is real, and bigger than expected", Greentech Media, 3 November 2016, https://www.greentechmedia.com/articles/read/the-california-duck-curve-is-real-and-bigger-than-expected.

In the United States, the number of CCAs has grown from just three in 2000 – in Lowell (Massachusetts) and in Cincinnati and Cleveland (both Ohio) – to several hundred nationwide.[159] In California alone, CCAs were present in 182 cities and counties as of 2020, meeting the needs of more than 12 million electricity customers.[160] In 2020, 14 cities and counties across the state were supplying their customers with 100% renewable electricity.[161] Elsewhere in the country, voters in Columbus (Ohio) approved a ballot measure in November 2020 to enable the city to establish its own CCA to help meet its goal of supplying 100% renewable electricity by 2023.[162]

In California, CCAs are present in
182 cities and counties.

An approach similar to a CCA has been adopted in Newstead (Australia), where the local government is developing a 5 MW community solar project on a public plot and offering residents the option to sign up for 100% renewable electricity via a local retailer that will own and operate the project.[163] By tapping into both economies of scale and increasingly low-cost solar, the project promises customers lower electricity bills than those from the region's current retailers.[164] Similar to a CCA, customers will be able to opt in, and the project is designed to be large enough to cover the needs of the entire community.

In addition, some municipal governments have started to benchmark local renewable energy potential, which helps raise awareness and encourages higher uptake among urban actors (→ *see Box 3*).[165]

2

BOX 3. Benchmarking to Harness Renewable Energy Potential in Cities

For many cities, untapped renewable energy potential exists within city limits at locations such as airports, along major rail and road ways, near or on water reservoirs, and on rooftops and vacant land. Cities also often have local sources of bioenergy – including wood chips, local agricultural wastes, and waste fats from restaurants, hotels and food producers that can be used for biodiesel – that can be considered part of the local renewable energy potential (→ *see Sidebar 5 in Markets and Infrastructure chapter*).

The potential for solar PV in cities is significant. For example, one analysis found that two-thirds of commercial buildings in New York City (US) had roof space suitable for solar PV, with the potential to supply around 14% of the city's total electricity consumption, including residential, commercial and municipal demand. An analysis of the solar potential in Berlin (Germany) found that using the city's available rooftop space could power up to 25% of city-wide electricity needs. Cities can better harness this potential by creating solar maps and introducing supportive policies that create the right enabling environments for investment.

Solar maps are tools (often interactive) that allow users to assess the potential and costs of installing solar PV or solar thermal systems on buildings and open land. Although these maps can be customised to produce tailored outputs for projects of all sizes, their main purpose generally is to facilitate greater solar use among property owners. Solar maps have been made available by municipal governments around the world, including in Calgary (Canada), Durban (South Africa), London (UK), Rome (Italy) and several US cities including New York.

One way to tabulate a city's success in harnessing its solar energy potential in new construction is to evaluate what share of the total new rooftop space built in a given year was equipped with solar PV or solar thermal systems. For example, among Germany's 14 most-populated cities, Hannover and Nuremberg managed to harness nearly half of their available rooftop potential[i], whereas Hamburg and Munich tapped into less than 10%. Such benchmarking can highlight which cities are most successful in encouraging the adoption of solar (whether building-integrated, rooftop PV or solar thermal) in new construction city-wide.

Source: See endnote 165 for this chapter.


Nuremberg, Germany

i To calculate this solar potential, the study compared the total newly built rooftop solar PV potential in a given year to the total annual installed solar PV capacity that year.

CITY-WIDE HEATING AND COOLING

Regulatory policies

Municipal regulatory policies to shift to renewables-based heating and cooling in buildings are less widespread than policies in the power sector.[166] Where these policies exist, they often focus on the installation of solar thermal systems for water and space heating (→ *see Sidebar 4*), particularly in new construction.[167]

In Carlsbad (California, US), a water heating ordinance that built on the city's 2015 Climate Action Plan came into effect in January 2020, requiring all new single-family and low-rise multi-family residential buildings to install either a solar water heating system or an electric heat pump coupled with a 0.3 kW solar PV system.[168] In China, Luanzhou's Special Plan for Green Buildings covering the period 2020-2025 requires new residential buildings with fewer than 12 floors to install a solar water heating system for each household (if suitable); for higher buildings the systems must be installed up until the 12th floor.[169] Similar regulatory policies exist in Abu Dhabi (United Arab Emirates), Los Altos Hills (California, US), Loures (Portugal), Montevideo (Uruguay) and São Paulo (Brazil).[170]

Regulatory policies mandating renewables-based heating and cooling in **existing buildings** remain rare. One exception is Basel (Switzerland), where a mandate to replace oil and gas heaters with renewable energy technologies at the time of equipment replacement went into force in 2017; a revision introducing a fine for non-compliance came into force in 2020.[171]

Fiscal and financial incentives

Municipal fiscal and financial support policies for heating and cooling have emerged in cities, particularly in the form of **grants and rebates**.[172] In 2019, as part of its Solar City initiative, the municipal government of Mexico City (Mexico) allocated funding to provide grants to businesses and residential buildings to install solar thermal heating.[173] During the programme period (until 2024), the grants will provide businesses with up to MXP 80 million (USD 4 million; with the target of supporting 400 businesses annually) and will provide residential buildings with MXP 170 million (USD 8.5 million; with the target of supporting around 135,000 systems).[174]

As part of a regional action plan to combat air pollution, between 2018 and 2020 the municipal government of Jiaozuo (China) provided a one-time equipment rebate of CNY 40 (USD 6.1) per square metre of heating area to residents who shifted from using coal to using biomass combined heat and power (CHP), ground-source heat pumps and/or sewage-source heat pumps.[175] In a similar effort to improve air quality, the municipal government of Olsztyn (Poland) allocated a special budget to help co-finance investments in more environmentally friendly heating sources in residential buildings, such as covering a portion of the costs of connecting to the local district heating network.[176]

In Berlin (Germany), the city government initiated a heating exchange programme to replace oil heating systems with wood pellet boilers, solar thermal systems and heat pumps. Owners of residential buildings can apply for grants distributed from a total budget of up to EUR 6 million (USD 7.4 million) for 2020 and 2021.[177] In a similar initiative in Leicester (UK), the municipal government provides grants of GBP 1,000 to GBP 7,000 (USD 1,357 to USD 9,504) for small businesses to implement renewable heating systems and energy efficiency measures.[178] In Barcelona (Spain), the municipal government renewed its housing renovation subsidy in 2020 to offer subsidies of up to 55% of the total costs of renovations to residential households that install solar thermal or solar PV.[179]

Fiscal and financial policies for heating and cooling have emerged in cities particularly in the form of **grants and rebates.**

SIDEBAR 4. Frontrunners in Solar Thermal Mandates in Cities

Building codes are widely used as a way to improve the energy performance of new and refurbished buildings. In around 20 countries worldwide, codes also include requirements that a certain amount or share of hot water and/or space heating demand is met using renewable sources or specifically solar heat. These additional regulations are respectively called renewable and solar thermal mandates.

Over the last two decades, cities have taken the lead in implementing solar thermal mandates, using their regulatory authority to stipulate the use of solar thermal systems on buildings for heating and cooling to reduce local air pollution and achieve climate targets. Mandates force the construction sector to consider renewable energy technologies early in the planning process. Given the labour-intensive nature of the building sector, which is dominated largely by local businesses, this approach also creates local jobs.

As early as 2000, Barcelona (Spain) – Europe's pioneer in solar mandates – adapted its building code to require that solar thermal energy cover at least 60% of the hot water demand in new buildings and in buildings undergoing major renovation. This solar mandate has been the main driver behind Barcelona's emergence as a mature solar thermal market, with more than 96,000 m^2 of collector area installed by small local companies in the last two decades. The policy also spurred broader action as some 50 Spanish towns and cities followed Barcelona's example, culminating in the implementation of national technical building regulations in 2007.

In some countries[i] (such as Germany and South Africa), building codes or mandates are set at the national level, making new solar or other mandates binding at lower levels of governance as well. In such cases, the key role for municipal administrations is to effectively implement the national regulation. In South Africa, a new building standard came into force in September 2011 (followed by a six-month transition period) stipulating that a minimum 50% of annual hot water demand must be provided by means other than electric resistance heating and fossil fuels. The city of Cape Town was able to fully apply the standard from April 2012 onwards, whereas other municipalities delayed the implementation by several years (→ *see Feature chapter*).

The experience of Bengaluru, the capital of Karnataka state (India), illustrates how strict implementation rules increase the effectiveness of solar mandates. To combat chronic power shortage, Karnataka enacted a solar mandate in 2007 requiring developers to install solar water heaters in all dwellings with at least 600 square feet (56 m^2) of floor space. Two years later, the municipal utility Bangalore Electricity Supply Company (BESCOM) started denying grid access to households that were not equipped with a solar water heater. This strict compliance rule led to 1,234 million m^2 of collector area installed across the city by 2017. BESCOM's policy was copied by other utilities across Karnataka, making it the leading Indian state for solar water heater capacity.

In countries where building codes can be set at the local level, several cities have emerged as frontrunners in solar thermal ambition, despite facing challenges. In 2007, São Paulo was among Brazil's first cities to enforce a solar mandate (applicable to all new residential and non-residential buildings), and by 2015 more than 110,000 m^2 of collector area had been installed across the city. Rosario (Argentina) is one of the few towns/cities in that country to have established a solar mandate (adopted in 2012), requiring 50% of hot water consumption in public buildings to be covered by solar thermal systems.


Honolulu, Hawaii

Some cities have pioneered stricter standards or requirements than those set at higher levels of government. In 2019, Honolulu (Hawaii, US) issued a stricter solar mandate, applying also to town halls and condominiums, than the overall state mandate for residential buildings that has been in force since 2010. The Hawaii mandate was the first on the continent and resulted in a high solar thermal penetration in buildings, with one in every two single-family houses using solar-heated water.

Source: See endnote 167 for this chapter.

i Solar mandates at the national level have proven to be able to boost solar thermal markets. Famously, in response to the oil crisis of the 1970s, Israel mandated the installation of solar water heaters in new residential buildings. Today, residential solar thermal systems are standard in the country, with 85% of households showering with solar energy. In Australia, a solar mandate issued in Victoria in 2005 requires residential home owners to install either a solar water heater or a rainwater tank for toilet flushing; 15 years later, 70% of new houses in the province have solar hot water systems.

Overall enabling environment

Municipalities increasingly have introduced enabling policies for renewable heating and cooling in buildings, such as **bans and/or restrictions** on the use of fossil fuel technologies (for example, new natural gas or oil-based boilers) as a way to improve local air quality and encourage the uptake of renewables. By the end of 2020, a total of 53 cities spanning 10 countries had either passed or proposed a ban or restriction on the use of natural gas, oil or coal in buildings for space and water heating purposes (→ *see Figure 11*).[180] While most of these policies target new buildings, some apply to existing buildings.

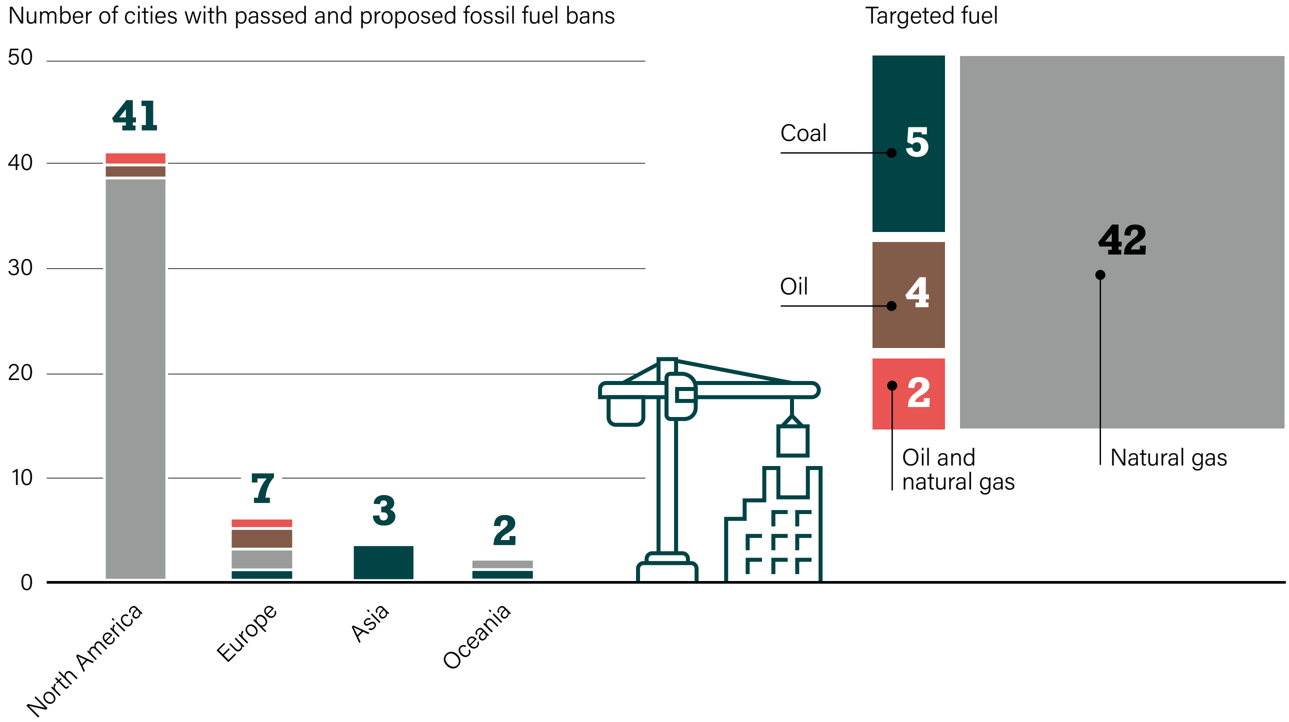
In the United States, several cities (mainly in California) have issued bans on natural gas infrastructure in new construction; although some of these have been contested in court. Berkeley was the first to ban the construction and use of natural gas lines for new residential buildings (in 2019), and more cities in the state have followed suit, including Milpitas and Palo Alto. Other California cities – including Carlsbad, Morgan Hill, Mountain View, Oakland and San Jose – have adopted regulations phasing out natural gas connections for new construction over time.[181] San Francisco banned the use of natural gas in newly built public buildings starting in 2020 and in new residential and commercial buildings and major building renovations starting in mid-2021.[182] Brookline (Massachusetts) bans both heating oil and natural gas for new residential and non-residential buildings.[183] In Canada, the Vancouver city council approved a bylaw requiring zero-emission space and water heating for all residential buildings of three storeys or less starting in January 2022 (→ *see City Snapshot: Vancouver*)[i],[184]

In Europe, Hamburg (Germany) introduced a ban in 2019 on oil-based heating and air conditioning, which will come into force in late 2021.[185] Amsterdam (Netherlands), in its wide-ranging climate-neutral roadmap published in 2020, pledged to phase out natural gas use in the city entirely by 2040.[186] Bans also are planned or in place in Krakow (Poland) and London (UK), among other European cities.[187]

In an example of the interplay that often occurs among various levels of government to drive meaningful change at the local level, the district of Ginninderry (Canberra, Australia) succeeded in overturning state-level laws that would have made natural gas supply mandatory for new construction.[188] The change to the state legislation now makes gas connections for new construction voluntary, and has enabled Ginninderry to establish one of Australia's first "gas-free" suburbs.[189]

i See City Snapshot: Vancouver online at www.ren21.net/cities

Figure 11. Fossil Fuel Bans and Restrictions in Buildings in Cities, 2020



Source: REN21 Policy Database and Reference Table R5. See endnote 180 for this chapter.

DISTRICTS AND NEIGHBOURHOODS

Municipal governments have a direct influence over district- and neighbourhood-level planning. They can engage in integrated urban and energy planning processes that take into account the specific spatial, environmental and economic perspectives of these areas. Scaling up renewables in key districts or neighbourhoods can contribute greatly to wider city-level renewable energy strategies and climate targets. Policy activities that local governments have undertaken in their role as planners and regulators include setting targets and plans at the district and neighbourhood levels for the share of district heating, cooling or electricity; the share of district energy in public or other buildings; and the number of buildings connected.[190]

Several cities have sought to scale up renewables at the neighbourhood level. Through the innovative "Barrio 31" Infrastructure Plan, which ended in 2019, Buenos Aires (Argentina) built 120 new homes with access to public services as a way to integrate this marginal neighbourhood into the city.[191] The plan included energy efficiency measures as well as solar panels and solar water heating systems.

In the "smart" city of Eliat (Israel), a municipal bylaw requires every new neighbourhood to include infrastructure for solar panels on the rooftops of homes.[192] The city's Mitzpe Yamthat neighbourhood aims to reduce energy consumption through energy efficiency in public buildings and private homes, and to upgrade existing infrastructure by installing LED lights on utility poles and public buildings, outfitting homes with energy-saving equipment and offering professional guidance on its use.[193] The neighbourhood is seen as a holistic unit, creating a model for other neighbourhoods in the city and elsewhere to replicate.

In Vienna (Austria), a ban on natural gas in new buildings led city authorities to estimate that by autumn 2020, "climate protection areas" would become possible in 8 of the city's 23 districts, with the rest following in 2021.[194] Within these areas, Vienna will be able to produce renewable heat for 80% of new buildings.[195] The city also has an ambitious heat zoning plan, with four districts already banning fossil fuel heating in new buildings and a targeted ban on fossil fuel heating in all buildings city-wide by 2040.[196]

The Haarrjin neighbourhood in Utrecht (Netherlands) aims to power as many as 1,400 households with clean energy from a new floating solar PV plant, which will contribute to the energy-neutral neighbourhood that already has many solar panels on its roofs.[197] In the new residential neighbourhood of Tamarinden in Örebro (Sweden), 600 housing units are being developed with plans to reduce, produce and share renewable energy.[198]

Momentum also has grown (particularly in Europe) for **positive energy districts**: energy-efficient and energy-flexible urban areas that produce net-zero greenhouse gas emissions and have surplus renewable energy generation.[199] These districts focus on energy production, efficiency and flexibility as a means to achieve local environmental, social and economic sustainability.

As of 2020, 61 European cities were developing plans for positive energy districts.[200] Most were in the implementation stage, and only a few had been realised or were in operation, including (since 2018) the Carquefou district in Nantes (France). Carquefou's La Fleuriaye "eco-neighbourhood", which consists of 620 housing units with 6,000 m^2 of solar PV panels, provides 80% of the district's energy needs through solar electricity and is expected to be one of Europe's largest positive energy districts when completed in 2022.[201] Another programme in Europe supports the planning, deployment and operation of "100 Positive Energy Districts and Neighbourhoods" region-wide by 2025.[202]

53 cities

have either introduced or planned a ban on the use of natural gas, oil or coal in buildings.

Amsterdam, Netherlands

2

Some US cities have **ecodistricts**[i] that involve urban planning to integrate the twin objectives of social equity and sustainable development, including reducing the ecological footprints of neighbourhoods. For example, the High Falls Ecodistrict, established in 2017 in Rochester (New York), aims to advocate and educate for reduced energy use through energy efficiency upgrades, to catalyse greater use of renewables, and to provide clean, energy-efficient transport options.[203] In Boston (Massachusetts), the Talbot-Norfolk Triangle eco-innovation district (also established in 2017) is implementing projects focused on equitable transit-oriented development, local renewable energy generation, open space, walkability, bikeability, urban agriculture, green infrastructure, public health and safety, and local job creation, addressing both sustainability and economic prosperity within a holistic urban regeneration process.[204]

Ecodistricts being built elsewhere include Yennenga, a sustainable city located 15 kilometres from Ouagadougou (Burkina Faso). The city, which runs on renewable electricity generated in part by a 270 MW solar PV plant, welcomed its first inhabitants in 2020 and is expected to house some 100,000 people by 2030.[205]


High Falls, United States

CITY-WIDE TRANSPORT

Until recently, efforts to increase the use of renewables in transport focused primarily on biofuels, whether ethanol, biodiesel or related fuels.[206] However, in recent years the opportunity to accelerate the uptake of renewables in the transport sector via electrification – using renewable electricity to charge vehicles – has attracted growing attention among urban policy makers worldwide.[207]

Regulatory policies

By the end of 2020, at least 33 cities had issued mandates or obligations to advance or enable the use of renewables in transport.[208] While **biofuel blending**[ii] **mandates** generally are set at higher levels of government, some cities have adopted plans and procurement requirements to promote the local use of biofuels (as well as the use of local biofuels). In 2020, Bogotá (Colombia) adopted a new development plan that encompasses a package of measures to increase the city-wide use of renewable energy, including advanced biofuels[iii].[209]

As momentum behind e-mobility continues to grow, **EV charger mandates** for new buildings have become more commonplace at the city level.[210] In 2019, several cities, including San Mateo (California, US) and Vancouver (Canada), adopted new or revised building energy codes requiring that certain new buildings be both "EV ready" and "solar ready", equipped with the electrical infrastructure required to enable EV charging stations to rely on renewable electricity.[211] Also in 2019, the government of Delhi (India) approved its Electric Vehicle Policy, which among other measures requires all new residential and workplace parking to have EV charging spaces.[212] In 2020, Chicago (Illinois, US) adopted an ordinance requiring new buildings to be equipped with EV charging infrastructure; this new policy – in combination with the city's target to power all buildings with renewable electricity by 2035 – will make it possible to meet the transport needs of building residents or users fully with renewable electricity.[213]

EV charger mandates

for new buildings have become more commonplace.

i Ecodistricts are home to positive energy buildings, or buildings that produce more energy than they consume.

ii Biofuel blending mandates require that transport fuels are blended with a minimum percentage of biofuel such as ethanol or biodiesel.

iii Advanced biofuels are fuels that can be manufactured from various types of non-food biomass, including waste and agricultural residues. See Glossary for definitions.

Several countries have adopted **hydrogen** strategies that have potentially far-reaching implications for cities. In 2019, the Republic of Korea announced plans to set up three hydrogen-powered cities by 2022, which entails a significant scale-up of hydrogen vehicles as well as hydrogen refuelling infrastructure (although it remains unclear whether the hydrogen will be renewables-based).[214] In China, both Guangzhou (Guangdong province) and Kunshan (Jiangsu province) adopted local development plans in 2020 for the production and use of renewable hydrogen in urban fleets.[215] China also was developing an ambitious roadmap to support the deployment of hydrogen vehicles in more than 20 cities, backed with several policy measures including financial subsidies.[216]

Fiscal and financial incentives

By the end of 2020, at least 17 cities were providing fiscal and financial incentives – including grants, subsidies, tax rebates and tax exemptions – for the purchase and operation of zero-emission vehicles, mainly **electric vehicles**, as well as for associated infrastructure.[217] In a small number of cases, the incentives link EVs directly with new renewable power capacity. For example, in 2020 the municipality of Baden (Austria) and the car dealership Czaker promoted the combination of solar electricity and e-mobility, giving EV buyers a bonus if they already had a solar PV system at their house, and offering a subsidy of up to 30% more for installing a solar PV system if an EV is registered at the same address.[218]

Some financial incentive programmes are directed at expanding electric taxi fleets in cities, although without an explicit link to renewable electricity. Cities that have supported the shift to electric taxis include Edinburgh (Scotland, UK), Medellín (Colombia), Montevideo (Uruguay) and Vitoria-Gasteiz (Spain).[219] Since the end of 2019, Amsterdam (Netherlands) has provided financial incentives for zero-emission vehicles, offering rebates of up to EUR 3,000 (USD 3,684) for a taxi and EUR 40,000 (USD 49,129) for a delivery van, truck or bus.[220]

In China, the national New Energy Vehicles (NEV) policy has been the biggest driver for the uptake of electric passenger vehicles.[221] However, some cities also have provided municipal subsidies to NEV consumers in recent years.[222] In 2020, the local government of Shanghai started offering subsidies of CNY 5,000 (USD 766) to NEV buyers, while the city of Shenzhen offered CNY 20,000 (USD 3,064) for the purchase of a new battery electric vehicle and CNY 10,000 (USD 1,532) for a plug-in hybrid.[223]

In the United States, the District of Columbia's Clean Energy Omnibus Amendment Act, passed in 2019, aims to electrify all public buses and other fleet vehicles in Washington, D.C. and to incentivise owners of private, non-commercial vehicles to purchase fuel-efficient vehicles, in an effort to curb greenhouse gas emissions in the city.[224] The Act establishes a vehicle tax based on fuel efficiency, offers tax rebates for vehicles that are more efficient than the established benchmark and exempts EVs from the tax.[225] In 2019, São Paulo (Brazil) granted an exemption from the Vehicle Property Tax (IPVA) to electric, hybrid and hydrogen vehicles registered in the city.[226]

While financial incentives for **hydrogen** vehicles are still limited, some examples exist (although not linked to renewable electricity). Between late 2018 and mid-2020, Arnhem (Netherlands), in partnership with Gelderland province, supported the H2-Drive initiative, under which citizens could request financial support for leasing or buying a hydrogen fuel cell car.[227] The programme initially aimed to finance 90 hydrogen cars but stopped at 70 due to the COVID-19 pandemic.[228]

Financial tools remain popular among different levels of government supporting the transition to renewable fuels and alternative propulsion vehicles. Many cities rely on financial incentives and support policies set by national and/or state governments to complement the limited resources they themselves have to spend on such programmes. For example, in 2020 the North Central Texas Council of Governments (US) set up a grant funding programme for local governments and private companies working with local governments to replace heavy-duty diesel vehicles with alternative fuel[i] vehicles.[229]

Arnhem, Netherlands

2

i In the context of the programme, "alternative fuel" vehicles encompass vehicles that can rely on renewable fuels (such as biodiesel and ethanol) as well as electric vehicles and vehicles fuelled by hydrogen, natural gas and propane.

Overall enabling environment

As of the end of 2020, at least 14 cities had proposed or passed **bans and/or restrictions** on the circulation of certain types of vehicles in their jurisdictions.[230] Most of these measures focus on banning either just diesel vehicles (as many cities in Germany and Spain have announced plans to do) or banning/phasing out all internal combustion engine vehicles, regardless of whether they burn diesel, petrol or liquefied natural gas. Bans on sales of internal combustion engine vehicles have been more common at the national level, and can affect the uptake of biofuels, drop-in fuels and some renewable synthetic fuels that can be used in conventional engines; meanwhile, cities mostly have adopted bans or restrictions on the use of fossil fuel vehicles, which incentivise all renewable fuels and electricity use in urban transport.[231]

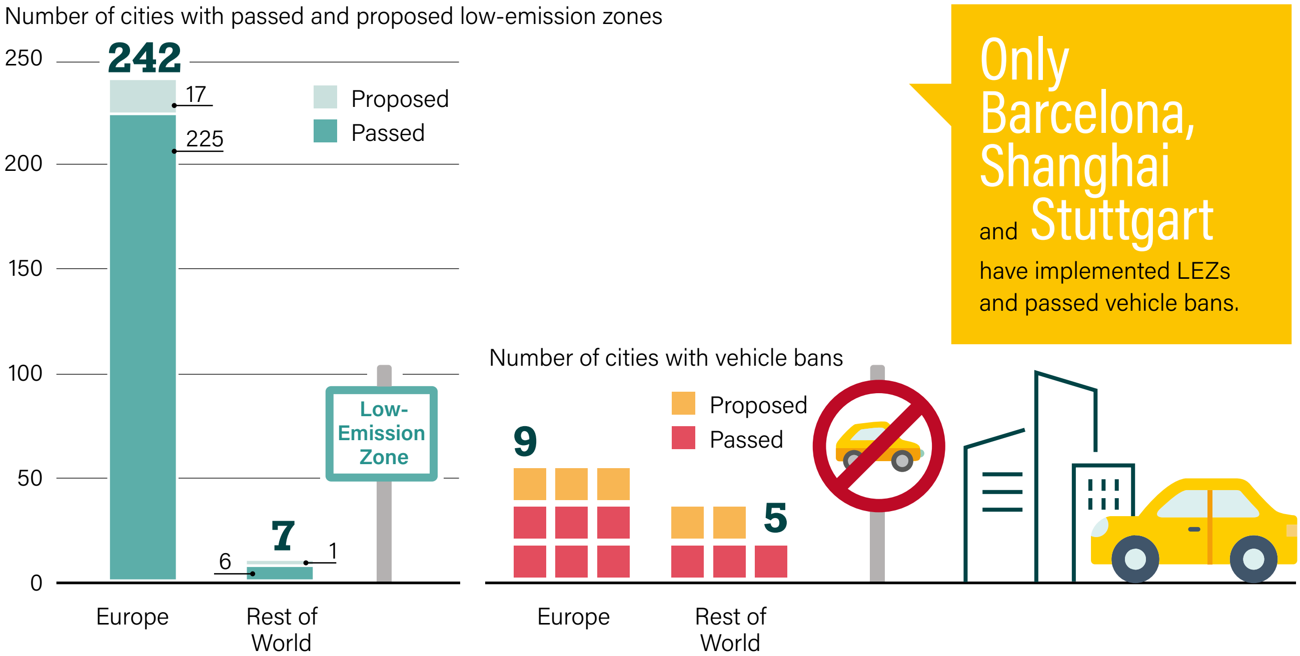
Beginning in 2020, diesel cars up to the Euro 5 emission standard[i] are banned on certain roads in Stuttgart (Germany), with similar restrictions in place in Barcelona (Spain), Berlin (Germany) and Bucharest (Romania).[232] Amsterdam (Netherlands) announced in 2019 that any cars and motorbikes running on petrol or diesel would be banned from driving in the city starting in 2030, and non-electric buses will no longer be able to enter the city centre from 2022.[233] Oslo (Norway) has outlined a plan to make its city centre fossil-free by 2024 and to be the first city to have a fully emissions-free transport sector by 2030.[234] Reykjavik (Iceland) took a different approach, pledging in 2019 to halve the number of petrol stations in the city by 2025 in an effort to phase out internal combustion engine vehicles.[235]

Low-emission vehicle zones (LEZs) continued to spread during 2019 and 2020, predominantly in Europe. By mid-2020, of the 249 passed or proposed LEZs worldwide, more than 97% of them were in European cities (→ *see Figure 12*).[236] Poland's first LEZ was established in Krakow in 2019, and additional LEZs were approved in Stockholm (Sweden) and in UK cities including Aberdeen, Bath, Birmingham, Dundee, Edinburgh, Leeds, Leicester and Southampton.[237] Due to measures enacted in response to COVID-19, some planned UK-based LEZs (including in Oxford) were postponed, and some existing LEZs and associated financial penalties and congestion charges were suspended and then later reinstated – including in Barcelona (Spain), London (UK) and Milan (Italy).[238]

Although the main goal of LEZs is to improve local air quality, they also can result indirectly in greater use of renewable fuels and electricity in transport by allowing concessions to alternative powertrains. In Madrid (Spain), for example, only certain vehicle types – including battery electric, fuel cell electric and plug-in

i Since 1992, new car models in the EU have had to meet increasingly stringent emissions limits, known as the Euro emissions standards, before they can be sold. The Euro 5 emissions standard, which relates to the EU standard for pollutants put in place in 2009, covers carbon monoxide, hydrocarbons, nitrogen oxides and particulate matter, and introduces particulate filters for diesel vehicles.

Figure 12. Number of Cities with Low-Emission Zones and Vehicle Bans on Certain Technologies, 2020



Source: SLOCAT, REN21 Policy Database and Reference Table R5. See endnote 236 for this chapter.

Note: The figure includes cities with LEZs and vehicle bans which have been passed or proposed. Of the total of 231 cities with passed LEZs, 195 were passed before 2020 (between 2006 and 2019), 23 were passed in 2020 and 13 are scheduled to be enforced between 2021 and 2028. Of the 9 cities that have passed vehicle bans, three were enforced in 2019 and 2020 and the remaining six were scheduled to come into force during 2021-2025.

hybrid vehicles with a minimum electric range of 40 kilometres, and range-extended EVs – are allowed to circulate and park in the LEZ without restrictions.[239] In 2020, Paris (France) stipulated that only battery electric and fuel cell vehicles will be permitted in its LEZ by 2030.[240]

Outside of Europe, LEZs have emerged in Chinese cities such as Foshan, Guilin, Huia'an, Shanghai, Suzhou and Zhengzhou.[241] Israel's first LEZ was established in 2018 in Haifa, and in 2020 a new LEZ was implemented in Jerusalem.[242]

The use of **fees and levies** to encourage or discourage certain behaviours and investment choices also can stimulate the transition to zero-emission transport alternatives – and, indirectly, greater use of renewables.[243] Several Dutch cities – including Amsterdam, Eindhoven, The Hague, Rotterdam and Utrecht – offer **free public EV charging**, as does Lisbon (Portugal).[244] Lisbon also offers free EV parking, while at least 12 Chinese cities, including Hefei and Shenzhen, offer reduced parking fees for EVs.[245]

During 2019 and 2020, many city governments – including Delhi (India) and Hong Kong and Shenzhen (both China) – continued to promote the use of EVs by subsidising the installation of charging infrastructure within city boundaries.[246] Community choice aggregation programmes also have started to explore scaling up investments in EV charging infrastructure and increasing the share of renewables used in charging, especially in cities across California (US).[247] By contrast, Amman (Jordan) was forced to cancel its EV financial incentive scheme due to the lack of charging stations to accommodate the growing number of EVs in circulation.[248]

More joint transport-related commitments involving cities and other jurisdictions were announced in 2019 and 2020. Under the Climate Mayors Electric Vehicle Purchasing Collaborative, some 182 US cities and counties have committed to purchasing a total of more than 3,500 EVs before the end of 2021.[249] Additionally, through the C40 Fossil Fuel Free Streets Declaration, 35 cities (including 7 non-C40 cities) pledged to establish major zero emission areas within their cities by 2030.[250] However, there is a high risk that these efforts will not be implemented or successfully linked to renewable energy without complementary policies, such as those highlighted throughout this chapter.

At least
14 cities
have proposed or implemented bans on the circulation of fossil fuel vehicles.

2

Chongqing, China


Bradley, United States

Toronto
Bristol
Klemetsrud
Duiven
Tampa
Cotonou
Lagos
Lalitpur
Hong Kong
Salt Lake City

3 MARKETS AND INFRASTRUCTURE

Cocody
Malmö
Oxford

MARKETS AND INFRASTRUCTURE

Cities are both consumers and producers of energy. They account for around 75% of global energy use[i] and are the leading growth markets for utilities.[1] Because cities (including their governments, inhabitants, and commercial and industrial entities) use so much energy, they have the potential to drive large amounts of renewable energy deployment. However, cities worldwide vary greatly in their energy use – depending on factors such as the level of economic development and the presence of industry, among others – and in their overall ability to deploy renewables, which may reflect local resource and other constraints. In 2020, the COVID-19 pandemic sharply reduced energy use in many cities, particularly in the transport sector (→ *see Sidebar 1 in Global Overview chapter*).[2]

City governments often are constrained by policies and regulations at higher levels of government, as well as by the availability and condition of energy distribution infrastructure. When provided sufficient autonomy, however, a city can exercise greater flexibility over its energy mix and define, to a large extent, the trajectory of its energy future. Overall, cities have significant opportunity and potential to steer the energy system towards renewable energy – not just locally, but well beyond.

Globally, a relatively small but growing share of the energy consumed in cities comes from modern renewable sources[ii]. To some extent, this renewable share is expanding in direct proportion to developments outside of the urban purview, thanks to the greater deployment of renewables elsewhere. For example, state/provincial or national mandates, as well as the changing economics of energy technologies, have led to rising shares of renewable electricity or fuels in regional grids – which has led to higher city shares as well. At the same time, more and more cities worldwide are directly increasing their production and consumption of energy from renewable sources.[3]

Urban demand for renewables is rising in response to growing recognition of the diverse economic, environmental, social and other benefits associated with renewable energy[iii]. So far, the greatest focus has been on meeting municipal government demand (via city procurement authority) followed by efforts to reshape the wider urban energy supply and demand structure. Private procurement also plays a growing role, as individuals and businesses determine their own renewable energy needs. Although most of the renewables used in cities are still sourced from outside the urban area (through regional grids, pipelines and other infrastructure), local production of renewable energy – in the forms of electricity, direct thermal energy and transport fuels – is significant and growing.[4]

i Not including energy embedded in imported agricultural, electronic and other products or materials. See endnote 1 for this chapter.

ii In many cities (especially in sub-Saharan Africa), the traditional use of biomass for heating and cooking is still widespread. See Glossary for definitions of modern renewable energy and traditional biomass.

iii See Drivers chapter in REN21, *Renewables in Cities 2019 Global Status Report* (Paris: 2019), https://www.ren21.net/wpcontent/uploads/2019/05/REC-2019-GSR_Full_Report_web.pdf.

Around the world, city governments as well as urban households and commercial and industrial actors are shaping their energy infrastructure and use to better accommodate rising shares of renewables. They are expanding district heating and cooling networks, implementing efficient end-use technologies, increasing electrification of the transport and heating sectors, installing energy storage capacity and facilitating greater flexibility on the demand side – all of which can provide benefits such as greater system efficiency, improved reliability of service and lower overall system costs.[5] To address multiple urban challenges in a cost-effective manner, city governments also are linking energy supply with other municipal activities – for example, using rapidly growing urban waste and wastewater streams as feedstocks to produce solid, liquid and gaseous biofuels (→ *see Sidebar 5*).[6]

The availability and reliability of energy data vary greatly across countries and cities. In general, data on renewable energy capacity and generation are tracked at the national (and often state/provincial) level, but not always at the local level. As a result, comprehensive global statistics on urban renewable markets (for both energy and technologies) and generation are incomplete or lacking.[7] Further, although energy consumption is reasonably well documented at the national level, the urban/rural breakdown of this use is generally unavailable.

Within these limitations, this chapter provides an overview of city-level renewable energy market and infrastructure developments during 2019 and 2020. It examines the installation of renewable energy technologies and associated infrastructure in cities, the energy capacity procured for use in cities, as well as relevant consumption trends across the buildings, industry and transport sectors (→ *see Global Overview chapter*).

Santiago, Chile

SIDEBAR 5. Waste-to-Energy in Cities

The rise of urban refuse, including municipal solid waste (MSW) and wastewater, has been a major component of the rapidly growing global waste stream[i]. As the volume of refuse in urban areas skyrockets – driven by population growth, urbanisation and changing patterns of consumption – cities have faced major challenges, leading many to undertake measures to improve their waste management systems.

Key challenges include: the effective and comprehensive collection and transport of refuse to waste processing facilities; separating and capturing recyclable materials and energy content from the waste stream (including methane emissions[ii]); and identifying adequate land for treatment and disposal of remnants (often at high economic cost) – all while minimising the impacts on public health from local air, soil and water contamination. In developing countries and emerging economies, more than two-thirds of MSW is deposited improperly in open landfills that lack advanced environmental protection, let alone adequate energy and material recovery protocols.

At the same time, waste is a resource that, if properly recycled, can be recovered to be used as an input for new products. Cities have numerous opportunities to manage their waste in a more sustainable (and economically beneficial) manner. To minimise the volume of waste going to landfill and to recapture both material and energy resources, many cities divert, capture and recycle usable materials. Any refuse with direct energy potential (meaning usable fuel and direct heat, as opposed to recaptured embedded energy in materials such as processed metals) can be captured for direct and indirect energy applications.

For example, organic waste can be extracted and reformed into solid, liquid or gaseous biofuels to generate electricity, to directly provide heat via combustion (for cooking and heat in buildings, and in industry) and to fuel vehicles. Organic waste also can be processed into organic fertiliser, which displaces demand for fossil fuel-based fertilisers and avoids emissions associated with using fossil fuel as a feedstock.

To extract energy from waste, cities have adopted a variety of technologies, including anaerobic digestion of solid and liquid organic waste to produce biogas, the capture and use of landfill gas, and direct combustion of solid waste[iii]. Biogas, whether from digesters or landfill, is considered to be a renewable fuel. It has high methane content and can be combusted directly to produce electricity and/or heat.

In Santiago (Chile) in 2017, the water utility Aguas Andinas transformed three wastewater treatment plants into the Greater Santiago Biofactory, which converts the city's effluent to biogas to produce heat and electricity; the utility also reuses the additional sewage sludge as fertiliser for agriculture. In 2019, the plant generated 57.2 gigawatt-hours (GWh) of electricity and reused 69% of bio-solid as fertiliser. In Victoria (Australia), the Environmental Protection Authority approved construction in 2020 of a second biogas plant at the Melbourne Regional Landfill, which is expected to generate 68,000 MWh of electricity annually.

Cities also are converting food waste to biogas. In the United States, both legislation and public demand to limit landfill sizes and reduce carbon footprints has motivated city actors to take action. In 2020, Los Angeles (California) expanded the capacity of its food-to-biogas plant from 165 tonnes to 550 tonnes of separated food waste per day, which is used to produce fuel for electricity generation and for transport vehicles. In New York City, the Newtown Creek Wastewater Treatment Plant has processed around 3% of the city's daily liquefied food waste into biogas for electricity generation since 2016, and plans were announced in 2019 to double the plant's capacity.

New Zealand was building its first large-scale food waste-to-biogas plant with anaerobic digester technology in Reporoa on the North Island in 2020. The facility, expected to be operational in 2022, aims to process up to 75,000 tonnes of household and commercial food waste from Auckland annually to provide electricity for the equivalent of around 2,500 households in the region and to provide bio-fertiliser for 2,000 hectares of local farmland, as well as to produce CO_2 and heat for local greenhouses.

Biogas can be upgraded to biomethane and used as a transport fuel or injected into fossil natural gas pipelines. Biomethane plants have become increasingly common, particularly in Europe where the number of facilities rose 51% between 2018 and 2020, from 483 to 729. Lille (France) converts more than 108,000 tonnes of household waste annually into biomethane to fuel half the city's bus fleet. In 2020, Bristol (UK) partly funded the deployment of 77 buses fuelled with biomethane derived from anaerobic digestion of food waste. Toronto (Canada) partnered with the gas company Enbridge Gas to install biogas upgrading equipment for biomethane production at the Dufferin Solid Waste Management Plant. The facility is expected to produce some 3.3 million cubic metres of biomethane per year for injection into the natural gas distribution grid, which supplies fuel to waste collection trucks and other municipal vehicles as well as heat for Toronto's buildings and other facilities.

i Global waste generation increased more than 50% between 2012 and 2016, from around 1.3 billion tonnes to 2.01 billion tonnes, according to the latest data available. See endnote 6 for this chapter.

ii Methane, emitted during the decomposition of organic wastes, is a potent greenhouse gas that contributes to climate change and can potentially cause explosions at waste facilities if ignited.

iii Not all energy produced from the remaining waste is renewable. Energy derived from MSW combustion cannot be considered entirely renewable, as MSW also contains inorganic material. Generally, about 50% of this energy is classified as renewable.

The direct disposal of MSW through incineration is a common practice, and more than 4,800 incinerators are in operation worldwide, a growing number of which use the thermal energy released through combustion to generate usable heat and electricity. However, only the energy produced from the organic portion of MSW can be considered renewable, and emissions from incineration greatly affect air quality in the absence of pollution control systems. Cities have begun to install control systems to reduce air emissions from incinerators. In 2018, the Norwegian government initiated a carbon capture project at the Klemetsrud waste-to-energy facility – which processes more than 400,000 tonnes of waste annually – to generate electricity and heating for the city of Oslo. In 2019, the Dutch waste-to-energy company AVR equipped its waste combustion plant in Duiven (Netherlands) with a flue gas purification system to reduce CO_2 emissions.

Source: See endnote 6 for this chapter.

Auckland, New Zealand

Toronto, Canada

BUILDINGS AND INDUSTRY

PRODUCTION AND PROCUREMENT OF ELECTRICITY

In towns and cities around the world, municipal governments and other urban actors – including residents, businesses, universities and places of worship – are producing and procuring renewable electricity to power building systems and run all forms of commercial and industrial activity. Depending on their local resource options, laws and regulations, and other location-specific variables (including institutional and financial capacities), these entities are pursuing activities in at least three general areas to increase their use of renewable electricity:

- installing distributed renewable power systems at or near the point of demand (on-site);
- purchasing renewable electricity through green tariff programmes; and
- signing power purchase agreements (PPAs) with developers for projects in and outside of urban areas.[8]

In cities where these options are not available or are insufficient – often because national and state/provincial laws and regulations govern activities related to energy production, procurement, and electricity transmission and distribution – municipal governments and other urban actors use alternative avenues to achieve their local renewable energy goals.[9] In many instances, city governments have partnered with diverse stakeholders, including utilities and other cities, to engage with legislators and regulators to remove barriers.[10] Many city governments are pursuing community aggregation efforts or the municipalisation[i] of electricity procurement and distribution (→ *see Citizen Participation chapter*).

ON-SITE GENERATION

Thousands of examples exist of recent on-site projects in cities, ranging in capacity from a few kilowatts to hundreds of megawatts. Based on available information, most of these local projects are solar PV systems (combined with battery storage in a small but increasing number of systems), although many cities also tap into local wind, biomass and hydropower resources. These systems are being installed on or near government buildings, schools and universities, single-family homes and high-rise apartment buildings, hospitals, airports, commercial and industrial facilities, places of worship, carports, rail and bus stations, urban waste sites and city streets (→ *see Box 1*).[11]

i See Glossary for definition.

BOX 1. Solar Streetlights

Public street lighting consumes as much as 40% of the electricity budget in some cities. To reduce costs, municipal governments around the world are embracing renewably powered streetlights (as well as energy-efficient lighting programmes) as cost-effective and reliable solutions.

In 2020, Epperson, a master-planned community in Tampa (Florida, US) was deploying more than 10,000 solar streetlights that will run entirely off the grid. In Canada, Prince George (British Columbia) launched a pilot project to test an off-grid solar-powered streetlight, and in Australia the Mareba Shire Council (Queensland) installed 10 solar-powered off-grid public lights, which helped the council save more than 30% on lighting costs in addition to improving road safety.

Solar street lighting also is providing more reliable illumination across Africa. In 2020, Djoum and Yaoundé in Cameroon, which suffer frequent power outages, installed solar streetlights, and 12 towns in Liberia's upper Bong County switched on 60 solar streetlights, serving more than 5,500 residents. In Senegal, a project to install 50,000 solar streetlamps in several cities was delayed by COVID-19 but was 50% complete by mid-2020, providing lighting to more than 20,000 urban dwellers. Cotonou (Benin) and Lagos (Nigeria) were testing solar traffic lights, mainly to reduce road congestion and accidents caused by unstable power supply.

At the same time, some cities with existing solar lights that no longer function due to theft or lack of maintenance are exploring other options. Ekurhuleni (South Africa), Harare (Zimbabwe), Kampala (Uganda) and Kathmandu and Lalitpur (both Nepal) have all opted for "smart" electric streetlamps, which send signals to a central power control module when they experience technical problems so that they can be fixed promptly.

Source: See endnote 11 for this chapter.


Colombo, Sri Lanka

In the **United States**, local government transactions related to renewable energy (for both on-site and off-site systems) increased considerably after the federal government announced in 2017 that it would withdraw from the Paris Agreement.[12] Many US cities – including Cincinnati (Ohio), Honolulu (Hawaii), Los Angeles, San Diego and San Jose (all California), New Orleans (Louisiana) and Phoenix (Arizona) – have built small-scale on-site or community solar projects as a first step towards achieving their renewable electricity goals.[13] By 2019, public authorities, residents and businesses in Los Angeles had installed some 440 MW of grid-connected solar PV capacity, supplying around 11% of the city's electricity mix and making Los Angeles the top US city for grid-connected solar PV.[14] Honolulu leads for solar PV capacity per capita, with more than 646 watts for each city inhabitant as of the end of 2018.[15]

In the US northeast, most renewable energy deals made by local governments are for on-site projects due in part to favourable policies for distributed energy (particularly solar PV).[16] New York City's transit authority launched an initiative in 2019 to lease many of its rooftops and parking lots for solar projects, and city agencies announced plans in 2020 to install solar PV on 46 public schools, a wastewater facility and other buildings as part of a goal to install 100 MW on New York public buildings by 2025.[17]

Elsewhere in the country, Seattle (Washington) generated nearly all of its electricity with renewables in 2019, thanks to an estimated 8,000 solar buildings and a public utility that has been carbon-neutral since 2005 (due mainly to hydropower).[18] Fayetteville (Arkansas) completed a solar project in 2019 to power two wastewater facilities that account for most of the municipal government's electricity use.[19]

Across **Europe**, numerous city governments added renewable power capacity in 2019 and 2020, with local projects including biomass facilities as well as other renewable power systems. In Ukraine, the eastern city of Dnipro began operating a 16 MW biopower plant in 2019.[20] In the United Kingdom, Glasgow (Scotland) opened an anaerobic digestion facility to convert organic landfill waste into methane for electricity generation, with the goal of powering nearly 26,500 households annually.[21] Exeter (England) was developing its first solar-plus-storage project in 2020, consisting of a 1.2 MW ground-mounted solar array co-located with a 1 MW / 2 MWh battery to provide electricity for city council operations.[22]

As of 2020, Athens (Greece) planned to install solar PV systems on 50 schools to cover all school electricity needs in the municipality, and Kaunas (Lithuania) planned to install systems on 77 city buildings, including schools and healthcare facilities – both with support from their respective national governments.[23] Tychy (Poland) announced plans to add hundreds of renewable energy systems, including 647 solar PV systems, by the end of 2021 to improve local air quality and reduce energy costs.[24] In Bordeaux (France), a 59 MW plant under construction on the site of a former landfill was expected to produce the equivalent of 28% of the city's electricity consumption when completed.[25]

In **Asia**, much of the city-focused activity has occurred in India, where several "smart cities"[i] have embraced renewables. In 2018, Diu Smart City became the country's first city to operate on 100% renewable electricity, thanks in part to a 9 MW solar PV park and solar panels installed on 79 government buildings; several other smart cities issued tenders in 2019 and 2020 for local solar PV capacity atop buildings, canals and sewage treatment facilities.[26] In Delhi, solar PV installations on government and educational buildings totalled around 105 MW in 2019, with another 5 MW on residential buildings.[27] By the end of 2019, the industrial city of Pune had more rooftop solar capacity (130 MW) than any other Indian city.[28] Across India, the higher electricity rates, readier access to financing and larger rooftops for industrial versus residential users have encouraged the industrial adoption of solar PV.[29]

Urban consumers in many other Asian countries have opted for solar PV rooftop systems. Hong Kong Disneyland (China) installed a 1.8 MW system that became viable after local utilities introduced a feed-in tariff scheme to help achieve Hong Kong's green goals.[30] In Malaysia, supermarkets, retail chains and one of the world's largest solar glass manufacturers (Xinyi Glass Holdings) launched projects or plans for substantial urban rooftop capacity during 2019 and 2020.[31]

In **Latin America**, falling solar PV system costs have propelled significant investments in several cities. The government of Mexico City (Mexico) installed rooftop solar PV on some municipal buildings in 2020 as part of the city-wide initiative Solar City.[32] Private consumers in the region also have embraced solar PV, with Walmart deploying systems on its Mexican stores in Aguascalientes, León, Puebla and Salamanca.[33] In Colombia in 2020, Bancolombia installed nearly 2,000 solar panels at its headquarters in Medellín, and in Bogotá the Diverplaza mall inaugurated a solar PV system with nearly 700 panels.[34] In Brazil, Uberlândia nearly tripled its solar PV capacity between mid-2019 and mid-2020, to nearly 50 MW, making it the nation's top city for solar PV.[35]

Across **Africa**, municipal governments as well as large commercial and industrial actors have deployed a significant number of distributed renewable energy systems to ensure reliable and affordable electricity supply (→ *see City Snapshot: Cocody*).[36] During 2020, several solar power projects were being developed in Libya to reinforce local grids and ensure security of supply, including in Benghazi, Kufra, Rajban, Sebha, Tripoli, Ubari and Zintan.[37] In the Democratic Republic of the Congo, the city of Goma inaugurated a 1.3 MW hybrid solar power plant (with a storage system) and distributes electricity to the local community via a mini-grid.[38] Egypt's New Administrative Capital east of Cairo planned to install rooftop solar PV systems on 65 municipal buildings starting in 2020.[39]

Private sector solar PV projects in Africa included the 2019 installation of the first system in Tatu City (Kenya) atop the headquarters of Dormans Coffee, and the installation of an off-grid system on the Windhoek (Namibia) production facility of beverage multinational Coca-Cola.[40] The furniture manufacturer Maroc Bureau installed solar panels on its factory rooftops in Casablanca and Rabat (both Morocco) In 2020.[41]

i See Glossary for definition.

COCODY

CÔTE D'IVOIRE

Land area (km²)	Population size (2018)
135	800,000

The City of Cocody, located north of Abidjan on the coast of Côte d'Ivoire, released its Green City Plan in 2017, pledging to reduce carbon emissions 70% by 2030 to combat climate change. The city established the pledge to complement efforts to achieve the national goal of 42% renewable electricity generation by 2030, as put forward in Côte d'Ivoire's 2016 Nationally Determined Contribution towards reducing emissions under the Paris Agreement. Achieving the city's emissions reduction target will be challenging due to Cocody's rising energy demand, which is caused largely by rapid urban development and economic growth.

Cocody Green City is an ambitious plan that aims to minimise local greenhouse gas emissions while also creating 100,000 direct jobs and 400,000 indirect jobs, promoting women's empowerment and increasing citizen participation in adopting sustainable living. This community-based climate action plan aims to reduce CO_2 emissions by up to 90% by 2030, using renewable energy and carbon sequestration efforts. The city has set up a Reforestation and Carbon Sequestration Program that includes the development of green spaces and the restoration and replanting of 2 million mangrove trees to protect local climate health.

The Green City plan takes a holistic approach towards upgrading energy use and generation, transport, habitat restoration and land use, conservation and protection of water resources, community sensitisation and adoption. As of 2017, 23 measures were under development, including using solar energy to power large public buildings, installing 5,000 solar lamp posts, installing 1,600 solar traffic lights at 400 crossroads and supplying 200,000 solar PV power kits to households. Other measures to reduce carbon emissions include distributing to households 300,000 efficient cook stoves that run on ethanol procured locally from sugarcane manufacturers, producing 1,000 solar dryers for community women, distributing solar water heaters and setting up four wind farms on the banks of Ebrie lagoon.

The Cocody Green City plan also emphasises the development of sustainable transport and mobility plans through a Transport Demand Management scheme that aims to remove 1,000 old vehicles annually from city roads to improve local air quality and eliminate some 50 million tonnes of CO_2 emissions per year. In addition, a used vehicle repair centre has been created to provide 100,000 catalytic exhaust systems for polluting vehicles.

Source: See endnote 36 for this chapter.

In the **Middle East**, as part of the Shams Dubai Initiative, the Dubai Electricity and Water Authority (United Arab Emirates) connected more than 1,300 solar PV installations (totalling 125 MW) on residential, commercial and industrial buildings across the city by the end of 2019.[42] As of 2020, Israel's Tel Aviv Solar Roof Project aimed to install solar PV systems on the roofs of residential and commercial buildings in the city to reduce living costs for residents and to protect the environment.[43]

Renewable power systems also have been installed at places of worship in the Middle East and North Africa (as well as elsewhere).[44] As of 2019, around 500 mosques in Jordan were relying on on-site solar power, thanks to a national initiative that aims to extend solar PV to most of the country's 6,500 mosques (as well as its smaller number of churches) to reduce energy costs and increase awareness of renewables.[45] In Casablanca (Morocco), the Hassan-II Mosque, Africa's largest, was undergoing extensive renovations in 2020 to install solar PV panels and reduce the building's energy use by more than half.[46]

In **Oceania**, the University of Monash (Melbourne), Australia's largest university, installed its first on-campus solar panels in 2010, and in 2019 it launched a Net Zero Initiative to achieve 100% renewable energy by 2030.[47] The university aims to transform its four domestic campuses to operate fully on renewable electricity (including converting all buildings, appliances and vehicles to electricity), relying as much as possible on on-site solar systems.[48] One of Australia's largest behind-the-meter solar installations, a 12 MW solar farm at Melbourne airport, was nearing completion in 2020.[49] Several other towns and cities nationwide, including Mosman, Greater Shepparton and Shoalhaven, have installed rooftop solar PV on local sports facilities.[50] As of early 2020, New Zealand's then-largest solar array (1.17 MW) was being built atop Foodstuffs North Island's distribution centre in Auckland.[51]

GREEN TARIFFS

In cities where this option is available, numerous urban electricity consumers are participating in green tariff programmes, purchasing electricity from traditional utilities along with associated renewable energy certificates or RECs (in the United States) and guarantees of origin or GOs (in Europe)[i] (→ *see Box 2*).[52] Commercial and industrial customers have driven most of these green tariff deals, but local governments are playing a role as well, often with a preference for deploying projects nearby that can provide local economic and environmental benefits.[53]

As of 2019, consumers in more than 80 cities and communities across 16 US states and Washington, D.C. were purchasing renewable electricity via green tariff programmes, for a combined total of nearly 8.6 billion kWh annually.[54] In early 2020, Charlotte (North Carolina) became the most populous US city to procure renewable electricity through a green tariff programme; the city is partnering with developers on a 35 MW solar PV project, and the utility Duke Energy will purchase the generated electricity and deliver it to Charlotte.[55]

In Europe, the market for GOs reached record levels in 2018 (latest data available).[56] Although corporations account for nearly all green electricity purchases, commercial businesses and residential consumers as well as local councils and government departments have turned to green tariffs to claim larger shares of renewable electricity (→ *see Citizen Participation chapter*).[57] Bedford Borough Council (UK) plans to rely on GOs from the local energy supplier to operate all council-owned and operated buildings as well as street lighting on 100% renewable electricity starting in April 2021.[58]

Melbourne, Australia

There are
thousands
of on-site renewable energy projects in cities, ranging in capacity from a few kilowatts to hundreds of megawatts.

i RECs and GOs are electronic certificates that verify that a specific amount of electricity corresponds to electricity from a specified renewable source. See Glossary for definitions.

BOX 2. RECs/GOs and Questions of Additionality

The concept of "additionality" originated in greenhouse gas project accounting and has been adopted by the renewable energy community to describe purchases of renewables that drive incremental (additional) investment and capacity and, perhaps, investment that otherwise might not have occurred. For accounting purposes, the concern is to avoid double-counting of credits for renewable energy and, at a minimum, to avoid the circumstance where purchases of RECs and GOs actually displace or undermine new and local capacity expansion.

The purchase of unbundled RECs/GOs (RECs or GOs purchased separately from the associated energy production) can undermine claims of additionality. The ample supply and resulting low prices for RECs/GOs further limits their support for the construction of new capacity. Therefore, while RECs and GOs provide a convenient way to lay claim to a share of the renewable energy supply, there is a risk of consumers claiming credit for renewable energy that is already being supplied or planned for service to other consumers.

In 2020, the Belgian renewable energy supplier Bolt returned 1,000 GOs to the Icelandic government in protest over the GOs' potential adverse impacts on Belgium's renewable energy market. Because all electricity in Iceland is renewable, no local GO market exists, and the country also is electrically isolated from the European power market. Yet, in accordance with EU market rules, GOs for electricity consumed in Iceland have been sold to suppliers of non-renewable electricity in Europe, enabling these suppliers to claim their product as "green energy" without any additional renewable energy being generated. Bolt claimed that this "greenwashing" both misleads consumers and undermines the actual renewable energy market in Belgium.

In other instances, the marketing of unbundled credits can lead to credits issued without the associated energy ever being produced. For example, in 2015 Luxembourg and the Netherlands had the highest share of consumers opting for green tariffs, yet both countries lagged in meeting their renewable energy targets. Although energy suppliers in these countries were selling a high number of GOs to customers, this did not translate into added domestic renewable electricity generation.

Many large corporations have achieved their renewable energy targets through purchases of RECs/GOs. However, as other cost-competitive options for purchasing renewables have become available, corporate actors are shifting towards sourcing options that allow them to play a more active role in adding new renewable capacity to the grid. Corporate power purchase agreements gained considerable momentum in the late 2010s, particularly in the United States and Europe. Still, the additionality of some PPAs, especially off-site, has been brought into question.

For example, Dutch Railways (Nederlandse Spoorwegen, NS) states that its customers' travel is "climate neutral" thanks to a recent offshore wind PPA. However, just over half of the company's renewable energy demand is supplied by projects in the Netherlands, while the remainder comes from wind parks in Belgium, Finland and Sweden. These wind parks were tendered and subsidised by their respective national governments, which are bound by their own renewable energy and emission reduction targets. It is thus debatable to what extent the PPA that NS signed has led to additional renewable energy capacity, especially on the Dutch grid.

The additionality discussion has extended beyond electricity, particularly since late 2018 when the demand for "green gas" certificates and GOs started growing. In the United Kingdom, a consumer buying a green gas certificate cannot claim to have directly produced "additional green gas". Because additionality is a difficult thing to prove under any circumstance, both credibility and transparency are key when making an additionality claim about renewable energy.

Source: See endnote 52 for this chapter.

Corporate actors

are shifting towards sourcing options that allow them to play a more active role in adding new renewable capacity to the grid.

Flevoland, Urk, Netherlands

POWER PURCHASE AGREEMENTS (PPAS)

City actors have **signed PPAs** for increasingly large amounts of renewable energy for both municipal operations and city-wide use.

Cities were responsible for thousands of megawatts of new renewable energy capacity procured through PPAs during 2019 and 2020, either already in operation or under development.[59] In the United States and Europe, city actors have signed PPAs for increasingly large amounts of renewables for both municipal and community-wide use.[60] Most existing PPAs are for off-site capacity, although the use of PPAs for on-site urban projects also has increased, and municipal governments often stipulate that projects be constructed close enough to provide local jobs and other benefits.[61] Towns and cities also have pooled their resources to negotiate more favourable terms.[62]

For local governments in the United States, off-site PPAs between cities and developers of large-scale projects accounted for the vast majority (90%) of new renewable power capacity from 2015 to early 2020.[63] During 2019 and 2020, local governments in at least 11 states signed 57 PPAs for off-site projects, totalling more than 3,730 MW of capacity; of this, nearly 80% was solar PV and the rest was wind and geothermal power capacity.[64]

Los Angeles (California) entered into a PPA in 2019 for what was then the largest solar and battery storage system in the country (400 MW / 1,200 MWh), at the then-lowest price for solar-plus-storage of less than 2 US cents per kWh.[65] Other US cities that have contracted for large solar capacity include Chambersburg (Pennsylvania), Cincinnati (Ohio) and Montgomery (Alabama).[66] In Florida, the first two (totalling 149 MW) of five planned solar PV plants began operating in 2020 under a PPA between the project developer and Florida Municipal Power Agency in partnership with 16 municipal utilities.[67] By aggregating the demand from multiple Florida cities, the project was able to deploy larger, more efficient facilities to minimise costs to consumers.[68]

In Europe, the number of annual PPAs for solar PV at the municipal level increased six-fold between 2016 and 2018 – rising from 66 to 399 – but then declined to around 300 in 2019 and to just over 200 in 2020.[69] Examples include a PPA between London (UK) and Voltalia in 2020 for an off-site 49 MW solar farm in Dorset; a contract for a wind farm in Motilla del Palancar (Spain) designed to create local jobs and provide electricity to the city; and a PPA for one-third of the output of Åndberg wind farm in Sweden to provide 250 GWh annually to the municipal utility in Skellefteå.[70] City airports in Europe – such as Bristol Airport (UK) and Frankfurt International Airport (Germany) – also have signed PPAs for offshore wind power to meet their electricity needs.[71]

In Australia, PPAs negotiated in several major cities in 2019 and 2020 are aimed at helping to achieve ambitious renewable energy goals. Adelaide plans to power all of its municipal operations with solar and wind energy, and in Melbourne seven large energy consumers signed a joint 10-year wind energy contract.[72] Sydney entered into a 10-year PPA requiring, among other things: that all solar PV and wind power projects be new capacity and located in New South Wales to reduce the marginal loss factor (particularly losses in electricity transmission) and create regional jobs; that the facilities achieve a combined 80% load matching[i]; to include a demand-response option for consumers; and that at least one project be community-operated.[73]

OVERCOMING CHALLENGES: PARTNERING WITH STAKEHOLDERS AND TAKING CONTROL OF SUPPLY

Although city governments often are more active in supporting renewable energy than national ones, they also are limited by laws and regulations issued at the national and state/provincial levels. These higher-level policies and regulations, as well as decisions by utilities, can create roadblocks to cities' renewables goals and commitments.[74] Cities have sought to address these challenges in a variety of ways, including by: influencing policy or regulation at higher levels of government (often in partnership with other stakeholders); partnering with utilities; municipalising local utilities; and launching community choice aggregation programmes (→ *see Citizen Participation chapter*).

Influencing higher-level policy and regulations

Several city governments have engaged with or challenged higher levels of government to remove legislative or regulatory barriers to local renewable energy production and procurement. For example, in 2017, Cape Town challenged the government of South Africa in court to release the city from having to procure coal-fired electricity from the centrally controlled national energy utility (Eskom) and to enable it instead to procure electricity from independent power producers.[75] In late 2020, the country's Department of Mineral Resources and Energy took a landmark step by amending national electricity regulations to allow municipalities in good financial standing to deploy their own electricity generation projects (→ *see Feature chapter*).[76]

City governments across the United States have partnered with community stakeholders, other cities and towns, and/or legislative or regulatory bodies at higher levels of governance to remove laws and regulations that restrict the deployment and use of renewables, or to enact new measures that encourage or require greater procurement of renewable electricity.[77] By one estimate, between early 2019 and early 2020, 24 US cities took at least 27 actions – including submitting comments on public utility commission proceedings, launching community choice aggregation programmes and formally partnering with electric utilities – to advance energy efficiency and renewables in the power sector.[78]

i This means that the combined electricity output of the wind and solar power facilities should, on average, achieve an 80% match to the electricity load (demand) profile of the city.

Several cities have **challenged** higher levels of government to remove legislative or regulatory barriers to local renewable energy production and procurement.

The US state of Virginia until recently limited the ability of many communities to purchase renewable energy. In response, localities worked to influence state-level regulations and policies, engaging with utilities to develop green tariff options and to reduce premiums on renewable energy programmes, and pooling their buying power with other cities, corporations and universities to demonstrate strong local demand for renewables.[79] Partly as a result of such efforts, in early 2020 Virginia committed to 100% zero-carbon electricity by 2050 and removed key restrictions on solar PV installations for local governments, businesses and others.[80]

Partnering with utilities

Increasingly, city governments have leveraged their status as large electricity consumers (sometimes in partnership with other cities) and worked directly with investor-owned utilities to encourage them to increase renewable energy generation.[81] A number of cities with renewable energy targets have formed productive partnerships with their local utilities, often collaborating to achieve shared goals for the deployment of renewables and energy efficiency technologies.[82]

Minneapolis (Minnesota) was among the first large US cities to partner with local utilities on increasing renewable power capacity to achieve a 100% renewable energy goal.[83] Several cities have since followed suit. In 2019, Denver (Colorado) entered a formal partnership with the utility Xcel Energy to achieve shared energy and climate goals through energy retrofits and renewable electricity procurement.[84] In Utah, after a three-year collaboration, Salt Lake City, Park City and Summit County, along with investor-owned utility Rocky Mountain Power, announced the passage in 2019 of the state's Community Renewable Energy Act, which allows the utility to work with communities to tailor electricity portfolios to meet their renewable energy targets.[85]

In several European cities – including Heidelberg and Munich (both Germany) – inhabitants are working with their municipally owned utilities to achieve renewable energy goals.[86] For example, Munich's municipal energy provider SWM is a co-owner of the DanTysk offshore wind farm, which is helping the city achieve its goal of being fully powered by renewable electricity by 2025.[87]

Municipalising local utilities

City governments that own their own utilities – such as Austin (Texas, US), Basel (Switzerland), Copenhagen (Denmark), Munich (Germany) and many others – have greater control over their energy sources and can provide renewables to their customers directly.[88] Although municipal utilities may have less financial clout than their larger national or private counterparts, due in part to their smaller scale, they also have the potential to quickly implement goals that are aligned with customer demands.[89]

Several cities have (re)municipalised their electricity systems (or debated doing so) in order to pursue renewable energy options.[90] In 2017, Barcelona (Spain) approved the creation of Barcelona Energia, the country's largest public electricity distributor.[91] Barcelona Energia, whose mission includes promoting locally produced renewables, began supplying renewable electricity to city council buildings and facilities as well as other entities in 2018, and to the general public in 2019.[92] Barcelona has inspired city councils in other Spanish cities, including Cádiz and Pamplona, to opt for similar models.[93] Additional cities that have pursued or considered (re)municipalisation include Berlin and Hamburg (both Germany), Hebron (Israel), Madrid (Spain), and the US cities of Chicago (Illinois) and San Francisco (California) (→ *see Citizen Participation chapter*).[94]

CONSUMPTION OF ELECTRICITY

Based on their estimated share of global energy demand (around 75%), cities may account for the same share of global electricity consumption (around 20,000 terawatt-hours, TWh).[95] Assuming that renewable electricity use in cities mirrors the global average share of supply[i] (an estimated 27.3%), then overall city consumption of renewable electricity could total around 5,500 TWh annually.[96] However, this figure may well be higher, to the extent that cities have successfully increased their renewable electricity supply relative to rural areas (through either committed external supply or local generation).

Differentiating city demand for renewable electricity from regional or national consumption patterns remains challenging, in part because most cities draw the majority of their electricity from regional or national grids. Even as more cities strive to increase their production and procurement of renewable electricity, city-wide accounting of renewable electricity consumption is lacking. In instances where cities do report this consumption, many (if not most)[ii] simply use local grid averages as a proxy for the city-wide electricity mix. Moreover, data on city-specific renewable energy achievements often refer only to the municipal load (city government and services) rather than to city-wide demand.[97]

i This first-order estimate makes no adjustment for any structural differences in average electricity consumption patterns between urban and ex-urban/rural areas, between relatively city-oriented demand (e.g., wastewater treatment and water supply, street lighting and traffic signals, data centres and general cooling load) and perhaps more predominantly ex-urban activity, such as energy-intensive industry (e.g., metals manufacturing).

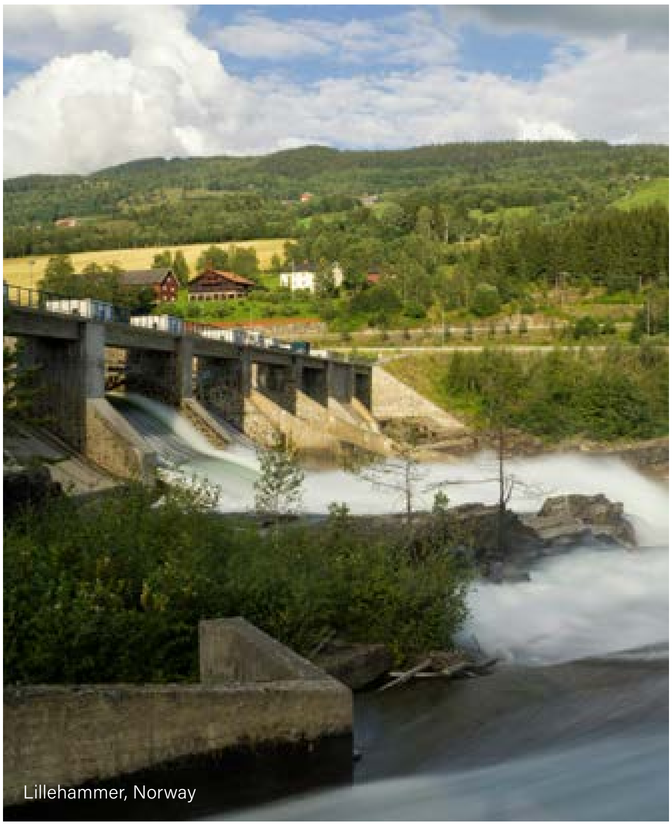
ii For example, data from CDP reflect that most cities that qualify/comment on their reported values note them as being regional or national values, based on local/regional grid data.

Further complicating the picture, city governments define their renewable energy commitments in different ways, with some specifying renewable shares of the electricity mix within a given time frame, some specifying commitments in terms of carbon reductions or carbon neutrality, and others specifying certain technologies. In some cases, cities have deployed solar and/or wind power capacity in connection with their wider city plans and have set targets to deploy even more (→ *see* ***Reference Table R6***).

Cities that already have high or rapidly rising shares of renewable electricity use can be divided into two distinct groupings. In one group are cities that benefit from large existing or rapidly rising renewable electricity supplies on regional and national grids, regardless of their own efforts to affect change to the electricity mix. Where renewable supply is already high, this is often due to plentiful and economical hydropower. In such cases, further rapid expansion of renewable electricity use may be somewhat limited, although many cities – including Montreal (Canada), Oslo (Norway), Reykjavik (Iceland), São Paulo (Brazil), Seattle (Washington, US) and Zurich (Switzerland) – are filling in the balance of existing and incremental demand with new and diverse renewable electricity supplies.[98]

In the other group are cities (and their surrounding areas) that are not endowed with grid-supplied hydropower but have greatly advanced their use of local renewable energy (particularly solar PV and wind power) to achieve technical proficiency and economic competitiveness, sometimes despite substantial resource and cost constraints. Examples include many interior US cities, such as Austin and Dallas (both Texas), Denver (Colorado), Iowa City (Iowa) and Kansas City (Missouri), as well as Adelaide and Canberra (both Australia) and Copenhagen (Denmark).[99]

In all cities, the renewable energy supply grows at least in proportion to the expansion of renewables on the regional grid, but additional local commitment further increases the renewable share for the city, and for the regional supply mix as well. Examples of this interaction between internal and external effects are found in the US state of Texas, where the regional renewable electricity supply expanded from 19% of net generation in 2019 to 22% in 2020.[100] This advancement is driven in part by local efforts and initiatives that directly affect both local and regional supply. Houston, located in Texas' oil and gas heartland, has increased its renewable energy use beyond grid-supply averages: in 2020, the city government began purchasing enough renewable electricity to meet its entire municipal requirements (around 3% of total city demand), in line with its Climate Action Plan.[101] Meanwhile, Austin (Texas), which retains its own municipal utility and thus has significant autonomy in procurement decisions, exceeded the regional average to reach 43% renewable electricity consumption in 2019.[102]


Lillehammer, Norway


Lofoten village, Norway

HEATING AND COOLING: PRODUCTION AND PROCUREMENT OF THERMAL ENERGY

Municipal governments and other city entities are deploying modern[i] renewable energy systems to generate thermal energy for space and water heating as well as cooling in buildings, and for process heat in industry. Modern sources of renewable heating and cooling include direct thermal energy from renewable sources (through the combustion of solid, liquid and gaseous biofuels, as well as energy from geothermal and solar thermal sources) and renewable electricity, which is used to operate heating appliances, such as heat pumps.

Although urban production and procurement of renewable thermal energy is not at the scale of renewable electricity[ii] in most cities, an increasing amount of direct thermal renewable capacity is being installed for use on-site, in stand-alone applications for individual buildings, and to feed into district energy systems that connect multiple buildings. Tracking these market trends and opportunities is difficult due to a lack of city-level data (and the fact that some heating and virtually all cooling consumption is electrically driven); however, new capacity has been added in cities around the world, driven by building mandates, fiscal incentives, and other support policies, as well as plans to phase out or ban the use of fossil fuels for heating (→ *see Urban Policy Landscape chapter*).[103]

Stand-alone renewable energy systems use a variety of technologies and typically include solar thermal systems and modern biomass stoves and boilers (fuelled by, for example, wood pellets and forestry or agricultural residues, such as bagasse and straw). In addition, renewable electricity can be used to heat or cool with electrically driven appliances such as heat pumps. In urban areas, stand-alone systems have been installed on rooftops, façades and outside of buildings.[104]

While thousands of stand-alone thermal systems have been deployed around the world, consolidated data on how many of these are in cities are not available. In China, the chemical company Solvay installed a biomass boiler at its facility in Zhangjiagang in 2019 to switch from natural gas to renewables, and six large solar thermal systems were completed in five other cities to provide hot water for schools (in Hangzhou and Zhejiang), an office building (in Shanghai) and several large blocks of flats (in Hangzhou, Linyi, Nanchang and Zaozhuang).[105] In Turkey, solar hot water systems have been installed at several prisons, including in Diyarbakır in 2019.[106] Stand-alone solar thermal systems also are popular in German cities, especially for multi-family buildings, with new projects completed in Heilbronn and Regensburg in 2020.[107]

Markets for heat pumps have expanded rapidly, meeting an estimated 5% of the global heating demand for commercial and residential buildings in 2019.[108] Heat pumps require energy input (typically grid electricity) to power the transfer of thermal energy, which makes up a portion of the total energy output. For a heat source (or a heat sink in cooling mode), heat pumps can use ambient air, surface water bodies (lakes and rivers) or the ground (whether dry or water-coupled to aquifers). Electrically driven heat pumps serve as a bridge between variable renewable electricity supply (mostly solar PV and wind power) and the demand for heat, which traditionally has been met mainly through the combustion of fuels. The benefit is two-fold: allowing variable renewable energy to supply the heat market, while allowing the heat market to act as a regulating demand-buffer, which helps integrate ever larger shares of variable renewables into the electricity mix.[109]

Most heat pumps are relatively small stand-alone units serving individual or a small group of dwellings, although a growing number of district heat systems use heat pumps to tap low-temperature sources on a large scale, such as rivers or wastewater streams. Although both air- and ground-source heat pumps (the two most common applications) are very effective, ground-source units can have an efficiency advantage for heating because of the relative constancy of ground temperatures. In 2019, ground-source heat pumps represented 167 TWh (600 gigajoules, GJ) of global heat supply.[110]

In October 2020, a ground-source heat pump was installed in the first of 60 existing homes in Blackbird Leys, Oxford (UK); the project's heat pumps are connected to a series of boreholes incorporating communal ground arrays.[111] Later phases in Oxford will see up to 240 new-build homes, and potentially various commercial properties, fitted with ground-source heat pumps.[112] Similar initiatives were implemented in Drammen (Norway) and in Glasgow (UK) in 2019.[113] In Toronto (Canada) a ground-source heat pump system to provide heating and cooling for a new 600-unit apartment complex was completed in 2019.[114] That same year, Belgrade (Serbia) presented its long-term district heating and cooling plan, which builds on large heat pumps.[115]


Tavira, Portugal

i Excluding the traditional use of biomass for heating and cooking. See Glossary for definition.

ii Note, however, that electricity accounts for the vast majority of global cooling demand, and for a growing amount of heating demand.

District energy systems, which provide thermal energy to residential, commercial, public and industrial buildings, generally are located in densely populated urban areas. Existing district heating and cooling systems can be upgraded, or new networks can be created, to enable the integration of renewable energy technologies. Renewable district heating and cooling can be provided by sustainable biomass, geothermal, solar thermal, renewable gases and heat pumps operated using renewable energy.[116]

District energy systems supplied around 6% of global heat consumption in 2018.[117] Fossil fuels were the dominant energy source for district heating and cooling networks that year, with renewables accounting for only an estimated 8%.[118] However, the renewable contribution is growing: between 2009 and 2018, renewable energy use for district energy increased more than two-thirds, due largely to the shift from fossil fuels to bioenergy in the EU.[119] In addition, cities increasingly have used urban waste in waste-to-heat plants to deliver thermal energy through district networks, and have taken advantage of waste heat from industrial processes (which is primarily an energy efficiency measure).[120]

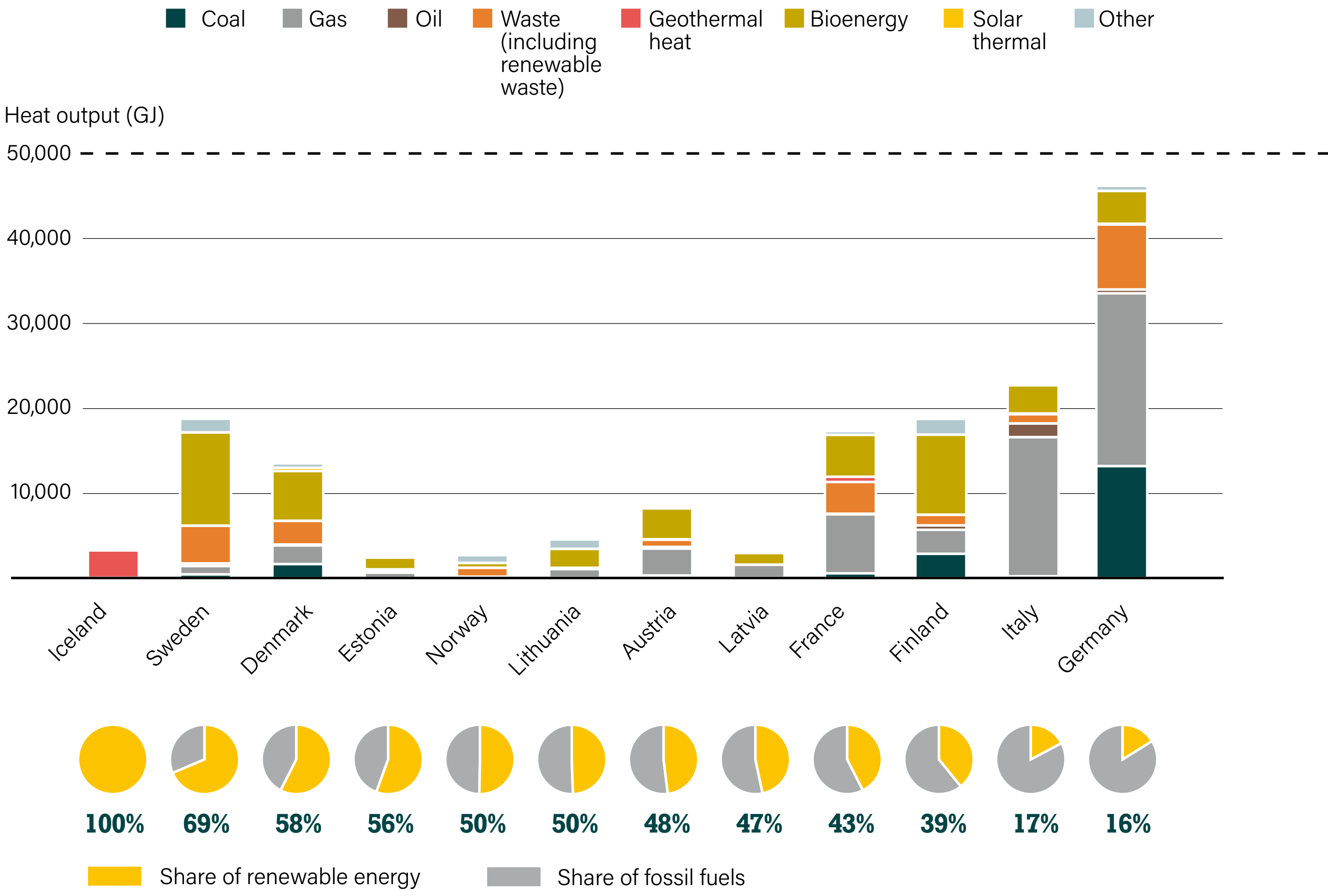
Each district heating system differs in its use of renewable energy. Because virtually all district heat systems serve urban areas (where population density makes the systems economical), it can be assumed that virtually all energy use in such systems reported in national data represents the energy demand of cities.[121] The Russian Federation and China dominate in total production of district heating (relying heavily on natural gas and coal), followed by Germany, the United States and Ukraine.[122] In Iceland, renewable energy supplies nearly 100% of the country's district heating needs and is derived mostly from high-temperature geothermal energy (plus some renewable electricity).[123] Other countries with high renewable shares in district heating include Sweden (69%), Denmark (58%) and Estonia (56%) (→ *see Figure 13*).[124]

Cities are starting to use a diversity of renewable thermal sources in their **district heating networks.**

Although many cities are starting to use a diversity of renewable thermal sources (as well as renewably powered heat pumps) for district heating, **bioenergy** is the most widely used renewable energy source in these networks, with an estimated 95% share.[125] Europe is home to most of this capacity (representing 87% of all biomass used for renewable district heating), where it continues to expand.[126] In 2019, the local district heating network of Lyon-Confluence (France) was connected to the central network of Lyon, and a new 51 MW biomass plant was commissioned to supply the networks.[127] Salaspils (Latvia) inaugurated a wood chip boiler as well as a 15 megawatts-thermal (MW_{th}) solar field in 2019, which together meet 90% of the district heating demand.[128] The district heating system In Oslo (Norway), which covers a quarter of the city's total heating demand, has shifted almost entirely (around 99%) to renewables, including biomass from residual waste.[129]

The number of **solar** district heating systems increased significantly in 2019, particularly in Denmark, Germany and China.

Figure 13. Renewable Share of District Heating, by Fuel Source, Top Countries, 2018



Note: "Other" includes waste heat recovery, non-renewable electricity, nuclear and any source not otherwise accounted for.

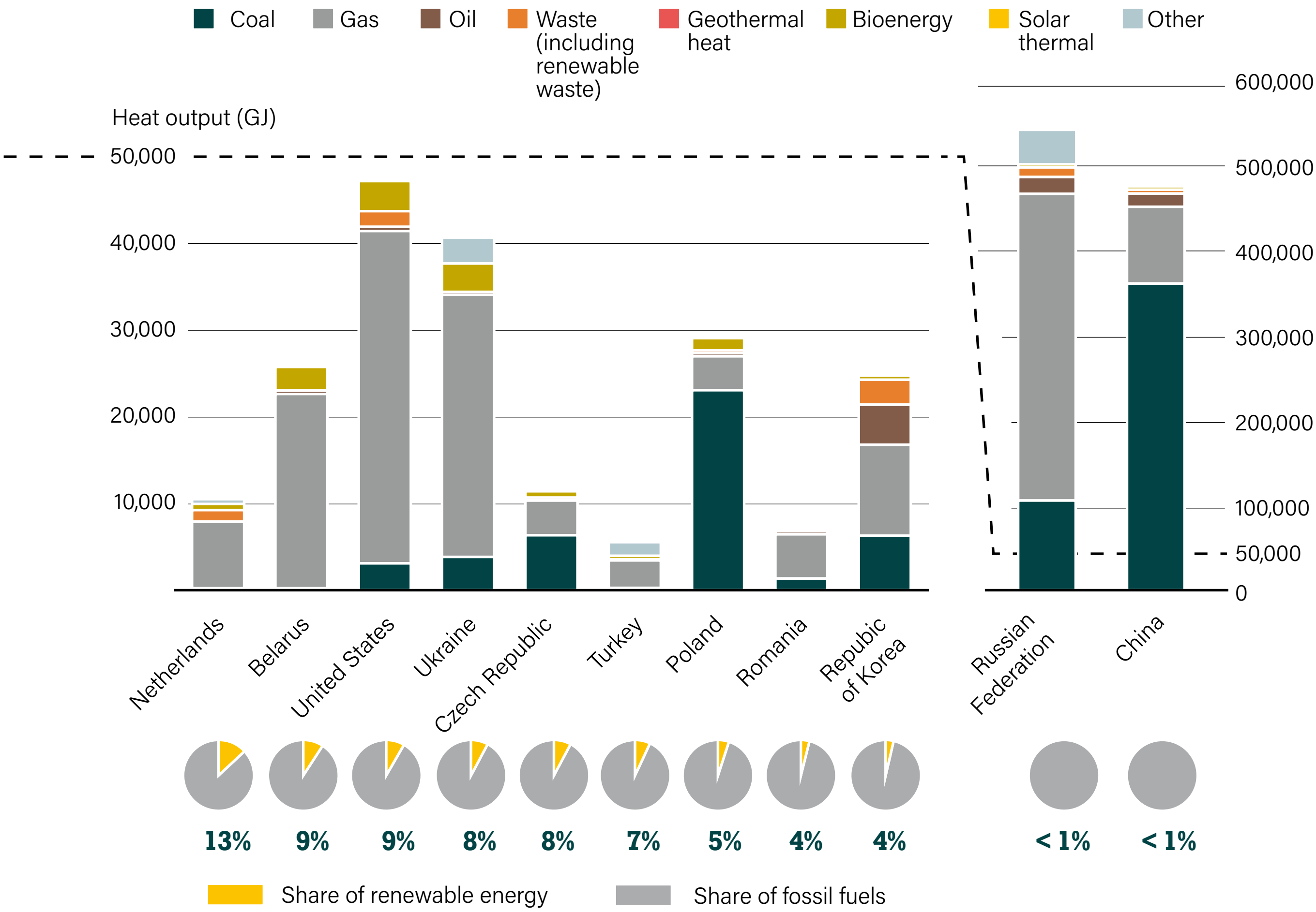
Source: IEA. See endnote 124 for this chapter.

By year's end, at least 417 solar district heating and central hot water systems were in operation worldwide (up from 345 systems in 2018), with a cumulative capacity of more than 1.7 gigawatts-thermal (GW_{th}) (including glazed and concentrating solar thermal collectors).[130]

In Denmark, the world leader in solar district heating capacity, 10 new plants were brought online in 2019 and 5 were expanded, for a total of 134 MW_{th} added; altogether, more than 113 Danish villages, towns and cities use solar heat in their district systems.[131] In Germany, six new solar district heating systems (totalling 9.9 MW_{th}) were added in 2019, and the country's largest solar district heating plant (10.4 MW_{th}) was under construction in Ludwigsburg.[132] In China, three solar district heating systems were commissioned in the Tibetan towns of Shenzha, Zhongba and Saga in late 2019.[133] Additional projects under construction worldwide included solar fields in the district heating networks of at least three Croatian cities near Zagreb in 2020.[134]

Direct use[i] of **geothermal** energy can meet various thermal energy demands in cities, including space heating and hot water supply. In 2019, geothermal direct use capacity totalled an estimated 30 GW_{th}, supplying 117 TWh (421 petajoules) of thermal energy.[135] Direct use of geothermal energy harnesses medium- to high-temperature geothermal fluid either directly or by direct transfer via heat exchangers. The majority of high-temperature geothermal energy is devoted to space heating and personal hot water applications such as bathing and swimming, and can therefore be assumed to be concentrated in urban applications, predominantly using district heat systems.[136]

i This does not include the use of shallow geothermal resources, specifically ground-source heat pumps, and the renewable portion of their final energy output. Direct use refers here to deep geothermal resources, irrespective of scale, that use geothermal fluid directly (i.e., direct use) or by direct transfer via heat exchangers.



The use of direct geothermal heat for district heating systems has increased, particularly in China and in several European countries, including Germany, Hungary and Sweden (→ *see City Snapshot: Malmö*).[137] China's largest geothermal heating system came online in Fengxi New City (Shaanxi province) at the end of 2019, providing water heating and space heating and cooling for a combined buildings area of around 1.6 million m^2.[138] Additional district heating projects, using deep rock geothermal and waste water, are being planned in Chanba (Xi'an).[139]

In Munich (Germany), drilling was completed in early 2020 for a geothermal plant that exceeds 50 MW_{th}, which was expected to go online in 2021 and to supply heat for more than 80,000 residents.[140] In the Paris (France) region, district heating systems have gradually increased their geothermal heating capacity.[141]

Also in France, the community of Champs-sur-Marne launched a EUR 40 million (USD 45 million) district heating project in 2019, while Drancy and Bobigny started drilling four geothermal boreholes, with expected project completion in 2021.[142] Szeged (Hungary) continued to expand its geothermal district heating plant, and as of 2019 geothermal energy provided heat for 23 Hungarian towns, in some instances supplementing heat from natural gas on existing networks.[143]

Cities in Europe and in China have been increasing their **geothermal heating** capacity and use in district heating.

MALMÖ

SWEDEN

Land area (km²)
76.8

Population size (2018)
344,000

GHG
Greenhouse gas emissions (CO_2 equivalent)
52.7 million tonnes

The City of Malmö has a track record of urban development initiatives that have led to its recognition as a pioneering sustainable city. The most well-known examples in the city are the Western Harbour district (Västra Hamnen), which has operated on 100% renewables since at least 2012, and Augustenborgin, an industrial area that has 450 square metres of solar thermal panels connected to the central heating system.

Malmö's goal is to make all city government activities climate neutral by 2020 and to ensure that the entire city runs on 100% renewables by 2030. Malmö plans to achieve its 100% renewable energy goal from a mix of renewable sources, waste-to-energy and recycled energy. As of 2020, around 43% of Malmö's energy was from renewable sources[i], primarily wind energy.

The city has identified two challenging sectors that need to be addressed to stay on track to achieving the 2030 goal: transport and district heating. Sweden's substantial district heating network was built in the 1950s, and many cities in the country have extensive systems. Malmö's district heating system runs on a combination of biomass and fossil fuels. To help reduce fossil-based energy use, all of the municipalities in southern Sweden send their waste to Malmö, where it is processed and converted to heat that is fed into the district heating network. For example, at the Sysav waste-to-energy facility, the waste is reduced through thermal treatment processes to produce energy in the forms of electricity and heat.

Additionally, Malmö is constructing a 50 MW_{th} geothermal deep-heat plant[ii], which is expected to start operation in 2022. The city plans to build a total of five geothermal heat plants by 2028, each with an installed capacity of 50 MW_{th}, to replace the use of biofuels and biogas for heat generation. The estimated budget for this pilot project is EUR 5.4 million (USD 6 million), with the Swedish Energy Agency providing EUR 1.2 million (USD 1.34 million). The city's partners include E.ON, a privately owned energy supplier that is investigating the geological conditions, as well as the Swedish Geological Survey and the University of Uppsala.

Source: See endnote 137 for this chapter.

Malmö is replacing the use of biofuels and fossil fuels in heat generation with **geothermal heat** in order to achieve its energy and climate goals.

i This includes organic waste incineration and industrial waste heat.

ii Boreholes will be in the range of five to seven kilometres deep, and the temperature of around 160°C is expected to be sufficient to directly enter the district heating network. This project will be one of Europe's first geothermal power plants to extract heat from such a depth at the industrial level.

District cooling networks[i] are less widespread than district heating but are present in cities around the world, including Berlin and Hamburg (both Germany), Dubai (United Arab Emirates), Geneva (Switzerland) and Toronto (Canada), all of which have had operational networks for years.[144] Momentum is growing to expand existing cooling networks and to commission new ones, especially in Southeast Asia, the Middle East and Africa (→ *see Distribution Infrastructure section*).

Although relatively few district cooling networks rely on renewables, there are some exceptions, and systems that use heat pumps offer the potential to operate with renewable electricity. For example, in addition to the new geothermal heating plant, the utility in Munich plans to expand the city's district cooling network, using absorption chillers coupled to the geothermal supply.[145]

In 2019, Toronto (Canada) announced a new investment into its district cooling system (launched in 2004) utilising direct heat exchangers and the municipal water supply from Lake Ontario to cool hospitals, data centres, educational campuses, government buildings, and commercial and residential buildings.[146] In 2018, China's largest district heating and cooling network using river water and a water-source heat pump started running in public buildings in the Chongqing Jiangbeizui CBD, which covers more than 4 million m^2 of new residential areas.[147] However, such systems are mainly energy efficiency measures that displace energy demand rather than being examples of renewable energy use, with the exception of any renewables used to run heat pumps for cooling.

TRANSPORT

Globally, the share of renewable energy in transport was 3.7% in 2018, most of which was biofuels (3.7 exajoules, EJ) followed by renewable electricity (0.3 EJ).[148] The transport sector accounts for 29% of total final energy consumption and is responsible for 25% of global energy-related CO_2 emissions.[149]

More and more cities around the world are working to increase local production and consumption of renewable energy carriers such as biofuels, renewable electricity and renewable hydrogen[ii] in urban transport in order to reduce local air pollution and CO_2 emissions, and improve security of supply.[150]

In 2020, the COVID-19 health crisis deeply affected urban mobility patterns, as large numbers of people avoided public transport and altered other transport-related behaviours.[151] Lockdown measures resulted in sharp reductions in transport demand and in related air pollution in cities worldwide, prompting calls for a "green recovery".[152] In response, several cities initiated or strengthened efforts to ensure that communities have access to safe, reliable, affordable and sustainable transport[iii],[153]

Although COVID-19 restrictions and recovery packages so far have not led to structural changes in the production and use of renewable fuels in cities, the purchase and use of electric vehicles (especially electric bikes) increased throughout 2020, as did the share of renewables in electricity generation.[154]

PRODUCTION AND PROCUREMENT OF TRANSPORT FUELS AND ELECTRICITY

The majority of biofuels used in transport are **liquid biofuels**, namely 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).[155] However, the production of other diesel substitutes such as **renewable diesel**[iv], as well as **gaseous biofuels**, namely biomethane, is growing in many countries.[156] While most transport biofuel is produced outside of cities, organic waste generated in cities, including waste cooking oil, also is an important urban source of liquid biofuels and biomethane (→ *see Sidebar 5*).[157]

Although the production of transport biofuel was deeply affected by the COVID-19 crisis, some positive developments occurred at the city level during 2020.[158] Public authorities in Mexico City (Mexico), in partnership with the National Polytechnic Institute, built a biodiesel production plant that uses waste cooking oil from local households, food manufacturing facilities and restaurants to produce 500 litres of biodiesel daily, with the aim of fuelling 200 public transport vehicles.[159] In Venice (Italy), waste cooking oil began being collected and transformed into biodiesel for use by the local

i District cooling networks are centralised systems that provide chilled water to air conditioning systems.

ii Hydrogen produced with renewable energy, also referred to as "green hydrogen". See Glossary for definition.

iii These efforts have focused on promoting active modes of transport via the establishment of car-free zones and new infrastructure such as cycling lanes, bicycle parking and expanded walkways.

iv Renewable diesel is a diesel substitute fuel made by treating animal and vegetable oils and fats with hydrogen, also known as hydrotreated vegetable oil (HVO) or hydrotreated esters and fatty acids (HEFA).

BOX 3. Water Transport in Cities

Waterways are an important part of transport infrastructure for many cities around the world. They expand the capacity of urban transport systems while re-directing some road traffic. City efforts to improve urban mobility are expanding to public ferries, water taxis and other boat fleets, with some of these vehicles shifting to renewable energy, including liquid biofuels, renewable electricity and renewable hydrogen.

Although biofuels represent a promising renewable solution to decarbonise water transport, most projects to date have focused on international shipping rather than on city boat fleets. Still, a few city-level examples exist. In 2017, the New York City Council (US) passed legislation encouraging the use of biodiesel to power the city's ferries, and in 2018 the Red and White Fleet – a sightseeing and cruise ferry business in the San Francisco Bay Area (California, US) – began operating a plug-in hybrid ferry running on 100% biofuel, as part of its commitment to have a zero-emission vessel fleet by 2025. In 2020, Copenhagen (Denmark) received delivery of five electric ferries that use renewable diesel for heating.

Several other electric ferry operations have embraced renewable electricity. In 2020, a solar-powered water taxi began operation in Nusa Penida (Indonesia), and renewably powered ferries were being developed to serve commuters in Cardiff-Bristol (UK) and resort guests in Bora Bora (French Polynesia). In 2017, India's first solar-powered commuter ferry started operations in the Alappuzha district of Kerala state, and in Europe a car ferry with 15 solar panels began navigating the Moselle River between Oberbillig (Germany) and Wasserbillig (Luxembourg).

Globally, around 185 battery electric vessels were operating or scheduled for delivery as of 2018, 58 of which were passenger ferries. In 2020, two such ferries were being tested on the Chao Phraya River in Bangkok (Thailand), and once the trials are successful a new fleet of electric ferries is scheduled for roll-out in 2021 as part of a plan to cut air pollution and improve the city's image for visitors.

In Norway, several electric ferries rely on the country's high share of renewable electricity, and a new hydrogen-powered ferry is planned to start operating on the Hjelmeland-Skipavik-Nesvik route in Ryfylket in 2021. Another hydrogen ferry, being developed for the Oslo-Frederikshavn-Copenhagen route in Scandinavia, is expected to be fuelled with hydrogen produced by an electrolyser in Copenhagen (Denmark) using electricity from offshore wind turbines. In Brisbane (Australia), local companies began building fuel cell passenger ferries in 2020 that are expected to be fuelled with renewable hydrogen.

Source: See endnote 160 for this chapter.


Norway

transport company ACTV to fuel its lagoon boat fleet (→ *see Box 3* for additional examples of the use of renewables in water transport).[160]

Also in Italy, a former petrochemical plant in Gela was converted in 2019 into a renewable diesel production facility that can process up to 750,000 metric tonnes annually of used cooking oil, animal fat, other by-products and algae.[161] In the United States, Neste (Finland) has partnered with the City of Oakland (California, US) since 2019 to fuel the city's fleet with renewable diesel made from used cooking oil and other waste material sourced from businesses in the surrounding metropolitan area.[162]

Interest in **biomethane** has risen in several countries as well as in individual cities that aim to move towards a circular economy[i].[163] In 2020, the number of operating biomethane plants worldwide (both biogas upgrading and biomass gasification facilities) exceeded an estimated 1,000, with some 20% providing vehicle fuel, 60% injecting biomethane into the gas distribution network and the rest serving a variety of other local uses.[164] In 2020, a new biogas upgrading facility near Bakersfield (California, US) began using cow manure to produce biomethane to fuel heavy-duty trucks and buses.[165]

Although the use of **renewable electricity** in transport remains low, a few cities began coupling their transport electrification efforts with renewables in 2020. In The Hague (Netherlands), a new solar PV park opened to offset the electricity needs of the inter-city rail line connecting The Hague, Rotterdam and Zoetermeer.[166] Poznan (Poland) announced plans to transform local organic waste into electricity to fuel the city's electric bus fleets.[167] In the United Kingdom, Abbey Ecosse Limited secured permission to build an anaerobic digester and biomass boiler plant

i A circular economy is a closed-loop system in which the waste from one process is a resource that can be used as input for another. By having a flow of resources that is circular rather than linear, the production of waste is eliminated. See Glossary.

near Thurso (Scotland) that will use the waste from whisky distillation to produce biogas to generate electricity for EV charging in Caithness County.[168]

> Although many cities continue to support the production and use of biofuels,
> **electrification of transport**
> has been expanding rapidly.

Although more than 98% of today's **hydrogen** is produced from fossil fuels, interest in using renewable electricity for this process (currently less than 1%) is rising.[169] Several cities have turned to renewable hydrogen for transport fuel. In Fukushima (Japan), Toshiba and partners completed a 10 MW electrolyser in 2020 that uses electricity from solar PV to produce hydrogen for transport use.[170] Also that year, a consortium of businesses announced plans to build a 10 MW electrolyser to produce renewable hydrogen for fuelling buses and trucks in Copenhagen (Denmark).[171]

Hydrogen projects were under way at several urban ports during 2020. In the United States, a 2.3 MW hydrogen plant was being built to supply renewable hydrogen to Toyota's facilities at the port of Long Beach (California) and to fuel the company's fuel cell trucks and consumer vehicles.[172] The Port Authority of Santa Cruz de Tenerife (Spain) partnered with Hyundai Canarias and Enagás to build a facility to generate renewable hydrogen for transport use.[173] In the Arabian Sea port of Duqm, in Oman's Al Wusta governorate, a Belgian company was conducting a feasibility study in 2020 to build a hydrogen production facility powered by solar PV and wind energy.[174]

Hamburg, Germany

CONSUMPTION OF TRANSPORT FUELS AND ELECTRICITY

Urban transport consists of two main groupings: *passenger transport* – which includes rail (light rail and metro), road transport (buses, cars, two- and three-wheelers) and water transport (public ferries and water taxis) – and *freight transport*, including light-duty commercial vehicles and heavy-duty trucks. In 2015 (latest data available), urban transport accounted for around 40% of the energy used in the transport sector and contributed an estimated 37% of transport-related CO_2 emissions (32% from urban passenger transport and 5% from urban freight).[175]

In some cities, the transport sector consumes more energy than do the buildings or industry sectors, highlighting the importance of integrated measures to reduce transport demand, shift to more efficient modes, and transition to renewable fuels and electricity.[176] Despite recent efforts to develop local urban capacity to produce renewable energy carriers for transport, most cities continue to source their fuels and electricity from beyond city limits.[177] Of the energy carriers used in urban transport, biofuels and hydrogen are used mostly in heavy-duty transport (such as buses and trucks), whereas electricity use has now expanded beyond rail to all modes of public and private transport (→ *see Figure 14*).[178]

URBAN RAIL TRANSPORT

Rail boasts the highest renewable energy share of any transport sector, at 11%, and virtually all urban rail networks are powered by **electricity**.[179] As of 2019, nearly 200 cities worldwide had metro systems (with a combined track length exceeding 32,000 kilometres), and more than 220 cities had light rail systems (another 21,000 kilometres).[180] The length of urban rail lines expanded 3.5% annually on average between 2010 and 2019, with new metro systems opening in 46 cities (34 of them in Asia) and new light rail systems launched in 65 cities (28 in Europe and the rest split roughly evenly among Asia, North America, and the Middle East and North Africa).[181] Sub-Saharan Africa's first light rail systems entered into operation in Ethiopia in 2015 and Nigeria in 2018.[182]

As the most electrified transport sector, rail has benefited from rising renewable energy shares in the electricity mixes of many countries.[183] To specifically cover the electricity demand of their metros and trains, some city authorities also have started to install their own distributed renewable power capacity or to purchase or contract for new or existing renewable capacity, as has occurred in Delhi and Nagpur (both India), London (UK), Medellín (Colombia), Santiago (Chile), São Paulo (Brazil), Seattle (Washington, US) and Utrecht (Netherlands).[184]

To date, the testing of **hydrogen**-powered trains has focused mostly on regional/inter-urban systems, including in northern Germany and in the Dutch province of Groningen.[185] In Groningen and Friesland (Netherlands), some inter-urban trains also run on **biodiesel**.[186] In the United Kingdom, the first **biomethane**-fuelled trams started testing in Birmingham and in Warwickshire county in 2020.[187]

URBAN ROAD TRANSPORT: PASSENGER VEHICLES

Road transport contributes to urban congestion and local air pollution, leading to varying health impacts.[188] The severity of these impacts has driven municipal governments and other urban actors to pursue measures such as banning the circulation of fossil fuel vehicles, shifting to electric vehicles and encouraging the use of more-efficient transport modes such as renewables-based buses, among others (→ *see Urban Policy Landscape chapter*).

Buses

By 2020, over 3 million city buses were in circulation worldwide.[189] Diesel remained the most popular bus fuel, used in more than half of the world's buses, followed by electricity (17%), compressed natural gas (10.5%) and biodiesel (4.1%).[190]

During 2019 and 2020, some cities launched bus fleets that run on **biofuel** blends (although many more cities have opted for electric buses). In 2019, Shanghai (China) started a programme to run 2,000 city buses on B5[i], and Trondheim (Norway) began operating nearly 200 city buses able to be fuelled with biogas or biodiesel.[191] As of early 2020, all of the buses in Tartu (Estonia) were running on biomethane, making the city one of only a few[ii] in Europe with a 100% renewably fuelled public transport system.[192] Several US cities started fuelling their buses using biodiesel (produced outside of the urban area) – including Columbia (South Carolina) in 2019 and Grand Forks (North Dakota) in 2020.[193]

As of 2019, around half a million **electric** buses were in circulation globally (→ *see Figure 15*), 98% of which were in China and most of which were operating in cities.[194] Although new electric bus registrations declined some 20% overall in 2019 (relative to 2018), due mainly to China's gradual phase-out of subsidies, the number of new electric buses procured in cities outside of China[iii] continued to increase.[195] Since many cities have high and/or rising shares of renewable electricity, the electrification of buses brings opportunities for increasing the share of renewable energy in transport.

Sanya, China

During 2019 and 2020, new electric buses started circulating in many European cities, including Hamburg (Germany), London (UK), Milan (Italy) and Warsaw (Poland).[196] The transport provider Qbuzz in Utrecht (Netherlands) acquired 55 electric buses in 2019 that are charged using locally produced solar electricity.[197] The electrification of bus fleets also was under way in several US cities, with Portland (Maine) introducing new electric buses that run on 100% wind energy, and Gulfport (Mississippi), Jackson (Wyoming) and Wichita (Kansas) rolling out their first electric buses (as did the Canadian city of Brampton (Ontario)).[198]

Some of Latin America's most populous cities – including Bogotá (Colombia) and São Paulo (Brazil) – have started to electrify their bus fleets to address local air quality concerns.[199] By late 2020, an estimated 1,229 electric buses were in operation in 10[iv] countries across the region.[200] Santiago (Chile)[v], with 452 electric buses, reportedly had the largest electric urban bus fleet outside of China.[201]

Several cities in India – including Ahmedabad, Bengaluru, Delhi, Gurugam and Pune – increased the number of electric buses in circulation due to procurement programmes launched in 2019 and 2020.[202] In some cases, developing-country cities rely on their national governments to buy electric buses for use in urban fleets. As of 2019, the Philippine government had introduced 90 electric jeepneys with integrated solar PV in the city of Tacloban to replace the ageing combustion engine fleet.[203] In Cairo (Egypt), the first electric bus line was launched in 2020 as part of a nationally led initiative.[204]

A few city governments have ordered both biodiesel and electric buses. In 2019, Gothenburg (Sweden) placed the largest single order for electric buses in Europe (157 buses) as well as an order for 27 biodiesel buses, and the RATP Group in Paris (France) started converting all city bus depots to support fleets running on electricity and biogas.[205]

Several Asian (particularly Chinese) and European cities have begun adopting **hydrogen** fuel cell buses, but so far only a few operate on hydrogen produced with renewable electricity.[206] Zhangjiakou (Hebei Province, China) is a renewable hydrogen demonstration zone, with more than 70 fuel cell transit buses running on renewable hydrogen since late 2018.[207] In Aberdeen (UK), the first green hydrogen-powered double-decker buses started operating in 2020.[208]

The electrification of **bus fleets** around the world brings opportunities for increasing the share of renewable energy in transport.

i 5% biodiesel blend in petrol.

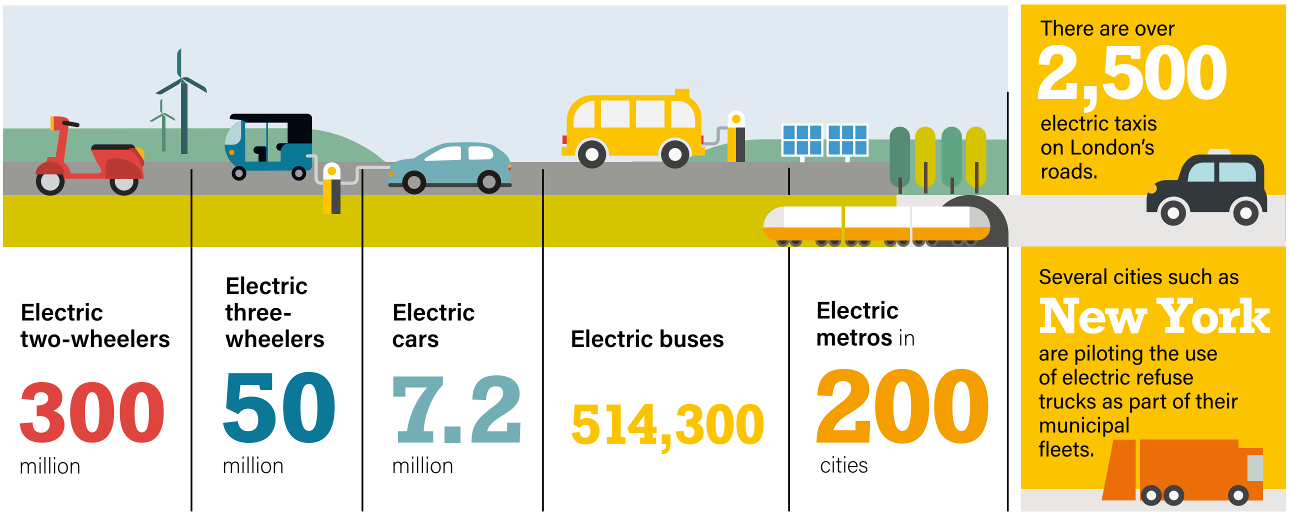
ii For example, in Stockholm (Sweden), all urban rail systems and buses have been using 100% renewable energy since 2017. Oslo (Norway) had a target to fuel all public transport will renewable energy by 2020. See Smart City Sweden, "Sustainable Public Transport in Stockholm", https://smartcitysweden.com/best-practice/368/sustainable-public-transport-in-stockholm, viewed 26 January 2021, and Oslo, "Public transport in Oslo", https://www.oslo.kommune.no/politics-and-administration/green-oslo/best-practices/public-transport-in-oslo, viewed 26 January 2021.

iii In 2019, 95% of new electric bus registrations were in China, compared to 98% in 2018. See International Energy Agency (IEA), *Global EV Outlook 2020* (Paris: 2020), https://www.iea.org/reports/global-ev-outlook-2020.

iv Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Panama, Paraguay, Peru and Uruguay.

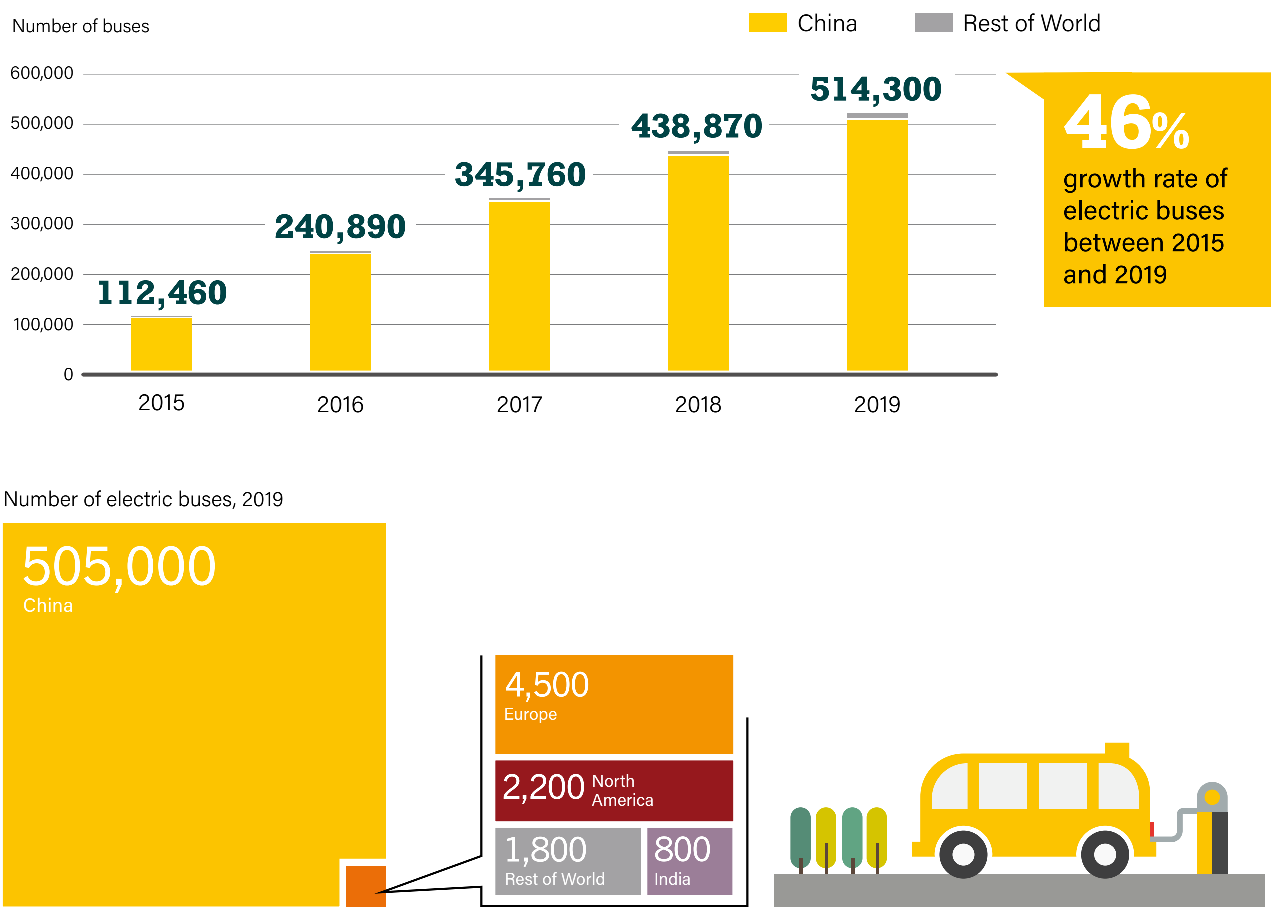
v The renewable share of electricity generation in Chile was 45% in 2019; calculated based on IEA, "Chile", https://www.iea.org/countries/chile, viewed 10 December 2020.

Figure 14. Global Electric Vehicle Markets in Cities, 2019



Source: Based on IEA data. See endnote 178 for this chapter.

Figure 15. Global Electric Bus Stock, China and Selected Regions, 2015-2019



Note: Discrepancies related to values reported in IEA's *Global EV Outlook 2020* are due to rounding.

Source: IEA. See endnote 194 for this chapter.

Passenger cars

Cities also have been exploring ways to encourage the use of renewable fuels and/or alternative propulsion technologies for passenger cars, to address the negative impacts associated with motorised individual transport, including associated air pollution and related illnesses (and fatalities).[209]

Although the number and share of **electric vehicles** on the world's roads is still small relative to vehicles with internal combustion engines, annual sales are increasing rapidly, and the EV share of the fleet is also rising. Electric cars accounted for 2.6% of worldwide car sales and for around 1% of the global car stock in 2019.[210] By year's end, an estimated 7.2 million electric cars[i] were on the road, up 40% from 2018.[211] A large portion of these vehicles were being operated in cities. The leading cities for passenger EV sales in 2019 were all in China (Shenzhen with 81,427 units sold, Beijing with 80,567 and Guangzhou with 72,270), while the leaders in the share of new passenger EVs sold were Oslo (Norway) at 64%, San Jose (California, US) at 20% and Shenzhen (China) at 19%.[212]

In some cities, municipal governments or private companies have made EVs available to residents and visitors via carsharing programmes; while some of these vehicles are offered for free public use (as in Trikala, Greece), others are for hire (as in Los Angeles (California, US) and Bristol (UK)).[213] The market for carsharing (as well as ridehailing services) has continued to grow, as has the industry's interest in electrification. A few companies – including WeShare in Berlin (Germany) and We Drive Solar in Utrecht (Netherlands) – procure renewable electricity for charging their electric fleets.[214]

Electric taxis have been in use for several years in cities worldwide, including Columbus (Ohio, US), Hong Kong, Macao and Shenzhen (all China), London (UK), Nairobi (Kenya) and New York City (US).[215] In 2019, India's Energy Efficiency Services – responsible for managing procurement programmes for government vehicles – was seeking to lease EVs to cab companies due to delays in integrating them into public fleets.[216] Also that year, four electric taxis started trials in Kigali (Rwanda) as part of the Moving Rwanda Initiative.[217] In Canada, the electric taxi service Téo Taxi put 55 EVs on the roads of Gatineau and Montreal in 2020.[218]

Passenger cars account for the majority of **hydrogen** fuel cell vehicles. In 2019, some 10,500 fuel cell vehicles were sold, for a total global stock of 22,350 vehicles[ii] (up from 5,800 vehicles sold and 12,950 total stock in 2018).[219] The hydrogen car market remains concentrated in California (US) – particularly in Greater Los Angeles and the San Francisco Bay Area – and a few pilot projects are under way in some European cities.[220] The taxi company Hype rolled out 100 hydrogen taxis in Paris (France) in 2019, with the goal of achieving a total of 600 in 2020, and a fleet of hydrogen taxis started operating in Copenhagen (Denmark) in 2019 using locally produced renewable electricity.[221]

i Including battery electric, plug-in hybrid electric and fuel cell cars.

ii Including passenger cars, buses and trucks.

iii See Glossary for definition.

iv See Glossary for definition.

v See Glossary for definition.

Two- and three-wheelers / Micromobility

The number of **electric** micromobility[iii] vehicles in use has expanded rapidly, with more than 350 million electric two- and three-wheelers in circulation in 2019, up from 300 million in 2018.[222] Although heavily concentrated in China, electric scooters, electric-assist bicycles and electric mopeds were present in over 600 cities in more than 50 countries, including in Europe, India and the United States.[223]

In a small but growing number of cities, electric two- and three-wheelers are being charged using renewable energy. Solar-powered hybrid rickshaws started operating at the Indian Institute of Technology's Delhi campus in 2019.[224] In Kampala (Uganda), motorcycle taxis ("boda bodas") began relying on a network of solar-powered charging stations in 2020, and in Windhoek (Namibia) the local company Ebikes4Africa produces SunCycles, or electric bicycles powered by solar energy.[225]

URBAN ROAD TRANSPORT: FREIGHT

Freight traffic accounts for a large share of urban traffic volume, contributing to air and noise pollution.[226] Urban freight transport[iv] involves mainly road-based vehicles, specifically light commercial vehicles[v] (such as vans) and heavy-duty trucks.

Light commercial vehicles

Around 380,000 light commercial **electric vehicles** were operating in 2019, often as part of company or municipal fleets circulating in cities.[227] China had the largest fleet of electrified light commercial vehicles worldwide in 2019, with 65% of the global stock, followed by Europe (31%).[228]

Numerous fleet owners switched to EVs for delivery services in 2020, and some coupled these vehicles with renewable energy. In 2020, the e-commerce delivery company Sendle (Australia) rolled out electric delivery vans powered by a rooftop solar PV system in western Sydney.[229] In the United Kingdom, the Royal Mail announced plans to trial a new electric van for deliveries across several cities, and the retailer John Lewis (which also operates the supermarket chain Waitrose) announced plans to transition its delivery fleets to electric in 2021, starting with 1,700 electric vans.[230] The Dutch supermarkets Albert Heijn and Picnic and the parcel delivery services DHL and PostNL were using various types of light-duty EVs in cities across the Netherlands during 2020.[231]

Cardiff, Wales, United Kingdom

Heavy-duty trucks

Trucks remain the dominant mode for transporting goods in cities, and the rise in urban energy use in recent years is attributed in part to the growing demand for delivery services in city centres. To address this challenge, municipal services, private companies and others have worked to mitigate the social and environmental impacts of truck traffic through the use of renewable fuels and electrification.[232]

Truck fleets in numerous cities have begun using **biofuels**. As of 2019, the municipally owned Orlando Utilities Commission (Florida, US) was using biodiesel (B20) to reduce greenhouse gas emissions from its 775 trucks, and in Hong Kong (China) the restaurant group Maxim's partnered with Shell (Netherlands) to launch a pilot programme to fuel more than 100 delivery trucks with biodiesel produced from used cooking oil.[233] In 2020, 22 new biogas refuse trucks entered into circulation in Esbjerg (Denmark), and in the Netherlands the fast food retailer McDonald's partnered with Neste (Finland) to recycle used cooking oil into renewable diesel to fuel delivery trucks in Dutch cities.[234]

Increasingly, city actors are exploring the **electrification** of heavy-duty freight vehicles. Although global sales of refuse collection trucks (which reached 62,155 units in 2018) continue to be dominated by internal combustion vehicles, support for electric refuse trucks is growing in cities worldwide due to favourable government policies, product innovation and the push for environmental sustainability.[235] In China, the shift from conventional heavy-duty trucks is mostly towards battery electric alternatives, used primarily for refuse collection and other municipal operations.[236] In 2018, the Chinese manufacturer BYD was contracted to deliver 500 electric refuse trucks to operate in its home town of Shenzhen.[237]

In the United States, Los Angeles and Sacramento (both California) began operating small fleets of electric refuse trucks in 2019, and the waste management company Recology acquired its first electric refuse truck in Seattle (Washington) that year.[238] In Australia, electric refuse and recycling collection trucks went into service in Adelaide, Casey and Yarra during 2020, with the electricity used for recharging Adelaide's truck being offset by a 36 kW solar PV system.[239]

Progress with electric trucks in Europe has been limited, with most deployments still in demonstration and customer trials.[240] A fully electric 16-tonne truck designed for inner-city freight deliveries began trialling in London (UK) in 2020.[241] Also in the UK, the contractor responsible for waste management in Manchester concluded an agreement to purchase 27 new electric refuse collection trucks to replace their diesel predecessors.[242] Several pilot projects involving hydrogen fuel cell waste collection trucks also were active in European cities, including in Eindhoven and Veldhoven (both Netherlands).[243]

The use of **renewable fuels and electricity in trucks** has been slowly gaining momentum.

DISTRIBUTION INFRASTRUCTURE

No city is an island in the context of energy procurement and use. All cities are physically tied to and reliant upon a larger regional network of energy systems, infrastructure and supply lines. Cities rely on the territories that surround them not only for the bulk of their energy supply, but also to manage and balance the flow of energy with the pulse of activity within city limits. Typically, the larger a city is, the larger are its interactions with wider energy systems and infrastructure.[244]

As cities pivot their energy procurement towards renewable sources (sourced from within and outside of city boundaries), their interactions with and requirements from regional energy systems and infrastructure may change – with significant implications that go well beyond city boundaries. Likewise, external changes in supply and infrastructure affect cities in ways beyond their control.

In some instances, such shifts may create relative system redundancies that represent economic sunk costs – both within and outside the city – in infrastructure networks that were built over many years to accommodate a different energy mix and supply structure.[245] In other cases, a relatively rapid, large-scale transition to renewable energy may hit system shortages and economic constraints, such as physical or technical bottlenecks that disrupt the orderly flow of energy. For example, growth in distributed electricity generation may either relieve or overload local distribution capacity during different time periods.[246]

Strømmen, Norway

Amsterdam, Netherlands

The distribution infrastructure relevant to cities pursuing renewable energy is varied. The physical elements include mainly wires and pipes (both within and outside of cities) as well as rail systems, road transport, ships and barges. Transmitting renewable electricity from centralised generation facilities requires high-voltage lines and then sub-stations where the electricity is stepped down to lower voltages to serve urban customers with varying voltage requirements. Alternatively, distributed (often low-voltage) renewable electricity can feed the distribution system directly, sometimes entirely off the network (behind the meter).[247]

Renewable fuels – whether gaseous, liquid or solid – are distributed by pipelines or vehicles, sometimes blended with non-renewable fuels (such as methane mixed with natural gas and ethanol blended with petrol). Secondary distribution systems carry transformed renewable energy for specific applications within cities. For example, district heating networks carry usable thermal energy that has been acquired from primary (such as renewable fuels or geothermal heat) or secondary renewable sources (such as the output of heat pumps driven by renewable electricity).

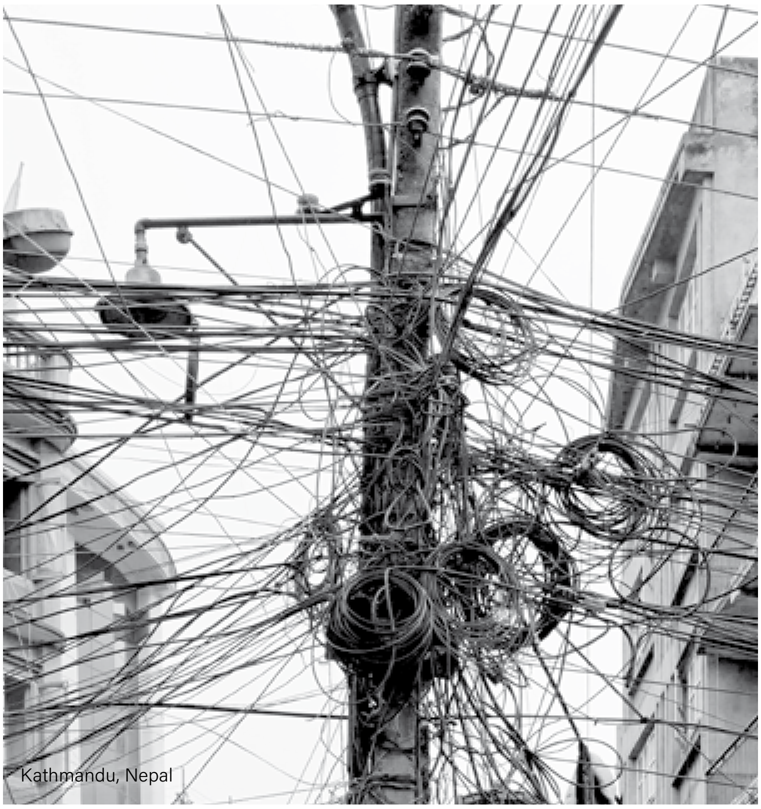
Some of the distribution infrastructure does not carry any energy but instead assists in the proper function and efficiency of the wider distribution network. Examples include storage facilities (such as tanks and batteries), metering devices that keep track of the energy flow and allow for the efficient allocation and distribution of energy (for example, "smart" meters), energy transformation devices (such as transformers, boilers, fuel cells and heat pumps) and system control infrastructure (for example, telecommunication systems and dispatch centres).

In 2019 and 2020, cities worldwide took steps to: address challenges to local and regional electricity distribution infrastructure (for example, by upgrading existing assets or deploying battery storage capacity); expand existing district heat networks or commission new systems that rely (at least in part) on renewable thermal energy or on heat pumps powered by renewable electricity; and install electric vehicle charging stations, including some that deliver 100% renewable electricity.

ELECTRICITY DISTRIBUTION

A city's electricity distribution grid is tied to, and dependent on, a larger regional or national power grid. Therefore, all city actions related to the procurement and use of electricity have implications for the broader electricity system.

In the case of distributed generation within city limits, the build-up of resources such as rooftop solar PV systems and electricity storage may relieve existing constraints on the regional transmission system and reduce excessive load on the local distribution system. However, rapidly expanding distributed (and variable) generation without also expanding system flexibility can create new challenges for the distribution network (→ *see City Snapshot: Oxford, and Citizen Participation chapter*).[248]


Kathmandu, Nepal

City actions

related to the procurement and use of renewable energy have implications for the broader electricity system.


Delhi, India

OXFORD

UNITED KINGDOM

Land area (km²)
45.6

Population size (2019)
152,450

GHG

Greenhouse gas emissions (CO_2 equivalent)
718,082 tonnes

In January 2019, Oxford City Council unanimously declared a climate emergency in Oxford and agreed to create a Citizens' Assembly to help consider new carbon targets and additional measures to reduce emissions in the city. As a result, Oxford aims to become a net-zero carbon emitter by 2030, a full 20 years ahead of the UK national target. In addition, Oxford City Council pledged to achieve net-zero carbon emissions in its own operations by the end of 2020, after the Citizens' Assembly requested such a move. Oxford City Council is a member of Low Carbon Oxford, a network of 40 public and private organisations that aimed to reduce city-wide emissions 40% below 2005 levels by 2020. Oxford also is part of the UK100, a network of local government leaders who have pledged to shift to 100% clean energy by 2050.

To decarbonise energy in transport and heat systems (the major sources of carbon emissions in Oxford) and to achieve the 40% emission reduction, the City Council has facilitated an energy storage project, the Energy Superhub Oxford (ESO). It expected to be the world's largest hybrid energy storage system, with a 50 MW grid-scale battery[i] that will support a 10-kilometre network of EV charging points and ground-source heat pumps for around 300 households.

The ESO project, which started construction in 2020, will help reduce 20,000 tonnes of CO_2 annually by 2021 and 44,000 tonnes of CO_2 annually by 2032. The project will be capable of integrating multiple sources of energy to manage energy demand, including renewables. Because Oxford is part of the UK100 network, by 2050 the ESO is to run entirely on renewable energy.

The GBP 41 million (USD 53.8 million) project will help accelerate the use of electric vehicles in Oxford, by providing charging points powered by the spare capacity of the battery to City Council depots and key businesses including local bus companies, taxi providers and commercial fleet depots. The project also aims to develop the first rapid charging hub in Oxford, making available around 20 ultra-rapid EV chargers for public use. Charging speeds will range between 10 and 30 minutes.

The project scope also includes a "Trial before you buy" programme by the City Council for taxi drivers in Oxford. This will help the taxis transition from 100% diesel to 100% electric by 2025. In total, the ESO pilot project will last for 36 months; once successful, the technology is to be expanded to up to 44 other sites across the United Kingdom.

Source: See endnote 248 for this chapter.

i The battery, connected to the Cowley sub-station in Blackberry Lane, South Oxford, will store and deliver electricity (including renewable electricity) to electricity suppliers and help balance the local requirements for the grid. Electricity will be stored at times of low demand and then resupplied back to the grid when demand peaks. The technology is capable of shifting demand to periods of low prices, minimising consumers' energy bills and overcoming local network constraints.

Procuring electricity via power purchase agreements for renewable projects outside of city limits may create or exacerbate constraints in the regional transmission system, depending on the scale and location of the renewable capacity under contract. Likewise, because most such PPAs are for electricity generated by solar PV or wind power facilities, system operators need to balance the variability of the contracted resources against other system resources across the regional or national control area.[249]

When city governments set targets to achieve a 100% renewable electricity supply by a future date, this allows time for planning the required resource commitment and any needed strengthening of energy infrastructure, in co-operation with regional regulators and system planners and operators. Moreover, once the newly committed off-site renewable generating capacity is built and interconnected to meet a city's energy needs, it typically serves not only the city but also the wider regional power grid as an interconnected resource[i]. Importantly, the city (with the assistance of the local utility and system operator) needs to ensure that the electricity purchased has somewhere to flow when it is generated.

In 2019, Salt Lake City (Utah, US) and more than 20 nearby communities entered into an agreement with the local utility to enable the achievement of net-100% renewable electricity no later than 2030.[250] The goal of this plan is to catalyse the construction of enough renewable power capacity to meet all net community electricity needs on an annual basis. However, the agreement acknowledges that this cannot be achieved without reliance on regional system-wide resources to help balance the community demand against the available committed resources; this requires relying at times on non-renewable resources to make up moments of shortfall, and sometimes sharing a surplus.[251]

Some cities have sought to address specific challenges related to the local and regional distribution infrastructure. For example, they have built new (or upgraded existing) transmission and distribution assets both within and outside city boundaries to reinforce the capacity to transfer electricity. They also have expanded the ability to buffer supply by installing greater storage capacity (such as via pumped hydropower, batteries or hydrogen conversion). Adding storage increases the system's capability to match load against available supply and to capture and use available renewable generation at each moment in time (regardless of demand) while also relieving potential transmission and distribution constraints.

In 2020, Los Angeles (California, US) announced plans to pursue a combined approach (upgrading transmission and enhancing storage) to support its goal of 100% renewable electricity.[252] As part of this effort, the city plans to replace an existing coal-fired power plant in Utah with a 840 MW gas-fired unit coupled with hydrogen storage in on-site underground salt caverns.[253] The hydrogen, generated using renewable electricity (via electrolysis), will be used to store any surplus electricity generated from variable renewable energy resources (such as wind or solar power) and will subsequently be used for electricity generation at the power plant as supply and demand conditions change.[254] The city also will build additional transmission interconnection to accommodate the bi-directional flow of electricity between Los Angeles and the new generating facility for the effective integration of renewables.[255] Upon its completion in 2025, the Utah facility would run on up to 30% renewable hydrogen (the balance being natural gas), with the aim of 100% renewable hydrogen use by 2045.[256]

Upgrading transmission and distribution assets and enhancing **storage capacity** can help cities achieve 100% renewable goals.

Salt Lake City, United States

i On the power grid, electrons flow to wherever they are demanded at each instant in time – it is only on a net basis that annual city demand is actually matched with the output of the specific resources committed to the city.

In addition to pursuing infrastructure improvements, some cities are striving to match the generating profile and other characteristics of the contracted supply against their demand profiles. For example, in 2020 Sydney (Australia) achieved its goal of meeting 100% of municipal electricity demand (buildings, facilities and streetlights)[i] with renewables via PPAs from solar and wind projects in New South Wales.[257] The PPA criteria included local supply to minimise transmission losses, and high load matching[ii] (80%) for economic and system efficiencies.[258] The city also is pursuing solar PV on municipal buildings and battery storage to improve the reliability and resilience of the distribution network.[259]

London (UK) offers an example of how storage can be used to time-shift system demand to match the available renewable supply. In a pilot project, battery storage is being deployed at some London homes to allow residential consumers to purchase excess electricity during off-peak periods (and thus at lower cost), which they can then store for later use during times of peak demand. This approach provides both load matching and grid management benefits, while potentially reducing the cost of supply.[260]

Many cities, especially in developing countries, struggle with insufficient distribution infrastructure. In these cases, renewable energy projects will require investment in local infrastructure. Building mini- and micro-grids can facilitate the deployment of reliable and relatively affordable renewable energy in locations with limited electricity access or where the main grid is frail and overburdened.[261]

Sweden

DIRECT THERMAL ENERGY DISTRIBUTION

District energy networks are present in the urban areas of more than 30 countries worldwide, with an estimated 80,000 systems in total (including more than 6,000 each in the United States and Europe).[262] In China, district energy networks provide heating to over 5.7 million m^2 of floor space.[263] The vast majority of these district networks worldwide are used for heating.[264]

During 2019 and 2020, several cities expanded their district energy infrastructure or commissioned new systems. Often, this activity was driven by the desire for an efficient, stable and reliable heat supply with low heat loss; for cost-effective cooling of large residential and office buildings; and for more options to integrate multiple renewable energy sources.[265]

In 2020, the first **district heating** network in Scotland (UK) using large-scale water-source heat pumps entered into operation in Clydbank to serve municipal, commercial and residential buildings, taking advantage of Scotland's nearly 100% renewable electricity mix.[266] The municipal government in Leeds (UK) plans to invest GBP 24 million (USD 31.5 million) in six new district heating networks (relying on biomass or heat pumps), following the success of the city's first such network, which was expected to provide waste-derived heat to some 2,000 homes by the end of 2020.[267] Montauban (France) is installing a district heating network using residual waste to heat 4,200 homes, with completion scheduled for 2023.[268]

Although less widespread, **district cooling** networks have operated for years in many European cities, particularly in Denmark (Aalborg, Aarhus, Copenhagen, Høje Taastrup) and Sweden (Gothenburg, Helsingborg, Linköping) but also in France (Bordeaux, Paris) and Germany (Berlin, Hamburg).[269] Elsewhere, district cooling networks are present in Canada (Toronto), Japan (Osaka, Tokyo, Yokahama), Kuwait, the United Arab Emirates and the United States (Boston, Chicago, New York).[270]

Berlin, Germany

i Sydney's municipal electricity demand represents 115 buildings, 75 parks, 5 swimming pools and 23,000 streetlights.

ii In this instance, the load matching was achieved by skewing the PPAs towards wind power over solar because the generating profile of wind power better matches the predominantly night-time demand of the city government (i.e., street lighting).

Several city governments, especially in Asia, plan to add new district cooling infrastructure, although it is uncertain whether these systems will incorporate renewables. Bangkok (Thailand) is developing a district system, expected to be operational in late 2022, to serve the cooling needs of several office, retail and residential properties.[271] Amaravati (India) signed a concession to develop a district cooling system slated for operation in 2021.[272] Singapore announced plans for a district cooling network for the Punggol Digital District, and new district cooling systems also were commissioned in Cyberjaya (Malaysia), Gujarat City (India) and Manila (Philippines), among others.[273]

A few cities in Scandinavia have developed **integrated district heating and cooling systems**. Copenhagen (Denmark) has a district heating capacity of 3,000 MW and a cooling capacity of 50 MW; the network is connected to a waste-to-energy combined heat and power plant and supplies the city itself as well as 24 surrounding municipalities.[274] In Stockholm (Sweden), the district energy network, co-owned by the city and a private company, has a 3,600 MW heating and 220 MW cooling capacity, supplying six municipalities.[275] Since Stockholm's last coal-fired plant closed in early 2020, heat supply has been based on biofuel and municipal waste, with plans to use 100% renewable fuels by 2022.[276]

EV CHARGING NETWORKS

Widespread roll-out of EV charging infrastructure is key to the continued growth of electric vehicles and plays an important role in increasing the use of renewable energy in the urban transport sector.[277] Of the estimated 7.3 million EV chargers[i] worldwide in 2019, most were concentrated in urban areas of China.[278] Although the vast majority of chargers are not linked to renewable electricity, several municipal governments as well as private actors in cities in Australia, Europe, the United States and Latin America have made an explicit connection between EV charging and renewables.[279]

As of 2019, Adelaide (Australia) had installed 49 EV fast-charging points, which the city planned to run on 100% renewable electricity.[280] Chargefox, Australia's largest EV charging network, opened the country's first ultra-rapid charging station, delivering 100% renewable electricity in the city of Keith.[281] In Europe, Oslo (Norway) and Stockholm (Sweden) are among the leaders in the number of EV chargers per person, and their charging stations benefit from the high shares of renewables in the national electricity mixes (→ *see Table 2*).[282] Since 2019, Oslo's municipal government has worked with private companies to deploy wireless-charging infrastructure for the city's growing electric taxi fleet.[283]

i Of these, around 90% were private, light-duty vehicle slow chargers.

Table 2. Number of Public Electric Vehicle Charging Stations and Renewable Energy Uptake in Selected EV Capitals, 2019

City (State, Country)	No. of public chargers per million population	Share of renewables in city's electricity mix*
Asia		
Shenzhen (China)	4,800	
Beijing (China)	1,920	28%
Shanghai (China)	1,690	
Europe		
Oslo (Norway)	3,000	98%
Amsterdam (Netherlands)	2,750	18%
Stockholm (Sweden)	717	69%*
London (UK)	405	37%
Paris (France)	307	22%
North America		
San Jose (California, US)	1,200	48%*
Los Angeles (California, US)	590	32%*

Charging stations

in several EV capital cities benefit from high shares of renewables in the national electricity mixes.

Note: EV charger data were reported by ICCT in late 2019 and 2020. *Renewable electricity data for Los Angeles, San Jose and Stockholm are from 2018. All other city renewable electricity shares refer to national-level data from 2019.

Source: See endnote 282 for this chapter.

New York City (US) added 50 solar-powered EV charging stations in 2018.[284] In Latin America, renewable-powered charging infrastructure was being developed in 2019 and 2020 in Santiago (Chile) and across São Paulo state (Brazil), among others.[285] In addition, "smart charging"[i] solutions have been deployed and tested in some cities, mostly in Europe, including Amsterdam, Arnhem and Utrecht (all Netherlands) and Cranfield (UK).[286] In Tokyo (Japan), a partnership among utilities, automakers and other stakeholders is testing bi-directional EV charging stations.[287]

FUEL DISTRIBUTION

Much of the renewable fuel used in transport, including biofuels and hydrogen, is still produced outside of city limits. As a result, providing sufficient distribution and refuelling infrastructure in cities is key to enabling citizens to access alternatives to fossil fuels (which rely on established distribution networks and widely available petrol filling stations).[288]

Biofuel blends typically are transported from refineries to distribution terminals and sold at existing petrol filling stations.[289] In 2019, nearly 250 stations in Shanghai (China) were selling B5 biodiesel.[290] That same year, a new terminal for biodiesel storage and blending opened in Antwerp (Belgium).[291] In 2020, the US company Eco-Energy entered the final stage of construction of its ethanol distribution facility in Phoenix (Arizona, US).[292]

Hydrogen generally is distributed by pipeline, high-pressure tube trailers and liquefied hydrogen tankers. The costs associated with hydrogen distribution and delivery infrastructure depend on whether the fuel is produced centrally at large industrial sites (high distribution costs) or at the point of end-use such as in fuelling stations in cities (low distribution costs).[293]

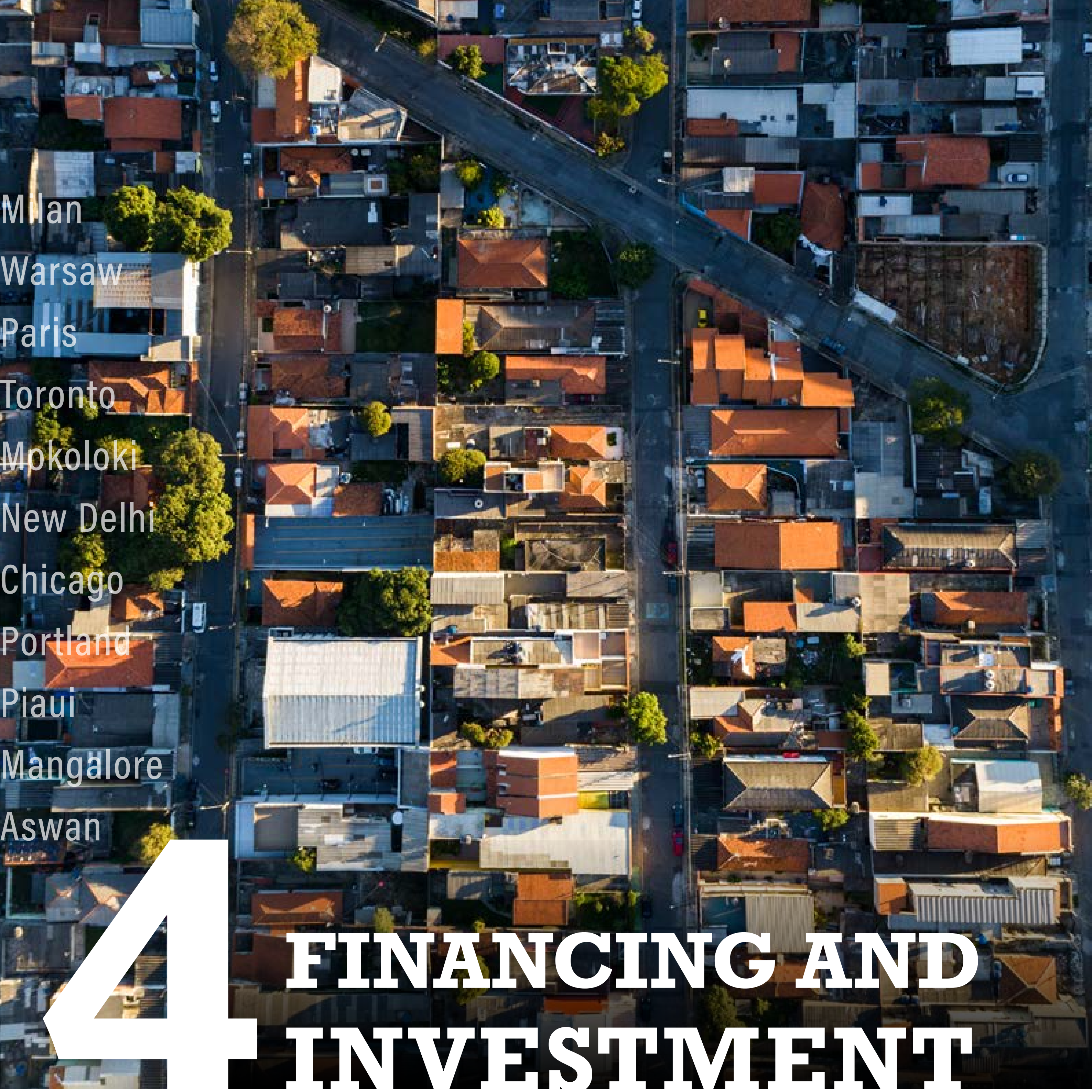
The number of hydrogen refuelling stations remains low but has continued to increase. By the end of 2019, some 470 such stations[ii] were in operation worldwide, up more than 20% from the previous year.[294] Most hydrogen refuelling stations are publicly available and located in cities, although only an estimated 24% of the stations globally provide renewable hydrogen.[295] Shell's hydrogen refuelling stations in Beaconsfield and Cobham (both UK) supply hydrogen produced on-site using electricity from renewable sources.[296] The first hydrogen filling station for passenger trains in Bremervörde (Germany) was scheduled to begin construction in late 2020, with the hydrogen to be produced on-site using renewable electricity.[297]

i See Glossary for definition.

ii Since virtually all hydrogen is still produced from fossil fuels, most of the hydrogen available in these stations is fossil fuel-based hydrogen.

Frankfurt, Germany

3



Milan
Warsaw
Paris
Toronto
Mokoloki
New Delhi
Chicago
Portland
Piaui
Mangalore
Aswan

4 FINANCING AND INVESTMENT IN CITIES

Palmas
North Lombok Regency

FINANCING AND INVESTMENT IN CITIES

Global investment in new renewable energy capacity, including power and fuels (but not including hydropower projects larger than 50 MW) totalled USD 282.2 billion in 2019, up 1% over 2018.[1] In the first half of 2020, global investment in new renewable energy capacity rose 5% relative to the first half of 2019, suggesting sustained growth despite the COVID-19 pandemic.[2] Some of this investment occurred in city-related projects – by municipal governments as well as other residential, commercial and industrial actors within cities – but the exact amount is unknown. Although data are becoming more available, no comprehensive dataset on renewable energy investment in cities by sector exists.

This chapter explores financing and investment in cities, including the provision of funding for renewable energy projects and the process of investing in projects to turn a profit. The discussion examines common financing mechanisms applied by cities worldwide and how these mechanisms are being used to support renewables across the world's regions. The chapter concludes with an overview of the challenges that cities face in investment and finance of renewable energy projects.

Each city operates within a distinctive framework that affects the amount and type of renewable energy financing and investment available. Variables include the policies and regulations that govern city actions, the nature of relationships with higher levels of governments, partnerships with the private sector, ownership rights of the electric grid, etc.

Municipal governments are responsible for only a small share of the total financing that occurs within a city; in contrast, private individuals and companies account for far more of the investment in city-related projects – whether in the energy, buildings, commercial or industrial sectors – and have their own priorities, planning horizons and funding constraints. The total finance package allocated to renewables therefore results from many different players, regulations, institutions and financing mechanisms and is specific to every city.


Barbados

4

BOX 1. Global and Urban Climate Finance Flows

Global climate finance flows reached an estimated USD 608-622 billion in 2019, up 6-8% from the 2017/18 averages of USD 574 billion annually. Climate flows, which crossed the USD half-trillion mark for the first time in 2017, were highly concentrated on mitigation efforts (representing 93% of total flows in 2019). By sector, renewable energy generation accounted for the largest share of the flows tracked, largely due to more investments originating in China (particularly solar, wind and hydropower investments) and the United States (with an increased volume of investments in solar PV and onshore wind). The second largest investment during 2017/2018 was in sustainable transport (around USD 140 billion annually, making it the fastest-growing sector for climate finance), followed by investment in energy efficiency (around USD 33 billion annually).

Cities face major capacity constraints in financing climate change mitigation and adaptation projects. First, the public sector, notably city governments, often has budget capacity limitations and low rates of creditworthiness, which hinders private investment or any major borrowing scheme. Also, many long-term climate-smart infrastructure investments need highly technical capacity to pull together investor-ready bankable projects with sufficient size and quality to increase climate finance flows. Many countries forbid their local governments from issuing any kind of debt, including municipal bonds. Also, many private investors lack experience working with sustainable urban infrastructure, which often impedes investments.

Because cities are key players in achieving the Paris Agreement, investments must be scaled to promote the shift to the low-carbon, climate-resilient infrastructure that is needed to face the climate emergency. However, while there is a clear picture of global climate finance flows, information on **urban climate finance**[i] flows is lacking. By producing clear data, measuring progress, and understanding gaps and opportunities, city governments can have a better picture of the sources of finance, the financial instruments employed, and the policies that can more effectively drive investment, leading to improved policy planning in cities.

Source: See endnote 5 for this chapter.

Sanxia Dam, Yangtze River, China

New Bedford, United States

i For further information on financing of city-level climate action, see the Cities Climate Finance Leadership Alliance, www.citiesclimatefinance.org, and its forthcoming report, *State of Cities Climate Finance 2021*.

Financing for renewables also must be tailored to meet the unique characteristics of each end-use sector: power, heating and cooling, and transport. In the power sector, municipal governments and other urban actors generally target renewable energy projects in two main categories: small-scale, on-site generating capacity (for example, rooftop solar PV on single buildings or on somewhat larger areas such as parking or waste sites), and larger-scale projects (for example, solar PV or wind farms) that often are located outside of geographical city limits.

In the heating and cooling sector, cities often target district heating networks. Different ownership models for these networks affect the allocation of financing and include, for example, municipal ownership, long-term concession agreements with private operators and "unbundled" networks with private ownership. The networks can be fed by large-scale heat pumps[i], municipal waste incineration, biomass boilers, industrial waste recovery, solar thermal and geothermal energy, although the share of renewables across these options can vary.[3]

In the transport sector, cities working towards climate mitigation goals typically target projects related to mass public transit and zero-emission vehicles (including electric vehicles), which enables renewable electricity to replace fossil fuels in some transport applications (particularly through smart charging[ii]).[4]

Each city operates within a **distinctive framework** that affects the amount and type of renewable energy financing and investment available.

FINANCING MECHANISMS

Municipal governments and other urban actors that aim to increase the share of renewables in their power, heating and cooling, and transport sectors have many options for financing such projects.

These options can be grouped into three general categories:

- the actors may have their own capital or assets available for funding renewable energy projects;
- if they do not have their own capital available, they may be able to raise funds through bonds, or make use of funds provided by other levels of government or external actors (such as local or domestic banks and development banks); and
- they may be able to leverage external funds for renewable energy projects by participating in arrangements such as public-private partnerships or power purchase agreements.

In addition, cities have relied on climate finance from private and public sources, some of which has included funding for renewables (→ *see Box 1*).[5]

USING OWN AVAILABLE CAPITAL OR ASSETS

In the first category, actors may have their own financing available or may be able to generate the necessary capital to develop renewable energy projects (→ *see City Snapshot: Palmas*).[6] Some municipal governments fund renewable energy projects based on fees and returns from the project itself. To generate capital, one option is to sell or lease land or assets.[7] For example, land value capture can be used to help finance new infrastructure projects by harvesting a portion of the increase in value of nearby property caused by the investment. Land value capture has been used in some cities to finance electric transport and new metro and rail investments.[8] Municipal governments, alongside other actors, also may indirectly support renewable energy by divesting from fossil fuels and reinvesting in renewable energy companies (→ *see Box 2*).[9]

Warsaw, Poland

i Although heat pumps are not renewable energy technologies in themselves, they may be viewed as enabling technologies because they can be powered by renewable electricity.

ii See Glossary for definition.

4

PALMAS

BRAZIL

Land area (km^2)	Population size (2020)
100.6	306,000

Palmas City, the capital of the state of Tocantins in north-central Brazil, aims to generate 100% of its electricity from solar power by 2022 and to have 100% of its local electricity energy supply based on solar energy by 2035 (foregoing the use of hydropower from the regional grid). Hydroelectric dams located on the Tocantins River account for nearly 97% of the electricity consumed in the city, in addition to providing power elsewhere in the country. However, electricity bills in Palmas are among the highest in Brazil, and growing uncertainties about hydropower's stability and climate and environmental risks have heightened interest in exploring the local solar resource.

The Palmas Solar project, established in 2015, provides tax incentives for companies and households to install solar PV panels and to feed surplus generation to the electricity grid. The benefits include reducing the city's dependence on hydropower and non-renewable energy sources, improving air quality and reducing greenhouse gas emissions. The main drivers for reducing hydropower are rising energy bills and the environmental risks of this generation source.

At first, the project focused on solar PV installations only in new buildings, but it has since extended city-wide. Users are encouraged to install solar panels in exchange for a discount of up to 80% on two municipal taxes – the Property and Urban Land Tax and the Real Estate Transfer Tax – for a period of five years. The costs for private users are drastically reduced, as the solar power they generate is fed into the grid and discounted from their energy bills. The local utilities maintain the distribution infrastructure, for which users pay a minimal equipment cost.

For Palmas, the tax incentives did not affect public revenue because the project was launched right after a tax increase, foreseeing that a share of municipal revenue would be allocated to this project. Three private banks, Banco da Amazônia, Banco do Nordeste and Banco do Brasil, have helped finance any remaining costs. The programme has led to the creation of a solar PV market with more than 20 local enterprises selling and installing imported or locally manufactured solar panels. As of October 2020, the city had granted discounts totalling BRL 415,785 (around USD 103,000) and supported 3.8 MW of installed decentralised generation capacity under the Palmas Solar programme.

In parallel, Palmas implemented the Parque Solar project. During phase 1 of the project in 2018, the government-owned bank Caixa Econômica Federal provided financing to install solar panels on public schools, saving the municipality an estimated BRL 5,000 (USD 1,240) per month. Phase 2 involves building a 5 MW solar farm to power all municipal buildings with solar energy, although funding is yet to be secured.

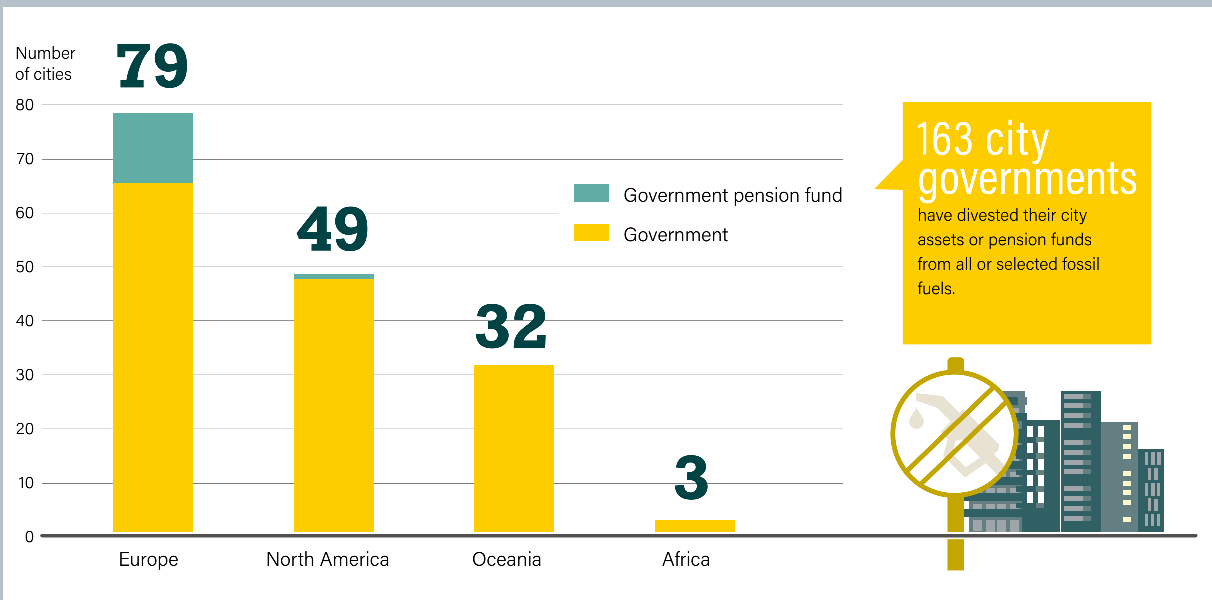
Source: See endnote 6 for this chapter.

BOX 2. Divestment of Municipal Public Funds from Fossil Fuels

By 2020, more than 1,300 institutions with around USD 14 trillion in investment value had sold off their financial interests in fossil fuel companies. Although the institutions undertaking this divestment are diverse, two entities critical to this movement at the city level are government bodies and their pension funds. The C40 Cities network, launched in 2018 in close co-operation with London (UK) and New York City (US), the C40 Divest/Invest Forum, an initiative that helps guide cities interested in divesting their pension funds and investing in climate-friendly solutions (14 cities signed up to the Divest declaration). Funds divested from fossil fuel companies are not necessarily reinvested in companies associated with renewable energy, however.

Numerous cities worldwide have taken strong action to divest their city assets or pension funds and, in some cases, to increase the investment in sustainable infrastructure (→ *see Figure 16*). For example, in 2020, as part of their COVID-19 recovery plans, 12 cities (Berlin, Bristol, Cape Town, Durban, London, Los Angeles, Milan, New Orleans, New York, Oslo, Pittsburgh and Vancouver) pledged to divest from fossil fuel companies and advocate for greater sustainable investment within the C40 framework.

Figure 16. Number of Cities with Fossil Fuel Divestments, by Region and Divestment Scope, 2020



Source: See endnote 9 for this chapter.

RAISING FUNDS FROM EXTERNAL SOURCES

If an actor is unable to draw from its own funds or assets, a number of options are available from other levels of government or external sources to address a given shortage of capital. Cities that are eligible to generate debt may choose to issue municipal green or climate bonds to support renewable energy projects.[10] Municipal actors also can apply for grants, subsidies and loans from national governments and international entities, such as the EU, multilateral and bilateral financial institutions, and multilateral development banks. On average, direct budgetary contributions from national governments supply 40% of urban infrastructure finance for transport, water, energy and other projects in developed countries and 60-65% in emerging and developing countries.[11]

Two common approaches for raising funds from external sources – issuing municipal or green bonds, and acquiring funds through development finance – are discussed in the following sub-sections. Another more novel approach is crowdfunding, or raising money from a relatively large number of people in small, individual amounts, generally via the Internet and social media. Crowdfunding is a growing option for both public and private projects and has been used in Africa (especially for small, off-grid projects), Asia, Australia, Europe and North America.[12]

MUNICIPAL AND GREEN BONDS

Since they were first used in the early 19th century, municipal bonds have become one of the most widely applied instruments for municipal finance, helping to fund trillions of dollars of urban infrastructure projects.[13] Bonds tend to provide more attractive conditions for financing long-term infrastructure projects than do traditional bank loans, and many municipalities (particularly larger cities) consider municipal bonds to be the best tool to meet their financing needs.[14] However, in some countries, particularly in developing or emerging economies, national legislation that limits borrowing power may restrict cities from using bonds (→ *see Challenges section*).

Although municipal bonds traditionally have been used to fund major infrastructure or other projects, they also have provided funding for renewable energy projects (especially solar PV) in cities around the world (→ *see Table 3 and Sidebar 6*).[15] 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.[16] In the case of revenue bonds, repayment of the loan is backed by a specific revenue stream, such as electricity sales generated by a renewable energy project, or power tariffs collected by the municipal utility.

Cities worldwide have been using municipal bonds to fund renewable energy projects since 2013.

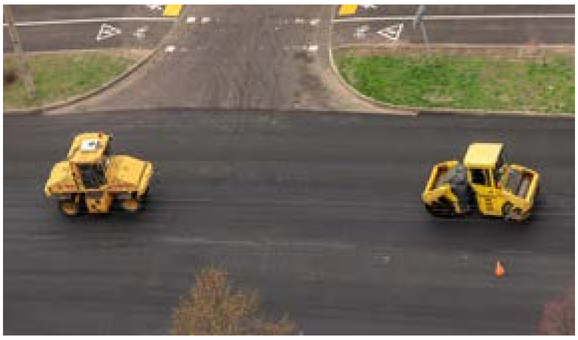


Table 3. Value of Municipal Bonds to Finance Renewable Energy Installations in Cities Worldwide, 2013-2019

City (State, Country)	2013	2014	2015	2016	2017	2018	2019	Total
					In USD million			
Africa								
Johannesburg, South Africa	–	136.4	–	–	–	–	–	**136.4**
Asia								
Tokyo Metropolitan Government, Japan	–	–	–	–	88.2	88.4	91.8	**268.5**
Europe								
Paris, France	–	–	319.8	–	–	–	–	**319.8**
Gothenburg, Sweden	78.8	27.0	126.6	120.3	138.3	165.6	393.1	**1,293.8**
Lund, Sweden	–	–	–	–	85.2	66.1	–	**151.2**
Malmö, Sweden	–	–	–	–	153.2	110.5	128.2	**392.0**
Nacka Kommun, Sweden	–	–	–	–	–	57.4	–	**57.4**
Norrköping, Sweden	–	–	–	68.3	–	–	–	**68.3**
Örebro Kommun, Sweden	–	103.8	–	58.0	59.2	55.0	155.2	**431.1**
Östersund Municipality, Sweden	–	–	–	–	95.6	–	85.2	**180.8**
Västerås, Sweden	–	–	–	81.2	–	–	–	**81.2**
Vellinge Municipality, Sweden	–	–	–	–	–	41.2	20.4	**61.6**
North America								
Toronto, Canada	–	–	–	–	–	–	150.7	**150.7**
Auburn, New York, United States	–	–	8.7	–	–	–	–	**8.7**
Honolulu (City and County), Hawaii, United States	–	–	–	143.8	–	–	–	**143.8**
Otis, Massachusetts, United States	–	–	6.2	–	–	–	–	**6.2**
Richland, Washington, United States	–	–	–	–	–	–	3.1	**3.1**
San Francisco (City and County), California. United States	–	–	–	–	–	–	247.8	**247.8**
Spokane, Washington, United States	–	181.2	–	–	–	–	–	**181.2**

Note: Table includes only city (and in some cases, county) governments that have used bonds to finance renewable energy projects. Within city boundaries, other entities such as banks, utilities and school districts also have used bonds for such projects.

Source: See endnote 15 for this chapter.

SIDEBAR 6. Distributed Solar PV to Empower Cities in Developing Countries

Grid-tied distributed solar PV is changing electric power systems worldwide, alongside other consumer-level, distributed technologies such as batteries. Installed on rooftops, as canopies above car parks, or floating on industrial ponds, solar cells can even be integrated into building materials such as glass and tiles, as well as into the surfaces of sidewalks and highways. The installed capacity of commercial and residential solar PV surged from just a few megawatts in 2000 to 259 GW in 2019. Since distributed solar PV energy is consumed close to where it is generated, it can provide affordable and resilient electricity service for consumers, help grid operators reduce energy losses and grid congestion, and defer or avoid expensive grid upgrades, among other benefits.

Distributed solar PV offers distinct solutions or use cases. Often such systems are used to reduce customer energy bills and to provide a least-cost back-up solution for consumers who otherwise rely on costly diesel generators to make up for unreliable or insufficient grid electricity. Governments that subsidise diesel fuel can incentivise the use of distributed solar PV as part of a subsidy reform strategy. In islands and similar settings, distributed solar PV can be a least-cost generation option due to the absence of land for ground-mounted power stations. In cities where the power grid lacks sufficient capacity to transmit and distribute bulk power to consumers, the utility or third-party provider may be able to deploy distributed solar PV, perhaps with batteries, as a fast, modular, cost-effective alternative to investing in traditional grid upgrades.

For low-income consumers, distributed solar PV can provide community social support to make electricity more affordable while also addressing fiscally responsible social inclusion. Many low-income consumers have a volumetric tariff rate below operating costs ("social tariff") and live in housing unsuitable for individual distributed solar PV deployment, and/or they lack access to finance to cover the upfront costs of distributed systems. City as well as national governments can install community-level distributed solar PV to serve subscribed consumers and mitigate the financial burden of social tariffs and/or to reduce chronic financial losses for retailers of grid electricity. The government also can deploy distributed solar PV to reduce the arrears of public institutions that are unable to pay their electricity bills.

Viable business models are crucial to support the deployment of distributed solar PV. Broadly, three generations of distributed solar PV business models have evolved over time: 1) direct deployment of distributed systems by individual consumers (first generation); 2) reliance on third-party providers who aggregate projects and facilitate some part of the design, installation and financing (second generation); and 3) engaging utilities to help drive deployment (third generation). Different models may be available simultaneously in cities: some users can buy the distributed solar PV systems from installers for self-consumption, while utilities can integrate distributed solar PV in their business by partnering with third-party companies to actively engage in deployment and share the value of increasing consumers' access to low-cost financing.

New financing models open up win-win opportunities for the stakeholders involved. For instance, the issuance of "solar bonds" by governments can potentially increase the availability of debt for distributed solar PV projects and lowers its costs. In India, a municipal entity aggregates projects for third-party distributed PV developers and enables them to overcome barriers to accessing debt capital markets. Solar bonds in India are expected to lower costs by up to 12%, and the funds are disbursed via a public-private partnership. Such public financing, especially at early stages of distributed solar PV market development, can help attract large-scale private sector participation, and can then be phased out over time in favour of a deepening commercial financing pool as the market becomes self-sustaining. In addition to direct and indirect financing, the public sector support may take the form of: a legal, policy and regulatory framework; planning, technical and operational capacity; government-sponsored guarantees; and investment in enabling infrastructure such as smart grids.

Financing also can be offered from third parties to creditworthy customers, such as renewable energy service companies, in the form of: a solar lease; a fixed monthly fee for a predetermined period with the option of buying the system at the end of the lease; and PPAs, with a fixed kilowatt-hour fee normally lower than that from the incumbent utility. Aggregating small projects can help attract more attention from investors and reduce transaction costs.


Douala, Cameroon

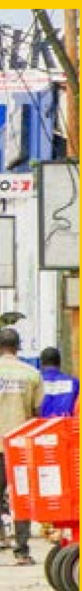
Urban settings, where there is higher potential for distributed PV projects, can be particularly effective in aggregating small projects. Users themselves also can collectively finance small-scale distributed PV projects via crowdfunding. Both Argentina and Mexico have online platforms where users can invest in distributed solar PV projects or access cheaper financing for installing a distributed system.

In India, New Delhi's largest distribution company, BSES Radjhani, with 2.3 million customers, is leading community distributed solar PV by aggregating projects and leasing or selling systems to customers. Multiple distributed systems are connected to the grid at a single metering point, with consumption costs and production benefits (such as lower electricity bills) shared among all households in the community. The involvement of distribution companies and community-level intermediaries assures both households and investors that the programme is viable. Intermediaries help ease the complicated application processes and contracting of distributed solar PV vendors. Once installation costs are paid off in full, ownership is transferred to the customers.

Nigeria is exploring the viability of microgrids or mini-grids for communities underserved by distribution companies. Microgrids up to 1 MW in size, for example, can improve service reliability compared to existing grid service while leveraging existing distribution infrastructure to achieve lower system cost than isolated mini-grids. Four business models have been identified, each led by a different actor: 1) a private operator, who would engage the distribution company and community; 2) a special purpose vehicle (SPV) formed by a distribution company's investors, for example, with certain functions subcontracted to an operator; 3) a co-operative formed by the community; and 4) a collaborative SPV where ownership and operation functions are shared among the operator, community co-operative and distribution company investors. Nigeria's first commercial "undergrid mini-grid" is under development in Mokoloki in Ogun State, with the first tripartite contract in which the mini-grid operator will pay a distribution usage fee to the distribution company.

Source: See endnote 15 for this chapter.


Ogun State, Nigeria




New Delhi, India

New Delhi, India

4

Green bonds give investors greater visibility over the actual use of funds than traditional bonds.

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 differ from normal bonds in that the proceeds are earmarked for qualifying investments in renewable technologies or in various forms of climate adaptation and mitigation.[17] Binding definitions regarding which projects qualify for green bonds are typically applied on a voluntary basis, although more uniform taxonomies have been developed, for example by the EU or Climate Bonds Iniative.[18]

With green bonds, investors (typically institutional investors, often with an environmental, social and governance (ESG) mandate or environmental interest) obtain a certain interest rate over a stipulated period of time, and the funds must be used for the specific purposes 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. Gothenburg (Sweden) was the first city to issue a green bond in 2013.[19] In 2019, the United States and China led in the total value of green bonds issued and in the number of issuers.[20]

DEVELOPMENT FINANCE

In many cases, dedicated funds from development finance institutions (also known as development banks) have supported renewable energy projects in cities. Municipal governments can receive these funds, which often require close co-operation across a range of stakeholders (including national governments) and a long-term commitment to renewables.[21] Development banks frequently partner with local banks to provide the catalytic finance required to unlock investments in renewable energy assets, including capital-intensive projects such as district heating networks. Such institutions step in where local commercial banks are either unwilling or unable to provide the financing required, offering long-term financing. Around 75% of finance for climate mitigation or adaptation activities in cities from development finance institutions comes at commercial rates, but concessional finance (for example, below-market rates) is also an option.[22] For decades, loans from development banks have been accompanied by safeguard policies on environmental and social impacts.[23]

Development banks also provided financing for renewable energy generation projects within in cities.[24] In one recent example, in 2019, the Green Climate Fund made available EUR 87 million (USD 107 million) to cities in nine countries (Albania, Armenia, Georgia, Jordan, Moldova, Mongolia, North Macedonia, Serbia and Tunisia) through the European Bank for Reconstruction and Development's (EBRD) Green Cities Program.[25] The programme provides grants and concessional funds for renewable energy projects along with projects in the areas of water, air and waste management.

LEVERAGING EXTERNAL FUNDS

In the final category of financing, actors may be able to leverage funds from external parties for a given renewable project. Three notable approaches for doing this are: mobilising private finance through public-private partnerships; borrowing through green banks; and signing power purchase agreements to encourage private finance.

PUBLIC-PRIVATE PARTNERSHIPS

Public-private partnerships (PPPs) 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.[26] Such projects typically are funded by means of government finance, private/corporate finance or project finance in which loans are secured for a specific partnership.[27] A blend of finance in PPPs is also possible: for example, if the private sector raises financing, it may be easier or more sensible for the government to take on some aspects or risks of the project.[28]

In the PPP model, local governments may leverage private investment to expand projects (→ *see City Snapshot: North Lombok*).[29] Such arrangements enable municipalities to access financing and technical expertise and to benefit from operational efficiency, while shifting performance and technology risks to the private sector.[30] On the down side, PPPs may have comparatively high transaction costs and may be complicated by differing timelines in the private and public sectors (with the latter heavily influenced by elections).[31] PPP arrangements vary across countries, sectors and projects and may take the form of build-operate-transfer, design-build-operate and lease-develop-operate.[32] Most PPPs supporting renewables are in the power sector, although examples exist of PPPs for renewable heat, such as in the village of Rittershofen (France), where a PPP helped support a geothermal project to supply process heat to a local biorefinery.[33]

Although PPPs are used worldwide, historically they have been more frequent in developing countries.[34] Data on private participation in infrastructure (PPI, which also may encompass agreements that are not necessarily PPPs) gives a rough indication of PPP use worldwide. In low- and middle-income countries, PPI investments are dominated by the transport sector (mainly road and railway projects), which attracted USD 47.8 billion across 123 projects in 2019.[35] By comparison, the energy sector received USD 40.1 billion across 169 projects, of which 136 were renewable energy projects, mainly solar PV and wind power.[36]

Wadi Rum Village, Jordan

NORTH LOMBOK REGENCY

INDONESIA

Land area (km^2)

776.3

Population size

200,000

North Lombok is the youngest regency (municipality) in the Indonesian province of West Nusa Tenggara, located on Lombok Island. Energy demand in West Nusa Tenggara totalled more than 1,950 GWh in 2019 and was growing by 5.9% annually. With increased economic development in the region, energy demand is expected to continue to grow rapidly to 2030.

To reduce greenhouse gas emissions in the city and to support the provincial target to generate 35% of electricity from renewable sources by 2025, the local government has set ambitious goals to deploy renewables in a cost-efficient and sustainable manner. North Lombok has rich potential for cheap biomass residues and opportunities to harness wind and solar energy. Out of 8.97 MW of operating power plant capacity in North Lombok, 8.82 MW is derived from renewables, primarily micro-hydropower (the 7 MW Segara and 1 MW Santong plants) and solar energy in Gili Islands.

To support local communities, the North Lombok government developed a Cost-sharing Financing Scheme for Household-scale Biogas to simultaneously reduce dependence on traditional biomass and cut greenhouse gas emissions in the residential sector. Although this scheme was originally an initiative of the provincial government, the North Lombok government has taken measures to adopt it in the city region. The cost is shared between the local government and Hivos / Yayasan Rumah Energi, along with the household users of the biogas, who pay a small amount to ensure citizen participation and ownership.

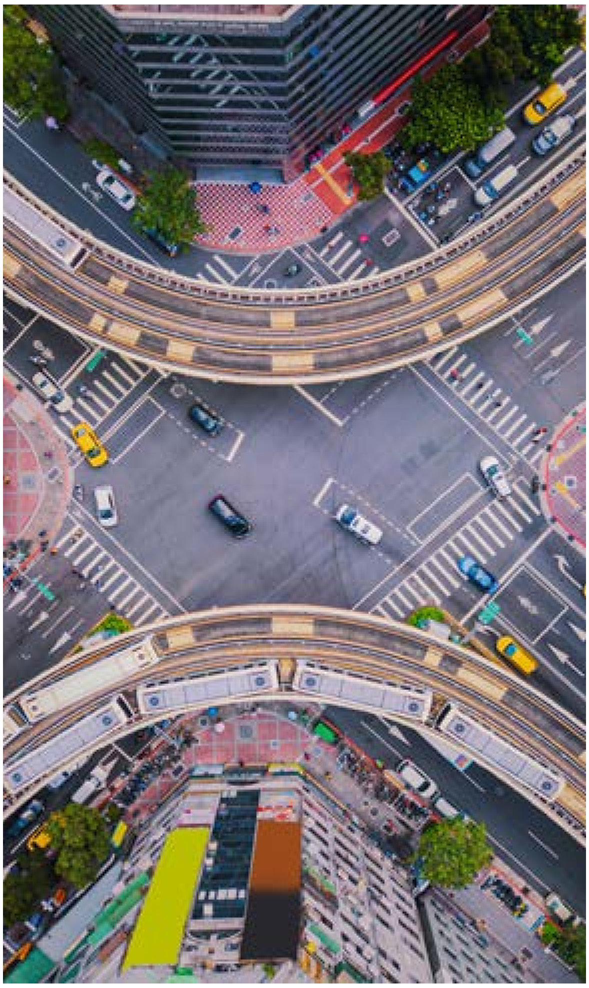
As of 2020, some 1,152 household-scale biogas units using organic waste had been installed in the North Lombok region through this scheme. The cost of one unit of biogas is IDR 13 million (USD 933), and the local government shares this amount by contributing IDR 4-5 million (roughly USD 290-360) per unit (30-40%). To support the technical portion of the project, Hivos / Yayasan Rumah Energi provide high-quality biogas digesters to the users as well as three years of after-sales service for civil buildings and one year for pipe and stove installations.

Source: See endnote 29 for this chapter.

GREEN BANKS

Green banks offer another option for leveraging funds for renewable energy projects, in a PPP of sorts. Green banks function as banks only in terms of being financial intermediaries – they do not fall under traditional banking regulations, and are typically set up as a public financing authority that leverages limited public funds to attract additional private capital for renewable and other related technologies.[37] However, just like a traditional bank, green banks conduct their own financial assessments and lend funds to qualifying projects. The initial cash infusion to create the green bank 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), direct government allocation of funds, and revenues from dedicated taxes, such as on carbon.

As of May 2020, there were 21 established green banks worldwide, with the majority (14) in the United States and others in Australia, Japan, Malaysia, South Africa, Switzerland, the United Arab Emirates and the United Kingdom.[38] They include green banks in the US cities of Washington, D.C. (D.C. Green Bank) and New York City (New York City Energy Efficiency Corporation).[39]



POWER PURCHASE AGREEMENTS

A final option commonly used to mobilise private sector financing is power purchase agreements (PPAs), which are a useful tool for both municipal governments and corporations.[40] PPAs are long-term contracts in which a buyer agrees to purchase the energy generated by a renewable energy project for a fixed price during the contract's tenure.[41] A PPA typically specifies at least three factors: the volume, price and contract length for the electricity or heat that will be sold.[42] Although PPAs are usually associated with renewable electricity, they also can be used for heat supply to industry, agrifood and space heating.

Under most PPAs, the developer is responsible for financing, building and operating the renewable energy project.[43] City governments may initiate projects, for example by committing to buy electricity from a dedicated wind farm or solar PV plant. This essentially guarantees a steady income to the project developer, helping to incentivise the project and to enable the developer to secure financing. In this framework, PPAs are a way for cities to leverage private finance for a renewable energy project (→ *see also Markets and Infrastructure chapter*).

In some jurisdictions, cities wishing to pursue a PPA are limited by existing regulations that cover retail choice and electricity franchises. In markets that allow retail choice with favourable franchising, municipal actors typically can pursue PPAs, whereas in markets that do not allow retail choice they may be prohibited from purchasing electricity from any entity besides the existing utility.[44] In the latter case, a city still may have the opportunity to create a virtual PPA, in which the renewable electricity generated by the project is bought and sold into a power market that may or may not be the same as the customers.[45]

City governments have two main options for participating in a renewable energy PPA: they can sign a municipal PPA themselves, or they can work with other local institutions to arrange a joint-collective PPA.[46] The latter is particularly attractive for cities whose electricity demand is too small to make a bilateral PPA possible. Bilateral PPAs have been used most widely in the United States but also in Australia and South Africa.[47] Collective PPAs for renewable energy have been initiated in Melbourne (Australia) and in 20 US cities, including Boston (Massachusetts), Chicago (Illinois), Houston (Texas) and Portland (Oregon).[48]

Australia

INVESTMENT AND FINANCING IN CITIES BY REGION

In the 533 cities that self-reported to the CDP-ICLEI Unified Reporting System in 2019, a combined 171 renewable energy projects were in the pipeline with total project costs of USD 31.2 billion.[49] In addition, between 2015 and 2019, municipal governments identified USD 7 billion in finance and investment needs for energy infrastructure through ICLEI's Transformative Actions Program.[50] Generally, cities use distinctive approaches to finance renewable energy projects, depending on their government structure, development status and cultural norms. The following sub-sections explore the varying financing mechanisms used for renewable energy in cities across different world regions.


Tokyo, Japan


Valenzuela City, Philippines

ASIA

China and India account for most of the renewable energy investment in Asia (see later discussion). Outside of these countries, the non-OECD Asia-Pacific region accounted for USD 15.2 billion of renewable energy investment in 2019, up 17% from 2018 due largely to investment in offshore wind power in Chinese Taipei.[51] Diverse financial mechanisms have been used across the region, although data are limited. In Cambodia, dedicated funds from the Asian Development Bank have supported a number of PPPs for solar PV plants, including a 10 MW project in Bavet City and two 60 MW plants in the Krakor and Tek Phos districts.[52] In the Philippines, the private sector has been active in financing solar PV plants in San Carlos City and in cities in Cebu.[53]

In Japan, renewable energy investment totalled USD 16.5 billion in 2019, down 10% from 2018.[54] This drop reflected grid and land constraints that continued to hold back solar PV developer activity and auction bidding in the country.[55] Japan's cities, towns and villages lie under the jurisdiction of 47 prefectural local government areas, and it is common for renewable energy projects to be funded privately by individual companies or by a consortium of companies.[56] Prefectural governments occasionally use their own revenue to subsidise projects, at times with co-funding from the national government. For example, the Ministry of the Environment's Local Decarbonization Investment Promotion Fund provides capital contributions and loans for local renewable energy projects.[57]

Projects in Japan also rely on public or green bonds.[58] In the town of Shikaoi-cho (Hokkaido) in 2004, a biogas power plant that provides electricity and heat for greenhouses and fish farming and fuel gas for vehicles was financed mainly by a national subsidy (80%), with the remainder supplied via a public bond issued by the town.[59] The Tokyo Metropolitan Government used green bonds to finance building retrofits that included renewable energy technologies, and the city of Tsuru issued JPY 17 million (USD 164,640) in public bonds to build a 20 kW hydropower station in 2005 that supplies electricity to the city hall.[60]

Prefectural governments in Japan use PPPs (in different forms) to push developers to invest in renewables. A recent and innovative trend is for Japanese local governments to either invest in local energy companies or establish their own local energy companies, in part to ensure the incorporation of renewables in the energy mix and to aid in the circulation of related finance.[61] For example, the city of Kitakyushu provided funds to establish its own local energy company together with the private sector and is planning a 5,000 kW waste-to-energy plant and a 10 MW offshore wind power plant.[62]

Diverse financial mechanisms have been used across Asia, although data are limited.

4

CHINA

China has dominated global investment in renewable energy capacity since 2012.[63] In 2019, however, renewable energy investment in the country fell 8%, to USD 83.4 billion, following a slowdown in the solar PV market after the central government suspended the feed-in tariff for solar PV in 2018.[64]

In contrast to the bottom-up approach used in many Western countries to drive renewable energy development, projects in Chinese cities frequently are driven by policies and targets set by the central government, which officials at lower levels of jurisdiction then are required to implement.[65] The central and provincial governments often provide loans, grants and subsidies to finance project development, although finance for renewables also may originate from bank loans, venture capital, public and private funds, and bonds.[66]

Governments at the county and township levels often act as co-ordinators, linking financing with technological expertise in a PPP of sorts.[67] In Shanghai, the municipal government facilitated a partnership with Shanghai Electric in 2007 to expand offshore wind power capacity near the city.[68] Since then, other Chinese cities (for example, in Shandong and Guangdong provinces) have partnered with Shanghai Electric to build more offshore wind power projects.[69] The Nanjing municipal government joined with two private investors (Nanjing Fengsheng Industry Holding Group and Fengsheng New Energy Technology Consortium) to build a large-scale heat pump project sourced by river water.[70]

To reduce project costs by shifting away from renewable power plants located far from load centres, a number of Chinese cities (such as Beijing, Guangzhou, Shanghai and Shenzhen) have implemented small-scale wind power pilot projects closer to city boundaries.[71] Developers or private investors have funded most of these projects, supported by PPAs signed by utilities or grid companies to ensure that the electricity is sold at a specified price.[72]

Green bonds have been used to facilitate renewable energy investment in China. Between 2016 and late 2019, USD 17.5 billion in green bonds had been issued at the local level, most of them by provincial governments, although examples exist at the county and township levels as well.[73] Most of the green bonds issued locally were for low-carbon transport (such as local mass transit systems) or water infrastructure.[74] However, in 2020 Datang Henan Power Generation Co., Ltd issued a USD 144 million green bond to finance 14 offshore wind power projects.[75]

Some Chinese cities (such as Zhangjiakou) have been pro-active in developing and investing in hydrogen for transport, especially for buses.[76] In a few cases, the emphasis has been on hydrogen produced with renewable electricity. In 2019, the state-owned Hebei Renewables Construction and Investment Company completed the Zhangjiakou Guyuan wind power hydrogen generation project, with an investment of CNY 2 billion (USD 306.4 million).[77] Meanwhile, Shanghai and Shenzhen have been involved in China's push for electric vehicle infrastructure: in 2020, Shanghai completed a pilot programme that will allow utilities to co-ordinate EV charging with the availability of renewables.[78]

INDIA

Investment in renewable energy capacity in India fell 14% in 2019, to USD 9.3 billion.[79] Financing for renewables in Indian cities originates from three main sources: national and state-level schemes (such as the 100 Smart Cities Mission), which have increased in scale and number over time; international financing agencies and development banks, with many of these projects being small and experimental; and local private capital, for which very little information is available.[80] Although municipal bonds have been used to a limited extent for infrastructure projects in India, they have not been adopted for renewable energy projects to date.[81]

Historically, Indian cities have not been at the forefront of financing renewables, in large part because energy governance in the country remains constitutionally with the central and state governments.[82] In 2015, however, the government launched the 100 Smart Cities Mission, creating a new vision for the role of cities in renewable energy projects.[83] Subsequently, around 100 cities in India created plans for investing in energy distribution and supply, including solar PV, waste-to-energy and wind energy (to a limited extent), as well as electric mobility.

Of the first 60 approved proposals, around 10% of the budget – a total of INR 13,161 crore (USD 1.8 billion) – was for such energy projects, with the remainder directed towards other infrastructure projects such as water, buildings, transport and waste management.[84] The cities allocating the most of their proposed budgets to solar PV were New Delhi (INR 535 crore or USD 73 million), Mangalore (INR 311.85 crore or USD 42.5 million) and Vishakapatnam (INR 305.83 crore or USD 41.7 million), whereas the cities allocating the most to waste-to-energy were Jaipur (INR 200 crore or USD 27.3 million), followed by Kalyan and Surat.[85] The cities allocating the most to e-mobility were Chandigarh (INR 163.15 crore or USD 22.3 million), followed by Pune and Dharamshala.[86]

New Delhi, India

AFRICA AND THE MIDDLE EAST

Investment in renewable energy capacity in Africa and the Middle East fell 8% in 2019 to USD 15.2 billion, down from a record USD 16.5 billion invested in 2018.[87] Most of this investment was in the United Arab Emirates, followed by South Africa and Kenya.[88]

Development finance is important for renewable energy projects across the region, and many funds are available, some of which are applied in city settings.[89] One notable effort is the USD 4 billion solar PV park (comprising multiple smaller projects) outside of Aswan (Egypt), which is being financed by several international development banks on land donated by the Egyptian government, and is supported by a 25-year PPA with the local electricity transmission company.[90]

In 2020, the German development bank KfW announced a EUR 9.6 million (USD 11.8 million) grant for Kigali (Rwanda) to develop a "green city" project powered by solar PV, which also will be financed by the Rwandan government and the Green Climate Fund.[91] In addition, KfW provided USD 25 million to finance two solar PV plants in the Ghanaian cities of Kaleo and Lawra.[92] In the United Arab Emirates, loans from international banks were key for the USD 4.33 billion concentrating solar thermal power (CSP) and solar PV project south of Dubai, which dominated investment in the region in 2019.[93]

Cities in Africa and the Middle East also have relied on PPPs. Since 2011, South Africa's Renewable Energy Independent Power Producer Programme (REIPPP) has helped independent power producers design, develop and operate biomass, landfill gas, hydropower, solar PV, CSP and onshore wind power plants across the country, many of them in or near cities.[94] Private investors have readily supported the projects, since the government mitigated project risks through a transparent procurement process.[95]

In Kenya, a tender was issued in 2020 for a build-own-operate-transfer PPP to support a new 140 MW geothermal power plant, from which Kenya Power and Lighting Company (KPLC) will buy electricity under a 25-year PPA to supply local businesses, the city of Naivasha and several surrounding towns.[96] In Qatar, an 800 MW solar PV farm near the village of Al Kharsaah reached financial close in 2020, supported by a build-own-operate-transfer PPP and USD 330 million in loans from international banks.[97]

Comparatively few African cities have used green bonds to support renewable energy projects. Notably, Johannesburg (South Africa) issued a USD 143 million green bond to fund projects across a range of sectors including new dual-fuel buses and the conversion of 30 buses to biogas.[98] Although some larger players in the Middle East have issued green bonds (such as the Egyptian government and Qatar National Bank), cities in that region have not yet used this mechanism for renewable energy projects.[99]

Development finance is important for renewable energy projects in cities across Africa.

LATIN AMERICA

Investment in renewable energy capacity across Latin America has grown markedly, up 43% in 2019 to a record USD 18.5 billion.[100] Four countries dominated this investment: Brazil (up 74% to USD 6.5 billion), Chile (up 302% to USD 4.9 billion), Mexico (up 17% to USD 4.3 billion) and Argentina (down 18% to USD 2.0 billion).[101] PPPs, PPAs and development finance provide key support for projects in cities across the region.[102]

PPPs have been used widely in Latin America to finance transport-related projects as well as distributed generation. In 2019, Mexico used the PPP model to attract USD 2.1 billion for 15 solar PV projects, and in Santiago (Chile) a PPP was established to install 104 EV charging points of 22 kW each (which eventually will use renewable electricity) at a total cost of USD 2.5 million.[103] The state government of Piaui (Brazil) opened bidding in 2020 for a USD 32 million PPP to build eight solar PV plants of 5 MW each in six municipalities (Caraúbas do Piauí, Miguel Alves, Piracuruca, Jose de Freitas, Cabeceiras do Piauí and Canto do Buriti) as a way to meet the power demand of all state-owned buildings.[104] Also in Brazil, São Paulo initiated a PPP for a USD 32.6 million investment in solar PV to supply the city's health department, and Curitiba partnered with the local utility to jointly finance (51%/49%) a 5 MW solar-biomass project that will supply 43% of the municipal building's electricity needs.[105]

The public and private sectors have used PPAs to establish large-scale wind power and solar PV projects as well, both within and outside cities.[106] Private companies often are driven by a desire to meet sustainability goals. For example, in Mexico the beer producer Grupo Modelo signed a PPA for the construction of a 220 MW wind farm that will supply electricity for the company's brewery.[107]

National banks increasingly have helped finance renewables in the region.[108] The Development Bank of Colombia (Bancoldex) offers a green credit line totalling USD 14.4 million to finance renewable energy and energy efficiency projects in cities across the country.[109] In São Paulo (Brazil), the state's Bureau of Energy and Mining and the São Paulo Development Agency (Desenvolve SP) provide long-term, low-interest loans for small-scale renewable energy projects including solar PV, wind, and small hydropower plants, as well as equipment for biogas plants.[110] International agencies that finance distributed generation usually co-ordinate through partnerships with national and regional banks.[111]

Some innovative instruments have been used to provide finance for smaller-scale projects, especially for solar PV. This includes crowdfunding in Argentina and Mexico and the use of energy service companies (ESCOs) in Brazil, Chile and Colombia.[112] Municipal bonds and green bonds have not been used to the extent seen in some other world regions, although examples exist.[113] Mexico City (Mexico) issued Latin America's first municipal green bond in 2016 with a focus on mobility, energy efficiency, water infrastructure and management projects.[114]

EUROPE

Financing for renewables in cities across Europe is diverse. Cities provide their own funds, rely on national or EU funds and use PPPs or green bonds.

Investment in renewable energy capacity in Europe fell 7% in 2019, to USD 54.6 billion, with large variations across countries and technologies.[115] Most of the investment occurred in Spain (an increase to USD 8.4 billion), the Netherlands (an increase to USD 5.5 billion) and the United Kingdom (a decrease to USD 5.4 billion).[116] In Germany, local governments have relied mainly on their own funds to finance infrastructure projects, with contributions from the national and state governments and other purpose-tied investment allocations.[117] Only around 20% of finance for municipal infrastructure in the country has come from borrowed funds, mostly bank loans.[118]

Nonetheless, the use of green bonds is rising across Europe, with notable increases in 2019 in France (up 113% to USD 30.1 billion), Germany (up 144% to USD 18.7 billion) and the Netherlands (up 105% to 15.1 billion).[119] Although national governments account for the majority of government green bond issuance in Europe, several local governments and cities have issued a steady stream of bonds – including the Canton of Geneva (Switzerland), Gothenburg and Stockholm's Lans Landsting (Sweden), Ile-de-France (France) and Oslo (Norway).[120]

In Europe, both the aggregate value of PPP transactions that reached financial close in 2019 and the average transaction size decreased in 2019.[121] Although the transport sector dominated these transactions, PPPs also have been used for renewable electricity and heat. Ljubljana (Slovenia) announced a renovation project in 2020 that uses a tested PPP model with a consortium of companies to renovate sports centres, schools and a concert hall with energy efficiency and renewable energy solutions; the city will use the energy savings to repay project costs.[122] The Serbian cities of Niš and Pirot used PPPs to replace heating oil boilers with biomass boilers in schools.[123]

The EU provides funding (in the form of grants, equity, loans, guarantees or other) for urban renewable energy projects through various programmes, including the Connecting Europe Facility, EU Integrated Territorial Investments, European Local Energy Assistance, Horizon 2020 SC3 Energy, the Innovation Fund, the LIFE Programme, URBACT and Urban Innovative Actions.[124] Among recent examples of such support in the heating sector, Riga (Latvia) attracted EU co-financing to implement a 50 MW boiler house and biomass-fired water boilers of 4 MW each.[125] The EBRD provided Banja Luka (Bosnia and Herzegovina) with a loan of EUR 8.3 million (USD 10.2 million) to build a 49 MW district heating boiler plant fired by wood biomass.[126] Pancevo (Serbia) received a loan from the EBRD and KfW to construct a solar thermal field in 2017 as part of a solar district heating project.[127]

OCEANIA

Investment in renewable energy projects in Australia has increased in recent years, although it fell slightly in 2019 to around AUD 7 billion (USD 5.4 billion), down from AUD 8.5 billion (USD 6.5 billion) in 2018.[128] Most of the investment was in the private sector, supplied by domestic banks, but overseas financing has played an increasing role. Households have driven small-scale investment in renewables as well, with more than 25% of Australian homes now fitted with rooftop solar PV, many of them in cities.[129] Around 10% of the country's rooftop solar installations have been financed via short-term credit.[130]

PPAs also are being used in Australia. Historically, developers entered into PPAs with electricity retailers, but corporate PPAs are on the rise, and in some cases municipal governments have joined the ranks. To reach its goal of powering its street-lights, pools, sports fields, depots and other buildings with 100% renewables – which it did in 2020 – Sydney (Australia) signed an AUD 60 million (USD 46 million) PPA for electricity supplied mainly from a 270 MW wind farm and a 120 MW solar PV farm (plus a 3 MW community solar project) in New South Wales.[131] In Melbourne, 14 public and private institutions including the city, banks, universities and local councils signed a collective PPA in 2017 to enable the construction of an 80 MW wind farm in western Victoria state.[132]

In the Solomon Islands, the country's first ever PPP was signed in 2019 for more than USD 200 million for a 15 MW hydropower project 20 kilometres south-west of the capital city of Honiara.[133] Although the original plan considered only private sector financing, the final package also included dedicated funds from the World Bank, the Green Climate Fund, the Asian Development Bank and others.[134]

NORTH AMERICA

In the United States, a leading country in investment in renewable energy capacity, investment grew 28% in 2019 to USD 55.5 billion.[135] Since 2015, a majority of renewable electricity capacity transactions announced by cities have been supported by PPAs (mostly for capacity located outside of city limits).[136] This capacity is financed mainly by private rather than public entities, as private entities have the requisite tax liability to take advantage of national and state-level tax incentives. US cities are addressing this by partnering with private companies and by signing PPAs with private developers.[137]

US cities signed PPAs for a total of 2,625 MW of renewable power capacity in 2019, up from 2,056 MW in 2018.[138] Cincinnati (Ohio) signed a PPA in which the city agreed to purchase the electricity from a 100 MW solar PV farm some 64 kilometres east of the city to fulfil its renewable energy goals.[139] The PPA model also has been used in Canada: for example, in 2020 the Royal Bank of Canada signed a PPA for two utility-scale solar PV farms in Alberta totalling 39 MW.[140]

Some renewable electricity projects in the United States have been financed using municipal green bonds. Richmond (Washington) aims to use a USD 3 million green bond issued by the state in 2019 to build a 1 MW / 4 MWh solar energy battery storage system and training facility.[141] In Sacramento (California), the community-owned, not-for-profit electricity provider issued a USD 400 million green bond in 2020 to fund solar PV, hydropower and infrastructure projects.[142]

By contrast, the main source of finance in the transport sector is federal, state and municipal grants or budget allocations, although projects often are supported by or are in partnership with a nonprofit or private sector partner.[143] In Los Angeles (California), a USD 400,000 grant is providing four zero-emission mobility pilots to the city and the surrounding county, including two EV carsharing projects, an EV charging project and an e-bike project charged by solar PV.[144]

CITY-SPECIFIC CHALLENGES TO INVESTING IN RENEWABLES

Regardless of their location, renewable energy projects face inherent financing challenges that raise the investment risks and related financing costs.[145] These challenges include higher upfront technology costs, information gaps and hard lock-ins (the idea that once infrastructure is built, "green" retrofits can be costly or technically impossible to implement before the end of the productive life cycle).[146] Barriers to innovation – in the form of design, products, and new institutions or practices – also are a source of perceived risk for both public and private investors who may be unwilling or unable to evaluate unfamiliar investments.[147]

Any city wishing to invest in infrastructure faces challenges in mobilising revenue and allocating budgets.[148] Before seeking investment, municipal governments also must finance the pre-feasibility stage and project preparation, which can represent more than 10% of the total project cost.[149] Governments often have limited budgetary flexibility and face multiple competing claims on their resources, including public safety, water supply, pension liabilities, unemployment, poverty, roads, bridges and waste management.[150] Rapid urbanisation has intensified these pressures.

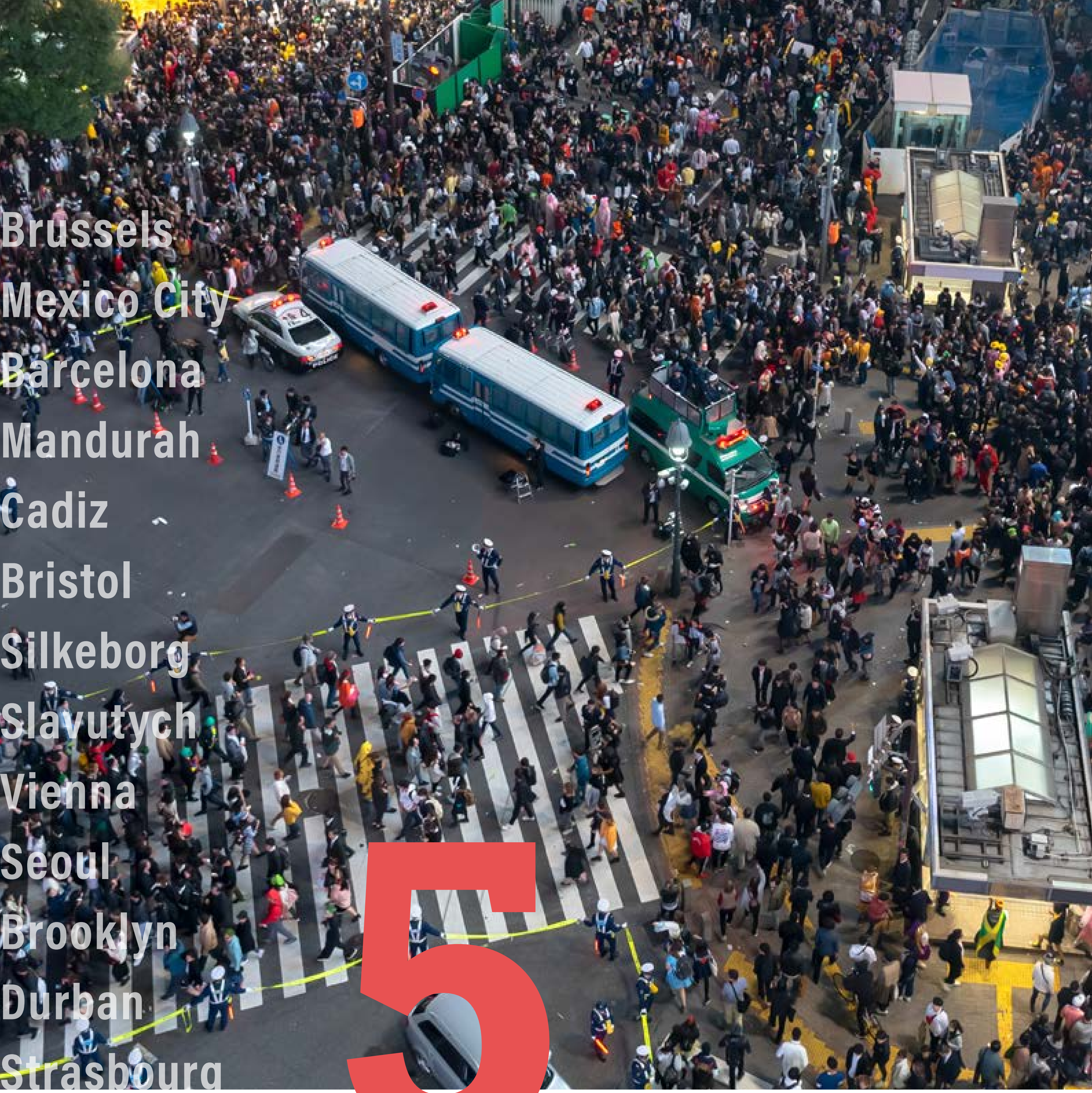
Municipal governments also may struggle with soft lock-ins, which include limits to institutional capacity and institutional inertia.[151] Additional barriers relate to a lack of organisational capacity, knowledge of funding opportunities, and/or equity and debt instruments.[152] For example, even when a municipal or other actor has identified centrally managed EU funds for a given renewable energy project, it must submit an application in English (often not the mother tongue of the applicant country) and partner with organisations from EU Member States to receive these funds. Finding international partners and preparing applications requires time, human resources and often knowledge on technical information and risk assessment.[153] Local governments in South Africa have reported that the complexity of available international/intergovernmental grants and the high level of human resource investment with no guarantee of return can result in inaction or paralysis.[154]

Although higher levels of government can help cities accrue sufficient capital for renewable energy projects, barriers can exist in co-funding arrangements or in limitations to borrowing power. Local governments often depend on national governments to provide a significant amount of finance, which can be inadequate, unpredictable or declining. For example, in the EU more than half of small sub-national governments have reported a decrease in grants from their federal governments since 2010.[155] In terms of limitations to borrowing power, less than half of countries (42%) are recorded as having devolved fiscal or legislative powers to sub-national governments, and of these the depth of revenue-raising powers is highly variable.[156] Only 22 countries (14%) allow borrowing without restriction, and 56% forbid outright borrowing by local governments.[157]

Cities in developing countries face additional barriers.[158] Poorer developing countries often suffer from a tax base that is inadequate to finance the cost of basic infrastructure.[159] Many developing-country cities are not perceived as creditworthy, making it more difficult for them to take out bonds and loans as well as to attract private investment.[160] Typically, cities that have lower credit ratings are charged higher interest rates to finance projects.[161] Of the 500 largest cities in developing countries, less than 20% are deemed creditworthy in their local context, and less than 4% are creditworthy in international capital markets.[162]

Los Angeles, United States

Any city wishing to invest in renewables faces **challenges** in mobilising revenue and allocating budgets.



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5 CITIZEN PARTICIPATION

CITIZEN PARTICIPATION

Citizen participation in renewable energy can be defined broadly as the different ways in which inhabitants are involved in planning, funding, managing, governing and/or executing the development of renewables in cities.[1] Citizens[i] can support the development of urban renewable energy by, for example:

- choosing to purchase energy from a provider that offers renewable electricity or heat, in cities where consumer choice, such as green tariffs, is an option;
- becoming individual prosumers[ii] by producing all or part of their own energy;
- getting together to form community energy projects;
- participating in setting the direction for the development of urban energy systems; and
- making their voices heard through bottom-up initiatives and campaigns in favour of renewables.

The active engagement of citizens in renewable energy development – as energy producers and as members of energy communities engaging in decision-making processes and wider campaigns – has been pivotal to the rising penetration of renewables[iii,2] Citizen participation stimulates investments by individuals and local communities in renewable energy generation.[3] Citizen participation also is central to enabling a *just transition* to a decarbonised energy system that simultaneously considers the needs of impacted communities, addresses energy poverty and delivers on climate mitigation.[4]

Although citizen participation is usually based on bottom-up approaches and on the actions of inhabitants, municipal governments, because of their proximity to citizens, can play a strategic role in facilitating the involvement of citizens. Through their planning processes, municipal governments can include citizens in the design, ownership and management of energy systems to account for citizens in their positions as prosumers, owners of energy storage facilities, and holders of rights and entitlements to shape the development of urban energy systems.[5]

In return, engaging citizens at the local level increases public awareness about renewables and can accelerate cities' transitions to renewable energy. For example, the siting of renewable energy projects generally is easier if all stakeholders are involved in the planning from the beginning and understand the potential benefits.[6] Citizens also can play a central role in providing sites and investment for small-scale distributed projects. Further, citizen participation may address interlinked social issues relating to fuel poverty, health and well-being.[7] Decision-making processes that involve active citizen participation can increase trust in the local community and government.[8]

i Here, "citizens" refers to people living in a particular place, rather than to people holding specific legal rights due to their nationality. Usually, residents within a city (regardless of citizenship) are able to shape city-level energy transitions. See Oxford Learner's Dictionaries, "Citizen", https://www.oxfordlearnersdictionaries.com/definition/english/citizen, viewed 15 November 2020.

ii Both consumers and producers of energy. See Glossary for full definition.

iii For more information, see chapter on "Public support" in REN21's *Renewables 2020 Global Status Report*, available at www.ren21.net/gsr.

Engaging citizens at the local level increases **public awareness** about renewables and can accelerate cities' transitions to renewables.

The ability of municipal governments to engage citizens at the city level is greatly conditioned by decisions at higher levels of government. In addition, intermediary organisations, such as energy offices, innovation hubs and private consultants, play central roles in promoting citizen participation in the development of urban energy systems. These organisations can, for example, act as liaisons between local governments and communities; support existing or potential prosumers or community energy co-operatives by providing information, advice and investment support; assist in the implementation of technologies; and defend the interests of adopters.

CONSUMER CHOICE

For urban populations that have access to affordable electricity, the most basic way that citizens can participate in energy systems is through consumer choice, or allowing people to choose among different energy suppliers. While consumer choice is available outside the city context as well, it provides a key opportunity for urban residents to influence energy supply through their energy preferences. Consumer choice most commonly exists in the electricity sector, but it also can stimulate the uptake of renewables in the heating and cooling and transport sectors.[9]

One precondition for consumer choice is that energy markets have been liberalised, making it possible for consumers to select among a number of different suppliers that deliver energy to the city.[10] Although the ongoing liberalisation of energy markets supports the development of green tariff programmes – where utilities buy renewable energy to match a portion or all of the electricity bought by consumers – it does not ensure them, and these decisions generally are undertaken at the national or state level.[11] Municipal governments can support green tariffs through marketing campaigns that highlight the personal and societal benefits of renewable energy. Such awareness campaigns are particularly important for making green tariff schemes attractive to "light green" consumers who may have positive attitudes towards renewables but are not yet purchasing them.[12]

In some jurisdictions, interest in buying renewables has surged, often driven by the declining price of renewable power relative to other electricity sources, by awareness-raising on energy and climate issues, and in some cases by rising electricity prices.[13] In 2020, more than half (53%) of US residential consumers found it "extremely" or "very" important that renewable energy contribute a portion of their electricity supply, marking the first time in a US survey that renewables ranked higher than energy affordability.[14] A survey in the United Kingdom found that green tariff purchases motivated 19% of consumer switches between energy suppliers in mid-2020, up from only 9% in 2018.[15]

Consumer choice can manifest in different ways:

- **Green tariff programmes** typically allow consumers to choose among a variety of utility-offered plans that supply electricity or district heat generated fully or partly from renewables. Under "guarantee of origin" rules, the utilities are required to demonstrate the renewable energy content of this supplied energy.[16]
- **Pay-as-you-go (PAYGo) services** offer customers an alternative to contracting with utilities. These services are prevalent in cities where the electricity grid is not fully developed or lacks stability, or where electricity is expensive. Typically, the PAYGo electricity comes from decentralised solar PV systems.[17]
- **Peer-to-peer energy trading programmes** enable consumers in some cities to purchase renewable energy from other citizens or businesses rather than from utilities (→ *see Individual Prosumers section in this chapter*). Enabled by digitalisation, such programmes are becoming available for larger groups of consumers (→ *see Sidebar 7*).[18] Peer-to-peer trading is emerging as an important option for expanding renewable energy consumption in the future.[19]

One way that municipal governments seek to increase consumer choice opportunities for city inhabitants is by lobbying for the rights of citizens to be able to purchase renewable energy. In California (US), local officials in Los Angeles and San Jose have protested against exit fees[i] paid to incumbent utilities, which effectively disincentivise citizens from participating in community choice aggregation programmes (→ *see Urban Policy Landscape chapter*).[20] Cities can attract more citizens to such programmes by offering competitive tariff rates, greater shares of renewable energy, and a portfolio of incentives that provide environmental and economic benefits to participants, including small grants subsidising the purchase of solar PV equipment.[21]

Generally, green electricity markets have expanded in recent years, although no consolidated data on them exist at the city level, and data also are hampered by definitional differences (for example, in the types of green tariffs).[22] Among recent examples, in Ankara and Istanbul (both Turkey), a green tariff programme for 100% renewable energy became possible in 2020 following changes in national legislation.[23] In the United States, the share of households with access to green electricity purchasing increased from 14% in 2016 to 20% in 2020, and the share of households actually buying green electricity increased from 6% to 11%.[24] In the United Kingdom, more than 50% of the electricity tariffs available on the market in 2019 had renewable energy content, up from only 9% in 2016.[25]

However, not all countries with liberalised energy markets offer green tariff programmes for citizens. In Latin America, for example, the situation varies. In Argentina, Chile and Mexico, urban residents are able to purchase renewable power only if they buy a specified minimum amount of electricity, which effectively excludes much of the population from selecting renewable options.[26] In some cities, PAYGo models are filling the gap by offering a greater choice of providers and electricity sources.[27] In Medellín, Colombia, the public utility has a PAYGo offering that allows residential users to regulate their electricity consumption through pre-payment based on their real purchasing power.[28]

i Exit fees are intended to compensate utility companies for previous investments they have made in, for example, energy infrastructure such as transmission and distribution lines.

SIDEBAR 7. Digitalisation: Enabling Citizen Participation

Digitalisation refers to the increasing reliance of business models on digital technologies. In the case of renewable energy, digitalisation enables both consumer choice and prosumerism, allowing for increased flexibility and transparency for customers and greater profitability for prosumers.

On the consumer choice side, for example, the Australian company Power Ledger provides an energy trading platform to utilities, energy retailers and others that uses blockchain[i] technology to enable greater transparency in energy sourcing. Rather than simply choosing renewables, customers can fully design their own energy mix by selecting the specific projects that generate their electricity, from a certain wind turbine to a neighbour's solar PV installation[ii].

To support prosumers, peer-to-peer energy trading built on blockchain technology makes it possible for residential producers to supply other citizens with electricity, including in cities such as London (UK), Medellín (Colombia), New York (US) and Singapore. The municipal-level Brooklyn Microgrid in New York City, launched in December 2019, provides a digital platform for households to sell renewable energy to others. In New Delhi (India), communities in the Dwarka neighbourhood trialled group net metering solutions in 2020 whereby surplus solar electricity is sold to neighbours rather than fed into the grid. Such approaches can result in improved profitability for prosumers and in access to cheaper, renewable energy for neighbours.

Municipal governments can support pilot programmes that demonstrate the technical and commercial feasibility of new digital technologies. They also can provide financial incentives for deploying advanced metering infrastructure that allows two-way communication between prosumers and system operators. Such approaches help ensure that the data are used for the benefit of citizens by, for example, enabling people to better understand their energy use and the possibilities for reducing it or for shifting their time of use.

Source: See endnote 18 for this chapter.

i Blockchain technology is a distributed ledger technology that permits the storing of data on servers around the world while also allowing every network member to view all data stored on other members' servers.

ii Although consumers choose to support specific renewable energy projects, this does not mean that their electricity actually originates from these projects, as it is impossible to control where specific electrons go once they enter the grid.

New Delhi, India

INDIVIDUAL PROSUMERS

In their decision to consume renewable energy, individuals, households and businesses may opt to produce part or all of this energy themselves, in their role as prosumers (both consumers and producers of energy).[29] Rooftop solar PV is the preferred technology choice, particularly in cities where space is limited, but prosumers also are adopting solutions ranging from micro wind turbines to wood pellet heating (connected to district heating systems).[30] Prosumerism is an attractive option in many places. In a 2020 survey in Brazil, 90% of respondents said they would like to produce electricity at home, typically from solar PV systems.[31] However, consolidated data on prosumers in cities remain scarce.

Many of the policies supporting prosumers – including feed-in tariffs, net metering schemes and policies ensuring full compensation for electricity or heat fed back to the grid – are adopted at the state or national level[i]. However, some examples exist at the city level (→ *see Urban Policy Landscape chapter*), and municipal governments support prosumers in a variety of ways. In Brussels (Belgium), the regional government provides low-interest loans for households to invest in renewable energy equipment.[32] Mexico City (Mexico) allocates USD 17.1 million annually for distributed solar capacity, with the aim of adding 350 MW by 2024.[33] Municipal governments also play an important role in co-ordinating consumer awareness campaigns.

Another emerging trend is solar leasing agreements, whereby developers or financing institutions cover the long-term leases for rooftop solar PV installations, and citizens then pay a periodic fee to use the generated power rather than having to invest in the system themselves. The resulting energy cost savings or the profit from feeding electricity into the grid are shared with the citizen. Although public authorities typically are not involved directly in solar leasing, city governments can promote it by ensuring the availability and comparability of information on related costs.[34] Solar leasing was first developed in the United States but is diffusing rapidly, including across India and Malaysia in Asia.[35]

Among other innovations emerging at the city level is the provision of collective energy storage. In the Meadow Springs suburb of Mandurah (Australia), the PowerBank Community Storage System enables 52 individual prosumers to store excess energy from their solar panels in a shared battery facility, and then withdraw up to 8 kWh of electricity per day for a daily fee of AUD 1 (USD 0.77).[36]

Municipal governments support prosumers and community energy projects in a variety of ways.

COMMUNITY ENERGY IN CITIES

Traditionally a rural phenomenon, community energy projects have increasingly made their way into cities. In its most basic form, community energy refers to energy systems that are managed by local people for the benefit of local people.[37] This generally entails collective local ownership along with decision-making power that lies with a group of local inhabitants. Most community energy projects are focused on renewable energy production, but projects also exist for energy storage, energy efficiency, mobility, sharing and trading, among others. Assessing the full scope of community energy initiatives in cities is challenging because of a lack of data and varying definitions of the term[ii].

The collective character of community energy sets it apart from "simple" prosumerism. Community energy usually brings local benefits such as job creation and improved societal welfare, greater energy security through cost savings and price certainty, and expanded awareness and public acceptance of renewable energy technologies – in addition to contributing to wider sustainable development objectives and emission reductions.[38] Because community energy arrangements depend on collective decision making by local inhabitants, this broadens participation in the energy system and strengthens local cohesion and democratic processes, often empowering citizens beyond the respective community energy projects.[39] Community energy makes participants conscious about their rights and responsibilities and adds to a sense of energy citizenship and energy democracy.[40]

Milan, Italy

i Worldwide, as of the end of 2019, feed-in policies were in place in 113 jurisdictions at the national, state or provincial levels. In 2019, the shift continued away from feed-in policies and towards mechanisms such as auctions and tenders. See REN21's *Renewables 2020 Global Status Report*, available at www.ren21.net/gsr. In the European Union, the recent Clean Energy Package has greatly empowered prosumers, including ensuring their right to receive compensation that reflects the market value of the electricity that they supply to the grid.

ii For example, two formal terms for community energy are "citizen energy community" and "renewable energy community". In Germany, community energy refers 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.

Community energy projects are most common in countries that have liberalised energy markets and where incumbent energy providers are less powerful. The number and character of community energy projects within cities varies widely: projects are more frequent in European countries such as Belgium, Denmark, Germany and the United Kingdom, as well as in the United States, but they also are emerging in Australia, Canada, Japan, the Republic of Korea and Thailand, among others.[41]

While many community energy projects originate at the grassroots level, local authorities often actively support these efforts through funding schemes, favourable procurement rules, and the provision of expertise as well as access to public spaces (such as public land or roof space on schools, courthouses and other public buildings).[42] In the EU, municipalities can legally become members of community energy projects.[43] Through such support, cities can tap into the creativity, expertise and financial resources of residents as a way to meet their own local renewable energy and climate goals and strengthen citizen support for renewables through direct participation.[44] Municipal governments and citizens thus become allies in the transition towards a renewable-based energy system.

Municipal governments around the world play various roles in supporting community energy projects:

- **Regulatory and policy enablers.** Governments create an enabling environment for community energy development by, for example: including targets for community ownership in municipal climate and energy strategies; making it mandatory for developers to offer community ownership options; securing partnerships with rural hinterlands to set up urban-rural projects; and using urban planning to steer new neighbourhoods towards community energy.[45]
- **Project partners and facilitators.** Governments directly support community energy projects by, for example: creating a dedicated body at the city level to provide projects with information and know-how; mapping the city's renewable energy potential; acting as a liaison to bring interested stakeholders to the table; helping to secure funding from municipal sources or third parties; and even becoming a member of a community energy project.[46]
- **Infrastructure operators.** Governments invite community involvement in energy infrastructure by, for example: allowing community participation in municipality-owned utilities; providing opportunities for participatory financing; and teaming up with community energy initiatives to advance remunicipalisation efforts, which open the door for further community energy projects (→ *see Remunicipalisation section*).[47]

In **Europe**, EU Member States are required under the 2019 Clean Energy for All Europeans package to provide legal definitions of community energy projects and to develop supportive legal frameworks.[48] The number of active community energy projects across Europe increased from some 2,400 in 2015 to more than 3,600 in 2019.[49] Around 1,500 projects are members of REScoop, the European association of community energy projects, which represents more than 1 million citizens and acts as both an intermediary and lobby organisation.[50] Most community energy projects are in Germany, Denmark and the Netherlands, although no coherent trend exists and the situation varies greatly among EU Member States.[51] Studies point to the region's large potential for citizen-financed community energy projects.[52]


Madrid, Spain

The COVID-19 pandemic appears to have slowed the growth in community energy in Europe, with existing projects reporting lower turnover and delays in installing new equipment.[53] However, the emerging pandemic recovery packages and the European Green New Deal could have a positive influence on projects in cities and elsewhere. In Croatia, COVID-19 recovery funds enabled the construction of 1,000 community-owned solar PV systems in 10 cities, supported by the European Institute of Innovation and Technology and the Climate KIC Cities Accelerator Programme.[54]

In Spain, urban citizens are involved in community energy projects through several large regional co-operatives, including Som Energia (67,800 members) and GOIENER (more than 10,000 members).[55] The concept of collective self-consumption, introduced in 2019, allows citizens in densely populated areas to join together and become "off-site prosumers" by investing in solar PV installations near their homes and on neighbouring buildings, to the benefit of the wider community.[56] Municipal governments have spearheaded community energy projects in Spanish cities including Barcelona, Cadiz, Girona, Madrid, Pamplona, San Sebastian, Valencia and Valladolid.[57]

Germany has been a leading country in community energy development, with an estimated 1,750 projects in 2020.[58] Spurred by a strong domestic renewables sector and feed-in tariffs, many communities have benefited economically from renewable energy projects.[59] The number of new community energy projects in Germany peaked in 2011, with 167 initiatives added that year.[60] Since then, changes in national legislation – specifically, a shift from feed-in tariffs to an auction system – have created difficulties for community energy groups, and only 14 new projects were added in 2019.[61] Most of Germany's projects are located in rural areas, but some are in cities, for example in Jena where communities act as shareholders with decision-making power over their local energy suppliers.[62]

Denmark has a long history of community energy development. Although community-owned wind power projects often are located in rural areas, solar-based district heating systems frequently occur in or near cities. In 2019, Denmark was home to 120 such plants, including in the town of Silkeborg.[63] In Marstal, on the island of Ærø, a solar district heating system supplies 55% of the total heat demand (the rest is from wood chips and a heat pump), and citizens collectively own both the plant and the heating grid.[64]

At least 300 community energy groups were active in the United Kingdom in 2019.[65] These groups were involved mainly in electricity generation (with fewer projects related to heat generation), installing more than 15.4 MW of new electricity in 2019 for a cumulative total of 264.9 MW.[66] Groups pushed to finalise community-owned electricity projects in anticipation of the ending of the feed-in tariff programme in March 2020[i].[67] Among community energy activities in UK cities, the Community Energy London Network, which connects 700 people involved in 30 projects, has resulted in 450 tonnes of CO_2 savings since the start of the network in 2018.[68] In Edinburgh (Scotland), the Community Solar Cooperative produces 1.1 GWh of electricity per year from 24 solar PV systems.[69] Community energy projects also exist in Brighton, Bristol and Bournemouth (all England) and in Cardiff (Wales).[70]

Community energy projects have grown in Belgian cities as well.[71] In 2019, citizens in Brussels installed a rooftop solar PV system on a public building – producing 36,000 kWh annually – and then connected it with a public electric vehicle charging station.[72] A community project in Leuven installed a 57-panel solar PV plant in 2020 with a capacity of 16 kW-peak, and the city also worked with co-operatives to install two rooftop PV installations that citizens can invest in that supply a local daycare and a community centre with 98,000 kWh and 11,500 kWh annually, respectively.[73]

Also in Belgium, Cooperative Energy Mouscron installed 100 solar PV systems on residential homes in the city of Mouscron, with a total of 1,145 PV panels producing an estimated 292 MWh per year.[74] In Eeklo, the municipality and local citizens formed a co-operative to build two wind turbines in 2011, and by 2020 the project was supplying some 48,500 members with renewable energy; citizens who cannot afford a co-operative share get access through municipality-held shares.[75] Another co-operative, Pajopower, active in the Flanders region, creatively supported the city of Halle in replacing 445 public street lights with LEDs by having citizens "adopt" the street light in front of their door, thereby raising the EUR 225,000 (USD 276,355) needed for the project.[76]

Elsewhere in Europe, citizens and companies in Almere (Netherlands) financed a project to repower the 320 MW Zeevolde wind park by replacing 220 old wind turbines with 91 new ones.[77] In 2019, the Solar Town project in Slavutych (Ukraine) installed 200 kW-peak of solar PV on local roofs, in an initiative co-owned by local residents and private investors and financed via crowdfunding.[78] In Vienna (Austria), between 2012 and October 2020, 6,000 citizens had taken part in a programme whereby the city-owned utility Wien Energie installs solar panels on buildings and then offers people the opportunity to buy the panels and lease them back to the utility for an annual return.[79] In Strasbourg (France), a community solar PV project started in 2020 aims to be more inclusive by making shares available for only EUR 100 (USD 122.8); it relies on a network of people to identify feasible new sites for solar PV, and the project managers negotiate with homeowners and facilitate the installation.[80]

In the **United States**, energy communities differ from those in Europe and elsewhere in that they generally invite members to only purchase the renewable energy[ii] produced from community projects, rather than buying shares outright. However, the set-up and ownership structure of US community solar projects usually resembles that in other parts of the world. The number of community solar projects in the United States has increased, with an estimated 297 new projects operating in 2019 and another 43 projects operating in 2020, for a total capacity of 566 MW-peak among these 340 projects.[81]

Bristol, United Kingdom

Municipal governments use participatory governance to **include citizens** in decision making related to energy and climate protection.

i The Coronavirus Amendment Order extended feed-in tariff accreditation to September 2020.

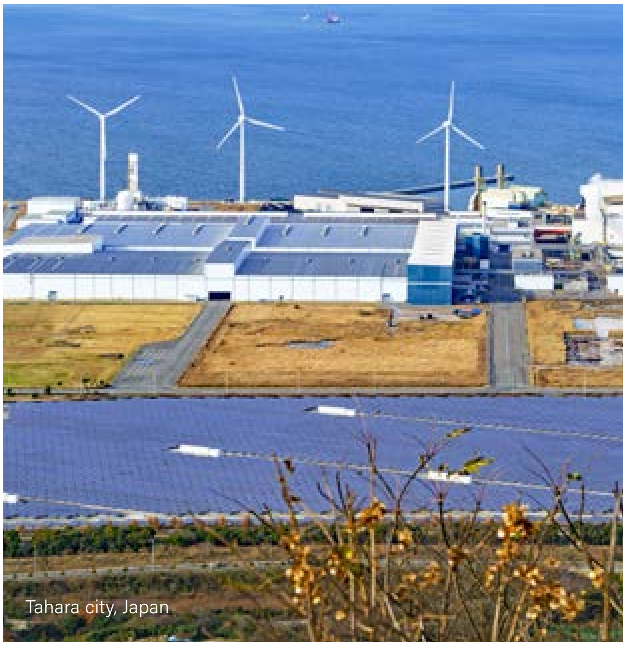
ii According to the National Rural Electric Cooperative Association, US co-operatives cover a territory equivalent to 56% of the country's landmass, powering more than 20 million businesses, homes, schools and farms across 48 states and serving 42 million people in more than 2,500 counties. Collectively, the 843 distribution co-operatives and 63 generation and transmission co-operatives generate 5% of all US electricity and deliver 12% of it. While 95% of the co-operatives include renewables in their energy mix, only 17% of the total energy they produce comes from renewable sources (10 GW). See National Rural Electric Cooperative Association, "America's Electric Cooperatives", June 2020, https://www.electric.coop/wp-content/uploads/2021/01/Co-op-Facts-and-Figures.pdf.

Among US projects in cities, the boroughs of Brooklyn and the Bronx in New York City deployed 20 and 16 new projects, respectively, between 2018 and 2020.[82] Based on a local ballot measure in 2018, Portland (Oregon) set up the Portland Clean Energy Community Benefits Fund, which supports renewable energy installations to benefit disadvantaged communities; it is anticipated to bring USD 44-61 million in new annual revenue for green jobs, healthy homes and a climate-friendly Portland.[83]

In **Asia**, many of the existing community energy projects were developed in response to Japan's 2011 Fukushima nuclear disaster, including initiatives in Japan and Thailand.[84] In the Republic of Korea, communities had established more than 100 renewable energy projects by late 2018, many of them in cities.[85] The country's first project, comprising five solar PV power stations built in leased public space, was installed in Seoul's Eunpyeong district in 2013, with a total capacity of 332 kW.[86] The community is planning another six or seven plants, totalling 600-700 kW, by 2021.[87] The surge in renewable energy communities in the Republic of Korea is attributed in part to the 2012 Cooperative Act, issued in response to the Fukushima disaster.[88]

Government funding for community energy in **Latin America** has tended to prioritise electrification projects in remote rural communities.[89] As a result, several urban areas have turned to crowdfunding to support community-based projects. The collective funding platform Red Giralsol connects small-scale investors with citizens and companies that want to invest in renewable energy projects in Mexico City and elsewhere.[90] In Brazil, community-owned solar systems sprung up after the National Energy Agency changed its regulations in 2015 to allow for shared distributed generation; by 2019, at least eight community energy initiatives were operating in the country, including solar options for urban residents who do not own the buildings they live in.[91] In 2020, a community solar PV project was started in Rio de Janeiro's *favela* (slum) that will supply 30 families with electricity from a 26 kW-peak solar PV system; the system will be refinanced by 50% of the savings on the energy bills of its members.[92]

In **Oceania**, community energy projects have emerged across Australia, supported by federal policies.[93] A solar garden in the Riverina region, which comprises 333 "virtual plots" of 3 kW each that will produce an estimated 4.2 MWh each per year, supports citizens who wish to become involved in renewable energy production but are unable to for various reasons (including living in an apartment, renting their property, heritage challenges or a lack of knowledge about solar panels).[94] The town of Yackandandah in Victoria state, in a community-led approach to bringing renewables to citizens, hosts three microgrids and a power storage project, all of which stem from a 100% volunteer-run initiative that aims to achieve energy sovereignty by 2022.[95] To the north, the renewable energy hub in Narrabri (New South Wales), established in September 2020, is one of 50 planned hubs in Australia to support new community energy projects.[96] The initiative demonstrates how cities can take an active role in supporting intermediaries and providing their services free of charge to community groups.



Tahara city, Japan

Community energy projects in **Sub-Saharan Africa**, where more than 600 million people still lack access to electricity, can help greatly to address this challenge.[97] Small-grant programmes enable citizens to invest in mini-grid solutions that bring electricity to low-income households in rural areas as well as in low-income urban areas with unreliable or no grid access.[98] Urban community energy projects help spread renewable installations in places that already have reliable grid access. In Cape Town (South Africa), where the local government facilitated the installation of an 84 kW solar PV system at Wynberg Girls High School, citizens who buy shares in the project receive a dividend over a 20-year period (→ *see Feature chapter*).[99]

PARTICIPATORY GOVERNANCE

Municipal governments have the opportunity to use participatory governance to include citizens in a range of decision making related to energy and climate protection – whether in planning, budgeting or policy development processes. Whereas at higher levels of governance, energy and climate planning have tended to occur without the involvement of civil society[i], municipal governments are generally closer to residents and thus have been able to use participatory governance more often to advance their sustainable development and energy transition goals (→ *see City Snapshot: Jakarta*).[100]

i Several European countries have introduced citizen assemblies to inform climate and energy policies. In France, the government set up a citizen assembly of 150 people in response to the 2018 yellow vest protests. This assembly, whose task is to suggest policies that can cut French emissions 40% by 2030 in a socially just way, will debate and propose laws in an approach that is "unfiltered" either by the French parliament or by referendum. Comparable bodies exist in Ireland, the United Kingdom and Spain, where the government set up the assembly after the country declared a climate emergency.

JAKARTA

INDONESIA

Land area (km^2)	Population size (2019)	Greenhouse gas emissions (CO_2 equivalent)
7,639	10.1 million	34.5 million tonnes

As the capital of Indonesia, Jakarta is taking effective action to reach its goal of reducing the city's greenhouse gas emissions 30% by 2030, a target set in 2012. The local action plan serves as a means to help achieve Indonesia's national emission reduction target of 29% by 2030, with a focus on renewable energy. Jakarta also committed in 2016 to reducing its water and energy consumption 30% and to achieving 30% renewables in its energy mix by 2030. To meet this latter target, the municipal government plans to increase its solar panel capacity by 600 kW-peak per year and to develop waste-to-energy plants.

The local government also is actively engaging citizens and stakeholders in the formulation of the Ikhtiar Jakarta ("city promise") initiative, which outlines Jakarta's commitments in the areas of energy, green buildings, transport, clean water, waste and disaster management. Six public consultations with a total of 300 attendees were conducted in 2018-19 to promote sustainable lifestyles and support the initiative. Jakarta also is developing a Regional Energy Plan (RUED-P), which contributes to achieving the targets set in the National Energy General Plan (RUEN) and the National Energy Policy (KEN).

In 2019, Jakarta implemented Governor Instruction No. 66, which mandates the city's Transmigration, Manpower and Energy Agency to install rooftop solar on large public buildings, including all schools, sport facilities, hospitals and government buildings during 2019-22. In 2019, a total solar capacity of 2,060 kW-peak was installed on 98 schools, bringing the combined rooftop solar capacity on schools and government buildings to 2,675 kW-peak and showcasing the great potential to minimise local carbon footprints.

Source: See endnote 100 for this chapter.

In Jakarta **citizens have actively helped** shape the city's climate action plan.

Municipal governments have a variety of tools at their disposal to increase citizen participation in decision making. Cities around the world invite citizen feedback by permitting ordinary people to review policies before they enter into force. Through **participatory planning**, cities enable citizens to develop and choose among different options for urban energy plans. Some cities also support participatory budgeting, through which citizens are granted the ability to allocate a share of the city budget following open and democratic deliberation. Although no consolidated data exist on participatory governance at the municipal level, the approach is being used increasingly in cities in Europe and the United States, among other places.[101]

The COVID-19 pandemic has negatively affected traditional approaches to participatory governance by limiting the ability to hold in-person meetings, which has raised concerns about community voices not being heard.[102] In response, some municipal governments have used digital tools such as apps and online forums to gather ideas from citizens. For example, Edinburgh (Scotland) initiated the Edinburgh Climate Talks to encourage citizens to get involved in developing local recovery plans and to support efforts to reach the city's net-zero emissions goal by 2030.[103]

In 2019 and 2020, several municipal governments involved their citizens in **developing climate and energy plans**. In Ii (Finland), the municipality and nearly 500 citizens jointly created a plan to reduce greenhouse gas emissions 80% by 2030 (from 1990), based on energy efficiency measures, the use of renewables in all public buildings and switching the municipal fleet to electric vehicles.[104] By 2020, they had already achieved a 62% reduction in greenhouse gas emissions.[105] In Münster (Germany), 1,200 local citizens helped draft the city's 2050 climate roadmap, which targets a 95% reduction in greenhouse gas emissions by 2050.[106] Citizens In Sønderborg (Denmark) participated in developing the city's 2025 energy roadmap.[107] In Amsterdam (Netherlands), citizens were invited to contribute to the city's heat transition vision for a fossil-free heating system by 2040, which was open to public comment until May 2020.[108] Citizens in Ghent (Belgium) contributed to designing the new mobility concept of the Dampoort neighbourhood in consultations through December 2020.[109]

Many cities and municipalities in the United States rely on a participatory governance model, holding town halls, city council hearings and other fora to hear from community members. This has pushed forward the development of community choice in energy provision as well as cleaner transport measures (such as electrification of urban transport infrastructure and electric vehicle charging). In Savannah (Georgia), high turnout and interest in the February 2020 town hall meeting led to the goal of switching the city to 100% renewable electricity by 2035.[110] Under California's community choice aggregation programmes, which are municipally owned and operated, citizens have a say in how the utilities conduct business and what they prioritise by virtue of influencing municipal climate action.[111]

South Africa's planning processes are by law open to comment from citizens. eThekwini municipality, which includes the city of Durban, aims to achieve at least 40% renewable energy supply by 2030 and 100% by 2050.[112] The Draft Energy Policy, which outlines how the municipality plans to reach these goals, was open to public comment until 15 January 2021 on the municipality's website.[113] Also in South Africa, the social enterprise iShack has helped disadvantaged communities in Stellenbosch and Cape Town, among other cities, electrify in a participatory manner. iShack's projects in various locations provide households that lack grid access with funding to install off-grid solar PV systems to meet basic energy needs.[114] In 2018, GreenCape's Witsand Informal Settlements project in Cape Town used a participatory co-design approach to identify people's energy needs, leading to the provision of 50 solar-powered streetlights and Wi-Fi hotspots in 2020.[115]

Cities in Europe increasingly have introduced **participatory budgeting**. Paris (France) reserves 5% of its investment budget for this purpose, with one-fifth of this funding, or EUR 100 million (USD 122.8 million), earmarked for climate-friendly investments.[116] Mouscron (Belgium) initiated a project In 2017 – financed through a participatory budgeting process that began in 2016 – to install solar panels on school buildings in low-income neighbourhoods; it then sold 55% of the shares in the panels to local residents at favourable rates to form a community energy project.[117] In Latin America, participatory budgeting is used in Bogotá (Colombia) and Porto Alegre (Brazil), but whether and how these governance mechanisms influence the deployment of renewables in these cities is unclear.[118]


Cape Town, South Africa

Several municipal governments have **involved their citizens** in developing climate and energy plans.

BOTTOM-UP INITIATIVES AND CAMPAIGNS

Rising public awareness and concerns related to climate change have increased citizen engagement in energy issues. During global climate strikes in 2019 and 2020, millions of citizens in cities around the world filled the streets demanding action to address climate change and shift energy systems away from fossil fuels.[119] In response to rising public pressure, cities have adopted climate and energy plans, and many have strengthened existing plans. Against the backdrop of increasing public awareness of sustainability and energy concerns and mounting public pressure, municipal as well as regional, national and supra-national governments have adopted more ambitious climate and energy strategies, remunicipalised local utilities and declared climate emergencies.

Many citizen groups target their local municipalities through bottom-up climate and energy initiatives. In the Netherlands, the group Lochem Energie is pushing for the city of Lochem to achieve "energy autarky" by 2030, meaning that all energy in the municipality is to be produced by citizens, companies or public suppliers within local borders.[120] In the United Kingdom, citizens successfully campaigned in Leicester and Eastbourne to have these cities adopt ambitious climate plans.[121]

Public demands also have helped address environmental problems related to fossil energy projects while simultaneously supporting renewables. Citizen pressure in Chile led to closure of the Ventanas 1 coal power plant and to the creation of an urban development plan for Puchuncaví and Quintero in 2020 that includes renewable energy and energy efficiency measures.[122] Also in Chile, following public demand, the coal power plant in Concepción will be taken out of service by 2022, and the city aims to expand its renewable energy capacity through hydropower and other renewables.[123]

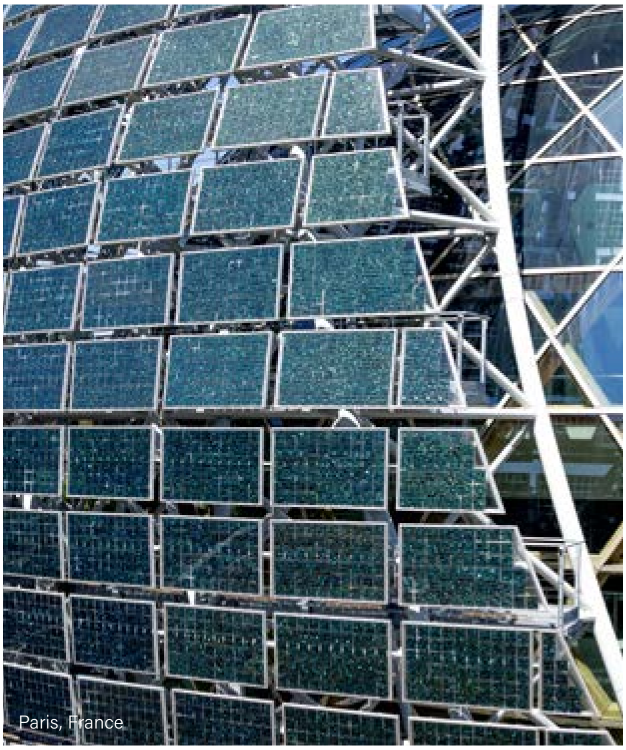
A growing number of residents have joined efforts with their municipalities to regain control over key municipal infrastructure. In the last decade, **(re-)municipalisation** campaigns have pushed more cities to take control of local power suppliers and grids. These campaigns frequently are a reaction to disappointment with the outcomes of previous privatisations in the energy sector.[124] (Re-)municipalisation has been seen as an important tool to advance renewable energy in cities, in addition to achieving broader objectives such as local economic growth and re-industrialisation.[125]

Globally, (re-)municipalisation of energy infrastructure peaked in 2016, but the upward trend has continued.[126] At least 1,408 cases of remunicipalisation of critical infrastructure[i] were recorded as of late 2020, including 369 energy-related cases (13 of them occurring between 2018 and late 2020).[127] The bulk of these cases (305, or around 80%) were in Germany, followed by Spain (18), the United Kingdom (13) and the United States (11).[128]

The case of Eau de Paris, the water utility in Paris (France), is an example of how city governments can use local utilities to support the development of renewables in a cross-sectoral manner. After taking water provisioning back into public hands in 2009, citizens of Paris did not simply benefit from lower tariffs for drinking water. In addition, the democratically elected board of Eau de Paris installed solar PV panels (generating 17,500 MWh of electricity in 2018) and decided to set an internal goal of 95% renewables in the company's power mix by the end of 2020.[129]

In Wolfhagen (Germany), citizens initiated a process of remunicipalisation of the local power supplier in 2012, and by 2020 the city together with a citizen co-operative owned the power provider. The co-operative has a 25% ownership share, effectively granting it two of the nine seats on the company board.[130] In the last decade, a number of UK municipalities attempted to set up publicly owned energy providers to address energy poverty in the country by offering low tariffs for struggling citizens. However, two of the main municipal-owned companies – Robin Hood Energy in Nottingham and Bristol Energy – were sold after severe financial losses.[131]

In Spain, the cities of Barcelona, Cadiz, Madrid and Zaragoza all initiated remunicipalisation projects that returned critical energy infrastructure into public hands, giving local politicians the chance to retain profits from energy sales and to set up local projects, such as an energy poverty fund in Cadiz.[132]Barcelona's publicly owned power provider, Barcelona Energía, buys renewable energy directly from small-scale producers in the region and sells it to citizens in the city, offering value-added tax reductions and favourable tariffs for disadvantaged citizens to ensure that all people can benefit from renewables.[133]


Paris, France

i Including water, transport, energy and waste.

In the Middle East, remunicipalisation took place in the city of Hebron (State of Palestine), where the publicly owned Hebron Electric Power Company is developing solar PV on all municipal buildings and an additional 500 rooftop PV systems on schools, for a total capacity of up to 35 MW.[134]

In another example of bottom-up action, by the end of 2020 more than 1,850 municipal governments in 29 countries (up from around 1,400 governments in 2019) had declared a **climate emergency**, representing 980 million citizens around the world.[135] Several national governments and supra-national institutions[i] have since followed suit. In 2020 alone, 411 municipal governments issued climate emergency declarations, many of them in Canada and the United Kingdom but also cities such as Barcelona (Spain), Boston (Massachusetts, US), Mülheim (Germany) and Osaka (Japan), along with the national assembly of mayors representing 226 local authorities in the Republic of Korea.[136] Municipal governments in Europe dominated these efforts, with a total of 826 declarations, followed by Canada (504), the Republic of Korea (228), the United States (127) and Australia (98).[137]

Climate emergency declarations have been leveraged to initiate or halt projects based on their climate performance.[138] Many municipal governments have issued **climate action plans** that complement their emergency declarations (→ *see City Snapshot: Recife*).[139] Although by the end of 2020, only 231 municipal governments had submitted a climate action plan alongside their declaration, the total number of governments doing so increased rapidly.[140] Between the middle and end of 2020, the number of action plans almost doubled, driven largely by UK municipal governments which added 87 plans in September alone.[141] Further action plans are expected in the near future, as emergency declarations usually include initiating a process to develop an action plan and then reporting back to council within three to six months.[142]

More than 1,850 municipal governments in

29 countries

have declared a climate emergency, representing 980 million citizens around the world.

It remains to be seen how municipal governments will implement their climate emergency plans in their policy documents and specify a role for renewables. Of the more than 1,850 municipal governments with climate emergency declarations, over 180 had already passed a renewable energy target as of late 2020, either specified as part of their climate action plan or as an independent target.[143] Cities that have issued both climate declarations and renewable energy targets are mainly in Europe (115) and North America (55) but also include Newcastle (Australia), Seoul (Republic of Korea) and Wellington (New Zealand) (→ *see Figure 17*).[144] Among these, some 61 cities had a climate action plan as well, in particular UK cities including Bristol, Edinburgh, Glasgow and Leeds, but also Auckland (New Zealand), Barcelona (Spain), Melbourne (Australia), San Diego (California, US), and Vancouver (Canada).[145]

Barcelona, Spain

i In November 2019, the EU parliament declared a climate emergency.

5

Figure 17. Cities with Climate Emergency Declarations and Renewable Energy Targets, 2020

Of all 1,852 cities that have signed climate emergency declarations,

10%

have renewable energy targets.

Seoul, South Korea

Source: See endnote 144 for this chapter.

RECIFE

BRAZIL

Land area (km^2)	Population size (2018)	Greenhouse gas emissions (CO_2 equivalent)
218	1.6 million	2.9 million tonnes

Recife, an Atlantic seaport in north-eastern Brazil, is the first city in the country to formally declare a climate emergency. According to the Intergovernmental Panel on Climate Change, Recife is the 16th most vulnerable city in the world to climate change. Drastic changes in the local weather have motivated the local government to make commitments towards a low-carbon future. In 2019, in response to its climate emergency declaration, Recife committed under the City Climate Action Plan to becoming carbon neutral by 2050. The local government also aims to achieve 100% renewable energy in city-wide operations by 2037.

In 2013, Recife created two municipal fora, Comclima and Geclima, to formulate climate change and sustainability policies. As a part of the Urban LEDS project, the city also has developed measures to reduce its greenhouse gas emissions. Under the Urban LEDS network, Recife was selected to receive support from the climate finance laboratory to install a pilot 17 kW-peak solar PV system at the Women's Hospital of Recife (HMR), which is expected to be operational by 2021. In addition, Recife City has approached a local energy company, Companhia Energética de Pernambuco (CELPE), to finance an initial investment of EUR 200,000 (around USD 225,000) to help define model financing for energy efficiency measures, distributed generation and replicability of actions in other buildings in the municipality.

To assist the city's sustainable development efforts, the Energy Efficiency Program (PEE) – promoted by CELPE in the regulations of the National Electrical Energy Agency (ANEEL) – provides 0.4% of the net operating revenue of local energy companies to fund research and development projects and the implementation of energy efficiency and renewable energy measures in the city. To promote greater citizen participation, CELPE holds public hearings where it presents the plans and results of renewables and efficiency projects in the region. Through public calls, it seeks partners to promote the development of new technologies, transform energy efficiency markets and create rational habits and practices for the use of electricity.

Source: See endnote 139 for this chapter.

Cape Town

Dakar

Kampala

Tsévié

Yaoundé IV

6 FEATURE: RENEWABLE ENERGY IN SUB-SAHARAN AFRICAN CITIES

FEATURE:
RENEWABLE ENERGY IN SUB-SAHARAN AFRICAN CITIES

Sub-Saharan Africa was home to an estimated 1.1 billion people in 2019, with around 40% of this population living in urban areas.[1] The region contains 27 of the world's 28 poorest countries and had an average poverty rate of 41% in 2018.[2] Major barriers to reducing poverty in Sub-Saharan Africa include conflict, a lack of robust institutions, and inadequate access to basic infrastructure services (such as drinking water, sanitation and electricity).[3] The region also is home to the world's most rapidly urbanising cities: Africa's urban population increased more than 16-fold between 1950 and 2018, from 33 million to 548 million.[4] This rapid urban growth is a key driver of energy consumption, with average annual energy use on the continent increasing 3% between 2000 and 2010 and 2.5% between 2010 and 2018.[5]

Even so, energy consumption in Sub-Saharan Africa remains among the lowest in the world, at around 17 GJ per capita per year in 2018 (excluding Nigeria and South Africa), nearly five times below the world average (84 GJ per capita per year).[6] Traditional biomass, mainly wood and charcoal, accounts for 66% of total final energy consumption region-wide and is used across all non-transport sectors, making Sub-Saharan Africa the only region in the world with such heavy reliance on biomass.[7] Despite the abundance of local renewable energy resources, renewables accounted for only 7% of the total primary energy supply, 8% of total final energy consumption and 26% of power generation in the region as of 2018.[8]

Meanwhile, many Sub-Saharan African governments have made great strides in integrating renewable energy into regional, national and even sub-national planning. By 2018, of the 53 African countries that had submitted Nationally Determined Contributions for reducing greenhouse gas emissions under the Paris Agreement, 45 had adopted quantified renewable energy targets.[9] Regionally, the Economic Community of West African States (ECOWAS) has set a target for 48% renewable electricity by 2030, and the East African Community (EAC) aims for 21% renewables in the power generation mix by 2038.[10]

City governments play a key role in shaping the energy landscape of Sub-Saharan Africa.

City governments play a key role in shaping the energy landscape of Sub-Saharan Africa, including meeting country-level renewable energy targets. However, legislative, financial and technological constraints – such as weak fiscal decentralisation, limited municipal mandates across key sectors and capacity constraints to executing municipal functions – continue to impede wider adoption of renewables.[11] Nonetheless, many cities in the region have joined global clean energy initiatives. For example, signatories to the Covenant of Mayors in Sub-Saharan Africa have voluntarily committed to implementing climate and energy actions in their communities, and the Climate Action Planning Africa Programme, led by C40 Cities, brings together 11 megacities in Sub-Saharan Africa – including Accra (Ghana) and Nairobi (Kenya) – that have pledged to become net-zero carbon by 2050.[12]

These locally driven ambitions have led to positive outcomes. In 2019, Nairobi enforced a national regulation that requires large buildings to use solar PV for water heating to reduce pressure on the electricity grid.[13] Rwanda is developing Africa's first "green" city – within the capital Kigali – to be powered completely by renewable energy, and in 2017 Accra initiated an incentive programme that reduces building permit fees by 10% if applicants include a 20 kW solar PV system in the design.[14] In Nigeria, Eko Atlantic City in Lagos State secured its first-ever EDGE (Excellence in Design for Greater Efficiencies) green building certification from the International Finance Corporation in January 2020, giving homeowners the assurance that their homes are designed and built to be resource efficient.[15]

The following sections provide an overview of the status of renewable energy in five Sub-Saharan African cities, highlighting existing practices as well as opportunities for scaling up deployment.

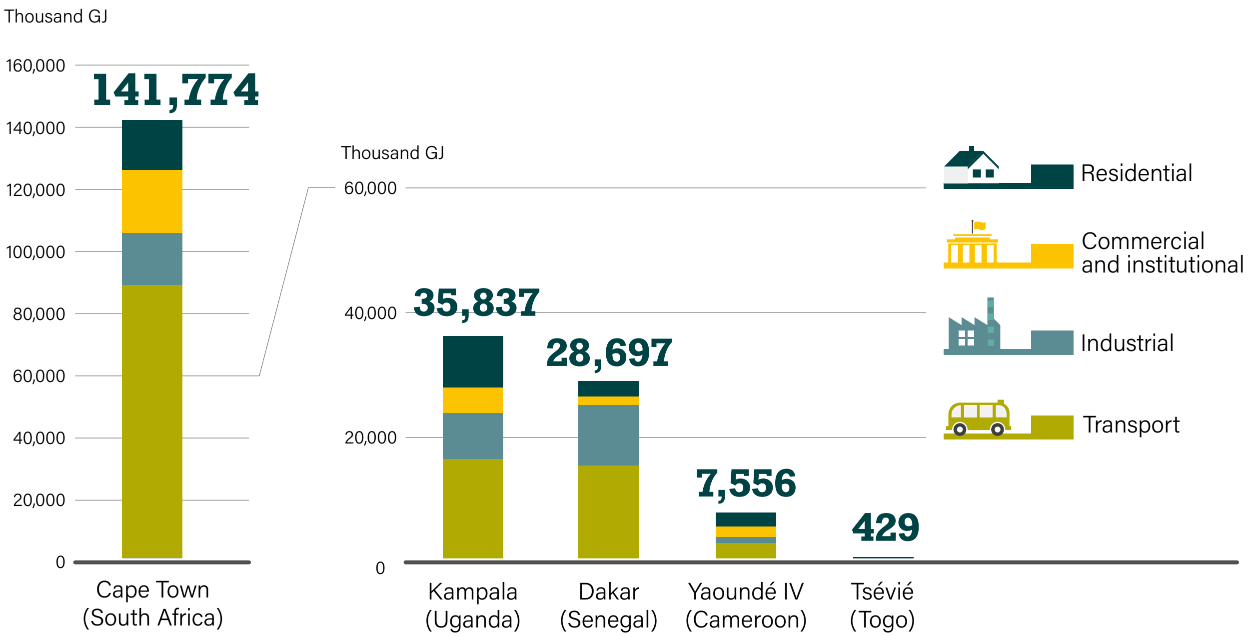
STATUS OF RENEWABLES IN SUB-SAHARAN AFRICAN CITIES

Cities in Sub-Saharan Africa differ widely based on their national context, area and population size, level of urbanisation, level of socio-economic development, access to energy and more. These factors directly influence their total energy demand and energy use by sector. The following sections explore renewable energy trends in five cities – Cape Town (South Africa), Dakar (Senegal), Kampala (Uganda), Tsévié (Togo) and Yaoundé IV (Cameroon) – selected[i] mainly because of their geographic and socio-economic diversity as well as the availability of primary (field-based) data.[16]

Cape Town has a much higher energy demand than the other four cities, reflecting its larger population as well as the relative economic advancement of South Africa. In the smaller cities (such as Tsévié), where the commercial and industrial sectors are less extensive, the residential sector accounts for a higher share of energy use. Meanwhile, in the bigger cities (Cape Town, Kampala and Dakar), where there is greater movement of people and goods, the transport sector plays a more prominent role in energy consumption (→ *see Figure 18*).[17]

i The selected cities, while not wholly representative of the vast environmental and historical contexts of Sub-Saharan Africa, depict the varying socio-economic and energy development realities of the region as well as the diversity of challenges and opportunities experienced in its cities.

Figure 18. Total Final Energy Consumption in the Five Selected Sub-Saharan African Cities, by Sector



Note: Data are from various years.

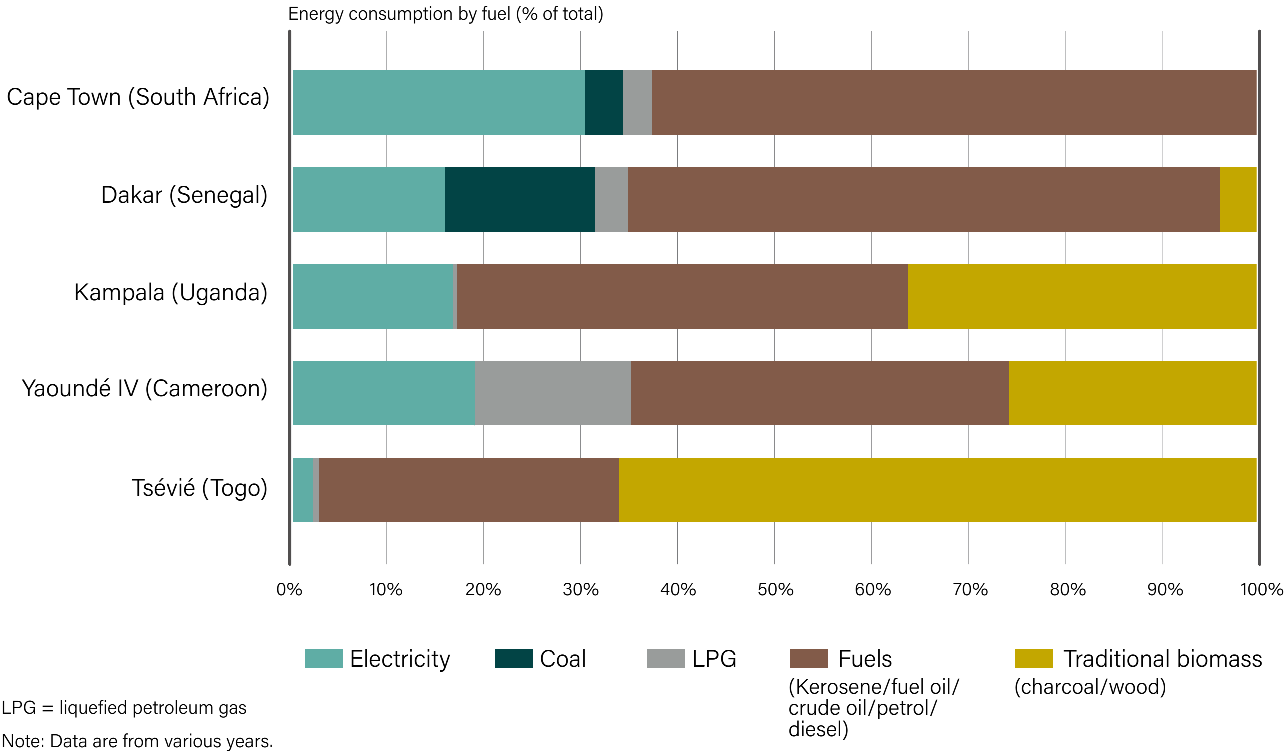
Source: See endnote 17 for this chapter.

The large urban economies also tend to have substantial transport infrastructure, a wealthier populace (resulting in higher car ownership) and greater economic activity (leading to increased freight).[18]

Because of the inefficient use of carbon-intensive diesel and petroleum fuels, the transport sector accounts for the highest share of greenhouse gas emissions in the five cities.[19] Vehicle emissions also are a major source of air pollution, as Sub-Saharan Africa's vehicle fleet consists largely of ageing vehicles (mainly from Europe and North America) that no longer meet emission standards in their countries of origin.[20]

In the less-urbanised cities of the region, high shares of residential energy use (in the case of Tsévié, representing up to 73% of final energy consumption) reflect the low levels of industrialisation of these economies.[21] Overall, the residential sector accounts for 65% of total final energy consumption in Sub-Saharan Africa, compared to only 22% globally.[22] In Tsévié, traditional biomass (wood and charcoal) represents more than 50% of final energy consumption, mainly for cooking (→ *see Figure 19*).[23]

Figure 19. Shares of Energy Use by Carrier in the Five Selected Sub-Saharan African Cities



LPG = liquefied petroleum gas

Note: Data are from various years.

Source: See endnote 23 for this chapter.

6

CAPE TOWN

SOUTH AFRICA

Land area (km²)	Population density (per km²)	Population size	Total final energy demand (million GJ)
400	1,700	4.2 million	145.3

Cape Town is South Africa's second largest economic hub, with a population of around 4.2 million in 2018 and a land area of more than 400 square kilometres.[24] Cape Town contributed 9.8% of the national economic output in 2018 and is dominated by the service sector, with significant finance, insurance, real estate and business activities.[25]

Coal contributed 83% of South Africa's electricity generation capacity in 2016 (latest available data), with nuclear power and natural gas representing 4% and 5% respectively and renewable energy making up the remaining 8%.[26] The government aims to increase the renewable share in the generation mix to around 40% by 2030 through various policy instruments, as promulgated in the Integrated Resource Plan (IRP)[i] of 2019.[27]

The City of Cape Town has taken an active leadership role in renewable energy deployment, emphasising not just technology change but also the need to improve governance and institutions and to engage key players in the energy transition, from national government to business and civil society.[28] The decoupling of electricity demand from economic growth in the Metropolitan Municipality over the last decade is attributed to energy efficiency and renewable energy interventions in the face of soaring electricity prices and insecure electricity supply in South Africa.[29]

The transport sector, which relies almost exclusively on petrol and diesel, accounts for 62% of Cape Town's total final energy demand and contributes a third (32%) of the Metro area's greenhouse gas emissions.[30] The sector's high energy use is largely a result of the city's sprawling and segregated form, which reflects the legacy of apartheid's spatial planning.[31] The commercial sector is the second most energy-intensive sector (14% of total final energy demand) followed by households (12%) and industry (12%) (→ *see Figure 18*).[32]

Electricity is the main energy carrier in Cape Town's non-transport sectors, and because most of the electricity in South Africa comes from high-carbon coal-fired power plants, the built environment accounted for 55% of the city's greenhouse gas emissions in 2018.[33] Residential electricity use in Cape Town is split largely across cooking, lighting and space heating applications, while in the commercial sector electricity use is dominated by lighting, heating and ventilation in office buildings.[34]

The City of Cape Town has been a pioneer in providing more affordable and secure energy access and in reducing the city's carbon footprint while also tackling rapid urbanisation and associated energy poverty, urban sprawl and vulnerability to climate change. Cape Town's long history of renewable energy efforts includes the establishment of a dedicated energy and climate change unit.[35] As early as 2000, an energy advisor was seconded to the City as part of the Sustainable Energy for Environment and Development (SEED) programme of Sustainable Energy Africa (SEA), bringing an energy lens to City operations and service delivery.[36] In 2003, with technical support from SEA, Cape Town completed its first *State of Energy* report, and in 2006 it became the first African city to approve a municipal Energy and Climate Change Strategy, setting an initial target for 10% renewable and clean energy by 2020.[37]

The city benefited from learning by doing. Catalysed by the Energy Efficiency and Demand Side Management Programme, launched by South Africa's Department of Mineral Resources and Energy, Cape Town began an extensive and ambitious drive in 2008 to improve

i The IRP provides a medium-term plan for expanding electricity generation in South Africa. It aims to guide sector investment to allow the country to meet its forecasted electricity demand at the least cost and accounting for considerations such as environmental sustainability and water use. The plan incorporates objectives such as affordable electricity, reduced greenhouse gas emissions, diversified generation sources, localisation and regional development.

the energy efficiency of municipal operations, saving a cumulative ZAR 225 million (USD 16 million) through 2019.[38] The City began supporting small-scale "embedded generation" in 2011, making it South Africa's first city to develop tariffs and rules for distributed renewables and serving as a blueprint for the rest of the country.[39]

In 2013, when South Africa had no national standards in place for solar PV on buildings, Cape Town published guidelines[i] promoting the safe and legal installation of distributed renewables in commercial and residential settings.[40] By 2019, the City had the highest concentration of registered rooftop solar PV systems nationwide.[41] In total, between 2011 and 2020, Cape Town approved the installation of nearly 42 MW of rooftop solar PV and installed 0.6 MW on City buildings through its rooftop PV programme.[42] These systems feed into the local electricity distribution network, helping to reduce reliance on coal-fired power from the national grid. Similar processes, guidelines and tariffs have since been adopted in more than 40 other South African municipalities.[43]

Building on earlier roll-outs of solar water heaters in low-income communities, in 2013 Cape Town implemented a programme to promote this technology more widely, helping to reduce energy from one of the highest electricity-consuming end-uses for city households, water heating.[44] By 2015, some 46,000 solar water heaters had been installed city-wide, saving 128,000 MWh per year, creating employment equivalent to 1,300 job-years[ii], contributing more than ZAR 380 million (USD 27 million) to the local economy and reducing more than 132,000 tonnes of carbon emissions per year.[45]

In 2015, the Cape Town Energy 2040 Vision, developed through an extensive process of energy modelling and stakeholder engagement, set ambitious city-wide targets for increasing energy access, improving energy efficiency and reducing carbon emissions.[46] It also set a target to achieve at least 500 MW of renewable and clean energy capacity by 2040.[47] To help achieve this ambition, the City of Cape Town elevated the role of energy institutionally, combining its two energy-related divisions (one focused on energy and climate change and the other on electricity generation and distribution) into a single new Energy and Climate Change Directorate.[48]

This change also signaled Cape Town's intention to expand its role in local electricity supply. In 2017, the City entered into a court challenge with the national government to enable it to purchase electricity from independent power producers (IPPs) and not be confined to procuring coal-fired power from Eskom, the centrally controlled national energy utility.[49] In a landmark step in October 2020, South Africa's Department of Mineral Resources and Energy amended the country's electricity regulations to enable municipalities in good financial standing to develop their own power generation projects, as a way to ensure security of energy supply in a co-ordinated manner aligned to the national IRP and the municipal Integrated Development Plans (which guide overall planning and development for municipalities in South Africa).[50]

The City of Cape Town has taken an **active leadership role** in renewable energy deployment.

The City of Cape Town has begun laying the foundations for supplying renewable energy at scale. Based on a legislative change in late 2020, the municipal government is exploring the commercial, legal and technical aspects of a municipal-level Renewable Energy Independent Power Procurement Programme (REIPPP) and is developing a guide on how to engage with industries in procuring energy from IPPs.[51] As of 2020, the City was working on a Zero Carbon 2050 action plan (and related policies) as well as developing low-income energy services, a framework for electric vehicles and innovative financing opportunities for engaging households in small-scale rooftop solar PV.[52]

Cape Town is also honouring its international commitments to climate action. It is a signatory to various initiatives including the Mexico City Pact, CDP, the carbon*n* Climate Registry, the Covenant of Mayors in Sub-Saharan Africa and the C40 Cities Leadership Programme.[53] The City also has committed to achieving carbon neutrality by 2050, recognising that this will require ambitious actions across all sectors.[54] To translate these commitments into action, Cape Town has woven them into its Integrated Development Plan for the period 2017-2022.[55]

The City's transport plan includes exploring the potential production and use of biofuels in transport, using renewables for infrastructural facilities such as depots and transport interchanges, and replacing the municipal diesel bus fleet with electric buses (which eventually would be powered with renewables).[56] In a pilot project in early 2018, the City's "MyCITI" bus rapid transport service added 11 locally manufactured electric buses to its fleet.[57]

Cape Town is working to prepare its power grid for high EV penetration in the near future. The Electric Vehicle Framework includes leveraging EV roll-out and charging to increase the share of renewables in final energy consumption, and is considering requiring public EV charging stations that exceed a specific demand threshold to operate on renewable energy.[58] This energy is expected to be either generated from local solar PV capacity or purchased through a contractual arrangement.[59]

i The guidelines, which are non-binding, outline a comprehensive list of City-approved suppliers of inverters, the steps for installing solar systems and the application process for registering and selling electricity to the City.

ii A job-year refers to one of year of work for one person.

DAKAR

SENEGAL

Land area (km²)	Population density (per km²)	Population size	Total final energy demand (million GJ)
83	15,278	1.3 million	28.6

Dakar is the capital of Senegal in West Africa and is located at the western tip of the country. It is an Atlantic port city covering an area of 83 square kilometres with an estimated population of more than 1.3 million inhabitants.[60] As of 2016, the greater Dakar region was home to 50% of Senegal's urban population, 95% of its industrial and commercial companies, 80% of its infrastructure and services and 87% of its formal employment; as a consequence, Dakar contributed an estimated 68% of the country's gross domestic product (GDP).[61]

As of 2019, Senegal had around 864 MW of total installed electricity capacity, 13% of which was renewable (7% from hydropower and 6% from solar PV).[62] The National Energy Development Plan (Lettre de Politique de Développement du Secteur de l'Energie, or LPDSE), signed in 2012, targets increasing the renewable share in power generation from 10% in 2016 to 15% in 2020[i,63] The country's national economic and social development plan (Plan Senegal Emergent, PSE 2025) aims for a 23% share of on-grid renewables in power generation by 2030.[64]

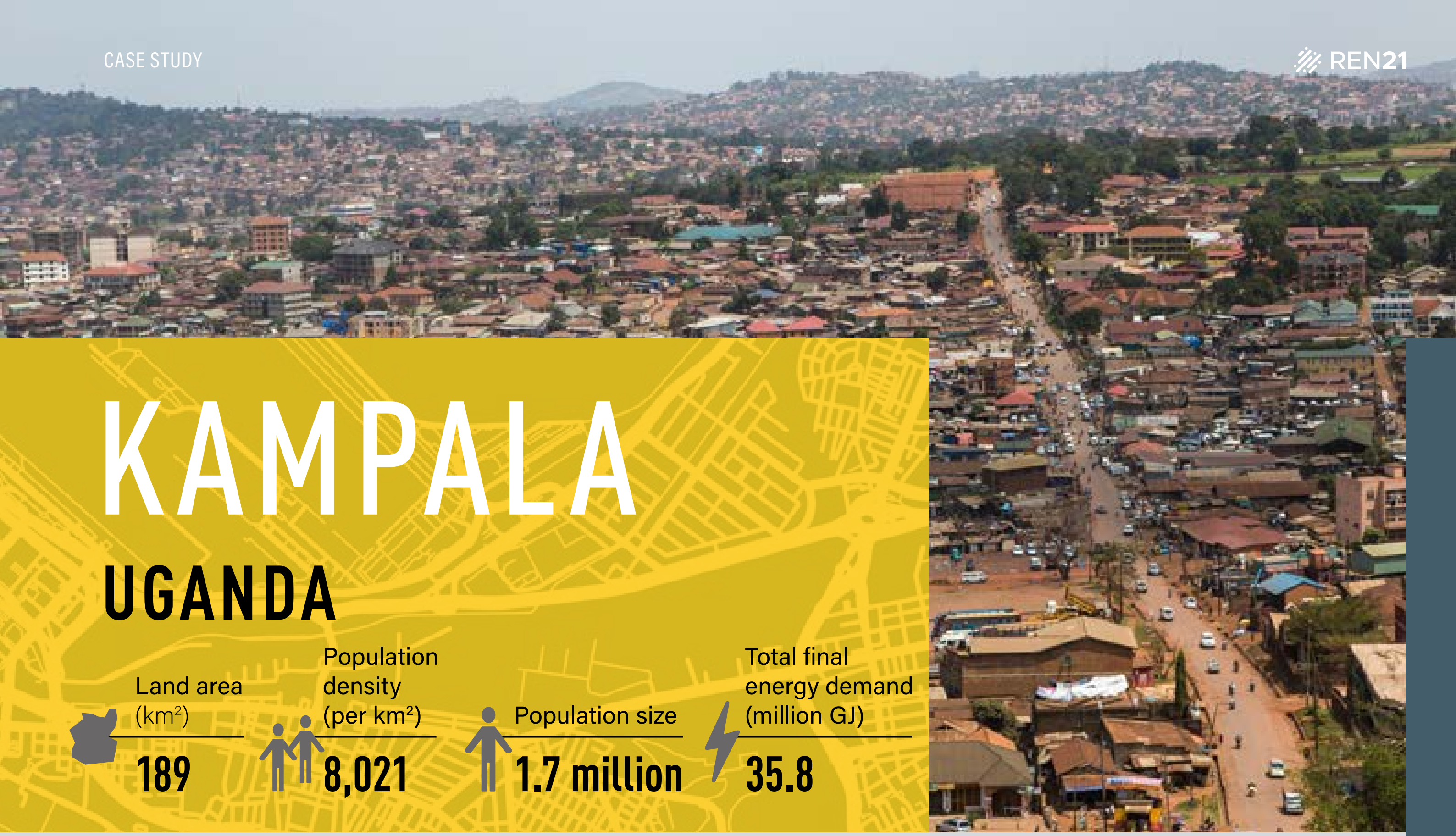
The City of Dakar reinforces these objectives through municipal policies and strategies such as the Environmental Action Plan (P.ACT.E.) and the Master Plan for Urban Development of Dakar and Its Surroundings (PDU 2035). The PDU aims to achieve 15% local electricity production from renewables by 2035 and to reduce reliance on diesel power generation from 90% in 2013 to 5% in 2035.[65] The City intends to finalise (by March 2021) its Plan Climate Energie Territorial (PCET), which will be the integrated energy and climate change development plan informing Dakar's short- and long-term renewable energy roadmap.[66] The PCET is being developed as a result of Dakar's commitment under the C40 Cities Leadership Programme to be net-zero carbon by 2050.[67]

The transport sector dominates the city's energy demand – accounting for 55% of total energy consumption – followed by the industrial (34%) and residential (8%) sectors (→ *see Figure 18*).[68] Despite Dakar's high electrification rate of more than 95%, household electricity use remains low at around 153 kWh per capita annually (compared to 10,649 kWh per capita in the United States), with lighting as the main end-use application.[69] Liquefied petroleum gas (LPG) is the primary energy source for cooking (averaging 12 kilograms per month per household), followed by charcoal (0.2 kilograms per person per day) and some use of firewood.[70]

The high energy demand for transport reflects Dakar's deteriorating road infrastructure, inefficient public transport networks and ageing vehicle fleet, with 80% of on-road vehicles estimated to be more than five years old.[71] This has led to urban mobility challenges, including permanent traffic jams at peak hours that contribute to high air pollution and negatively affect residents' economic competitiveness, health and well-being, and quality of life.[72] In response, the national transport entity, Conseil Exécutif des Transports Urbains de Dakar (CETUD), piloted the city's mobility and urban planning strategy, the PDUD 2008-2025. The plan articulates three ambitious infrastructure projects – the Express Transit Train (TER), bus rapid transit and renewal of the on-road transport fleet – with a common goal of increasing the share of electrification and reducing fossil fuel dependence across these three transport modes while also reducing air pollution from on-road transport emissions by 2030.[73]

Although the local authority has control over municipal buildings only, the City recently completed a pilot energy audit of all municipal and public buildings, as the first phase of an ambitious target to equip more than half of municipal buildings with grid-connected distributed rooftop solar PV by 2030, as envisaged in the PCET.[74]

i As of late 2020, no reporting had been identified to verify that this renewable energy target had been met.



KAMPALA

UGANDA

Land area (km²)	Population density (per km²)	Population size	Total final energy demand (million GJ)
189	8,021	1.7 million	35.8

Kampala is the capital city and largest urban centre of Uganda, with more than 1.7 million inhabitants in 2020.[75] As the country's economic hub, it accounted for 80% of Uganda's industrial and commercial activities in 2016 and generated around 65% of national GDP that year.[76] City operations fall under the responsibility of the Kampala Capital City Authority (KCCA).

KCCA is a pioneer signatory to the Covenant of Mayors in Sub-Saharan Africa (joining in 2015), through which the city developed its first energy and climate action plan – the Kampala Climate Change Action Strategy – in 2016.[77] This strategy frames KCCA's approach to furthering the deployment of renewables through assessing the local renewable energy potential, supporting the city's green economy, promoting the implementation of a feed-in tariff system and reducing the use of individual motorised transport in favour of non-motorised mobility and green and public transport.[78] KCCA's strategy is consistent with the Draft National Energy Policy of 2019, which promotes the deployment of non-hydropower renewable generation sources to diversify the energy mix and thereby mitigate Uganda's over-reliance on hydropower, which accounted for 90.5% of the national electricity supply in 2018.[79]

The transport sector dominates Kampala's energy demand, accounting for 45% of the total in 2016, followed by the residential (23%), industrial (21%) and services (11%) sectors (→ *see Figure 18*).[80] The majority of this energy demand is fuelled by fossil fuels used in transport (55%) and by (mainly traditional) biomass used for cooking and water heating (36%).[81] After biomass, electricity (90% of which comes from hydropower) is the second largest non-transport energy carrier, accounting for 17% of total final energy consumption; it is used across the industrial, services and residential sectors, mainly for lighting, cooling and the powering of heavy machines.[82]

The transport sector's large share of energy consumption is seemingly in contrast with Kampala's service-based economy. However, the service sector has low energy intensity, in part because 57% of businesses in the city were informal as of 2017, focused mainly on non-tradeable services such as retail, transport and restaurants.[83] Informal roadside vending has added to city congestion, and significant passenger travel also occurs through inefficient transport modes such as motorcycles (boda boda) and private cars, which together accounted for 70% of total passenger transport energy demand in 2016.[84]

These transport and mobility challenges helped shape KCCA's Climate Change Action Strategy 2016 and the Kampala City Strategic Plan 2025, which hinges on the principle of SMART mobility[i] to improve the efficient movement of people and goods within and through Kampala City.[85] The City established an air quality monitoring and assessment system and is promoting electric mobility to gradually replace conventional commercial motorcycles as a way to reduce noise and air pollution, petrol demand and traffic jams.[86]

KCCA's leadership has enabled successful public-private partnerships, and by 2020 start-ups such as Bodawerk and Zembo had resulted in the use of more than 200 new and retrofitted electric motorcycles for public transport in the city (charged mostly from the hydropower-dominant grid).[87] Electric mobility through e-motorcycles provides a framework for KCCA to contribute to national and international climate change mitigation efforts by deploying renewables in the transport sector. Because electric motorcycles require little infrastructure, are silent and produce virtually no emissions (thereby improving air quality levels), they hold promise for successful uptake among boda boda riders.

i The SMART mobility strategy, detailed in the Transport Master Plan for the Kampala Metropolitan Area, supports the construction and operation of a Mass Rapid Transit System based on buses, rail and cable cars by 2040.

TSÉVIÉ

TOGO

Population density (per km²)	Population size	Total final energy demand (million GJ)
596	103,000	0.4

Tsévié, a small town 35 kilometres north of Togo's capital Lomé, had a population of around 103,000 in 2017, growing at a rate of 2.8% annually.[88] The town has minimal industrial activity, and its economy is built largely on agricultural activities centred on crop production and livestock farming, generating a low annual economic output of USD 519 per capita.[89]

Togo's electricity infrastructure development plan, as outlined in the national Electricity Sub-Sector Strategic Plan of 2010, is based on a least-cost electricity supply and demand balance, taking into account security of supply and the environment.[90] This led to the development of the Togo National Action Plan for Energy Efficiency (PANEE) and the Togo National Renewable Energy Action Plan (PANER), which respectively define the country's objectives for energy efficiency and renewable energy deployment by 2030.[91] The national objective for renewables is to increase the share of solar PV in total final energy consumption to 10% in 2030, including both on- and off-grid PV.[92]

Due to Tsévié's low levels of industrialisation and electricity access (estimated at 24% in 2017), traditional biomass in the form of wood and charcoal is the single most important fuel in the peri-urban settlement.[93] Traditional biomass accounts for 64% of total final energy consumption and is used to meet household cooking and water heating needs.[94] The residential sector is responsible for 73% of total final energy consumption, followed by the transport sector (25%) and the town's few commercial facilities (2%).[95] Because of the low levels of electrification, the town's street network is largely unilluminated, limiting potential economic activity in the evenings.[96]

To boost local energy access and development, Tsévié implemented a three-year municipal energy programme (2017-2020) under the Covenant of Mayors in Sub-Saharan Africa, with the goal of developing a community-wide energy and climate action plan (the Plan d'Action en faveur d'un Accès à l'Energie Durable et du Climat (PAAEDC) de la commune de Tsévié). Under this flagship programme, the municipality aims to achieve its sustainability ambitions in four strategic areas: 1) sustainable biomass use, 2) deployment of distributed rooftop solar PV, 3) increased adoption of electric motorcycles and 4) a modal shift to public transport.[97]

Under the PAAEDC framework and with funding from the European Union, Tsévié led a series of pilot projects in 2018-2020 to boost energy access and development and increase the share of renewables in energy consumption.[98] To improve access to clean cooking facilities, the municipality distributed 8,200 improved and efficient cook stoves in the town and its environs as a means to limit the prolific household use of traditional biomass for cooking and water heating (and thus improve indoor air quality and human well-being).[99] The city also sought to bridge the electricity access gap and to improve lighting solutions by installing 75 solar street lamps for public lighting, distributing 95 solar home systems to the most vulnerable households and installing five community solar kits in schools.[100]

To boost local energy access and development, Tsévié implemented a **three-year municipal energy programme.**

YAOUNDÉ IV

CAMEROON

Land area (km²)	Population density (per km²)	Population size	Total final energy demand (million GJ)
59	13,445	793,000	7.6

Yaoundé IV is one of the seven communes of Yaoundé (Cameroon), with an estimated 793,000 inhabitants in 2018 spread over an area of around 59 square kilometres.[101] Yaoundé IV is primarily a service-oriented city, with a major informal economy that includes unlicensed street vendors (locally referred to as "sauveteurs") and small neighbourhood boutiques.[102] This translates to a low annual economic output (GDP) of around USD 1,632 per capita, comparable to the Sub-Saharan African average of USD 1,585 per capita.[103]

Renewable energy (exclusively from hydropower) makes up 73% of the power generation mix in both Cameroon and Yaoundé IV, with oil and gas constituting the remaining 27%.[104] Based on the national Economic Emergence Plan 2035, the country has ambitions to deploy increasing amounts of renewable energy, particularly hydropower and solar PV, to reduce its greenhouse gas emissions by 32% by 2035.[105]

Although the national government does not allow municipalities to undertake electricity generation and distribution projects, a number of decrees provide local authorities with the ability to receive technical and financial support towards climate action.[106]

Yaoundé IV's residential sector is the second most energy-intensive sector (accounting for 30% of total final energy consumption) after transport (35%).[107] An estimated 86% of households cook and heat their water with LPG, which represents 51% of the total residential final energy use.[108] Household electricity consumption averages 507 kWh per capita per year, above the national average of 280 kWh, and is used mostly for lighting and water heating services.[109]

As a signatory city of the Covenant of Mayors in Sub-Saharan Africa, Yaoundé IV in 2020 adopted its short-term energy and climate action plan (Plan d'Action Communal en faveur d'un Accès à une Energie Durable et du Climat, or PACAEDC), which sets out the municipality's ambitions to reduce greenhouse gas emissions and increase energy access by 2030.[110] As part of the plan, the city aims to increase the renewable energy share through multiple cross-sectoral actions, such as installing 3,000 solar streetlights in the 65 neighbourhoods, installing distributed rooftop solar PV on 30 municipal buildings, distributing 3,600 solar kits to poor households and incentivising increased adoption of electric motorcycles (to 5% by 2030, running mostly on electricity from the hydropower-dominant grid).[111]

> The city aims to increase renewable energy, installing 3,000 solar street-lights and distributing
> **3,600 solar kits**
> to poor households.

Motivated by studies suggesting that switching to biogas to offset just 20% of household LPG use could reduce residential greenhouse gas emissions by more than 12%, the municipality (through the PACAEDC) rolled out a demonstration project in 2019 to build nine micro biogas plants, each with a capacity of 20 cubic metres.[112] As of 2020, six of the systems were operational, meeting the cooking energy demand of 135 low-income households with biogas.[113] The success of the project has paved the way for similar programmes, notably ENERGIE PLUS, a municipal energy programme which in collaboration with relevant national entities and international donors seeks to build an industrial-scale biogas plant to supply electricity to Yaoundé IV and its environs.[114]

BARRIERS AND OPPORTUNITIES FOR ADVANCING RENEWABLES

The competitive advantage of renewable energy can be a key lever to power the economic growth of Sub-Saharan African cities, providing greater access to modern energy services.[115] Renewables also offer important co-benefits such as reducing air pollution (and thus improving public health), mitigating climate change, creating more liveable urban areas and enabling a better quality of life through increased access to basic services.[116] However, municipal governments in the region face numerous barriers to the deployment of renewables. Key areas of both challenge and opportunity include policy and regulation, underdeveloped grids and infrastructure, unstable off-taker arrangements, access to financial markets, data needs and internal capacity.

POLICY AND REGULATION

The control of energy supply in Sub-Saharan African cities remains largely the domain of national governments or utilities, with an emphasis on centralised, large-scale generation. As highlighted in the five city case studies, national energy strategies that chart country-wide renewable energy roadmaps rarely make provisions for local governments, whose roles are still considered secondary. Even when regulations and policies are in place to support renewable energy deployment and use, the requirements are often expensive, complex and difficult to navigate.[117]

However, municipal governments in most Sub-Saharan African countries have mandates to issue building permits, which could serve as incentives or mandates to advance the deployment of renewable energy systems. Local governments could fast-track permits for buildings that embed distributed renewables, or they could include renewable energy deployment as a requirement for obtaining a permit (or receiving one at a reduced fee, as in Accra).

In addition, the case studies illustrate how cities might leverage their facilitative roles to develop enabling policies or regulatory frameworks – such as local net metering and feed-in tariffs – to support the deployment and use of renewable electricity.[118] Focused local plans and policies can enable energy efficiency improvements and the uptake of renewables, even if national policy is inhibitive.

Although city authorities in Sub-Saharan Africa may have limited influence over infrastructure and services, they can all take action to encourage local renewable energy deployment. Developing low-carbon pathways requires multiple collaborations across a broad range of stakeholders, including national policy makers. City authorities are well placed to facilitate and co-ordinate such efforts.[119]

ACCESS TO FINANCIAL MARKETS

Although numerous fiscal programmes and instruments exist at the national level across Africa, fiscal decentralisation – whether through transfers from the central government or by granting local governments revenue-raising powers – remains a serious challenge for empowering local governments.[120] Most local governments in Africa depend on national government grants as their main revenue source; they borrow little money (even if they are formally able to) and spend most of their revenue on operations instead of capital investments.[121] This means that they have few funds to invest in new infrastructure projects such as distributed renewable generation.[122]

As a result, nearly all renewable energy projects in Sub-Saharan Africa rely on some form of non-commercial grant or equity investment, with funding coming largely from development finance institutions, donor agencies, foundations and governments.[123] Although this helps to reduce debt risk, it is not always adequate to enable renewables to achieve true scale into the future.[124] Moreover, factors such as the lack of available income to allocate to energy consumption – as well as the prevalence of a strong informal sector that experiences poor housing quality, irregular income flows and low demand for electricity – constrain the business case for electrification for utilities.[125]

Nonetheless, cities across the region have demonstrated progressive leadership through piloting various demonstration projects. For example, Yaoundé IV was able to leverage on the visibility and proof-of-concept of its pilot biogas micro-project and to draw sufficient interest from investors to take the pilot project to scale.

In most cases, national policies also allow local governments to enter into public-private partnerships. Although such partnerships are few and generally have occurred outside the scope of electricity generation and distribution projects, the rise of electric mobility in Kampala is a strong example of how such relationships could be leveraged to advance the renewable energy agenda at the city level.

Notably, local governments are constrained in how they can spend public funds (for example, to ensure public finance management best practice, as articulated in South Africa's Municipal Finance Management Act).[126] However, this can pose a barrier when trying to demonstrate and pilot pioneering and innovative work.

DATA NEEDS

> **Renewable energy deployment** benefits from collaboration between municipalities and like-minded stakeholders.

Primary data are notoriously difficult to access in the African context, particularly at the city level given the often limited capacity, funding and political ambitions to undertake such exercises. This is a major barrier for private investors who often do not have access to statistical data on key parameters needed for investment and for project-level decisions, such as grid expansion plans, consumer baseload, customer willingness to pay, etc.[127]

This places local governments, which generally are closer to the population (potential customers), in a unique position to provide investors with such information or to engage with relevant entities (including electric utilities) to facilitate data collection. Such leverage helped the City of Dakar to complete the energy audit of its own buildings in a bid to generate sufficient data for future renewable energy deployment strategies.[128] Building data resources is crucial to support decision making and resource allocation, as evidenced by the City of Cape Town.

INTERNAL CAPACITY

Due to capacity constraints (in skills, experience and knowledge as well as human and financial resources), local governments in Sub-Saharan Africa generally are limited in their ability to play a more pro-active role in renewable energy deployment. The ability to influence local uptake of renewables often requires new areas of work and new skillsets to deal with the complexities of this development.

To help build internal capacity and knowledge, municipalities can form partnerships with external organisations (for example, universities and environmental organisations / intermediary organisations[i]) that could bring much-needed skills and capacity, and can establish or join other local city networks (such as the Urban Energy Network in South Africa[ii]) or international urban-related networks (such as the C40 Cities Leadership Programme and the Covenant of Mayors SSA Programme, which helps to share implementation experience (technology, regulatory frameworks, funding, etc.).[129]

Municipalities also could develop public-private partnership platforms to facilitate private sector engagement with local government to aid the implementation of renewable energy.[130]

To leverage these opportunities, it is important for municipalities to build a support base of like-minded stakeholders, such as renewable energy industry players and specialists in energy and urban development from academia, non-governmental organisations, development institutions and other cities. This would enable cities to further their renewable energy deployment aims, participate in networks and develop their own networks – signalling a more dynamic system involving many more players.

As demonstrated in the five case studies, the effective implementation of city energy action plans necessitates developing a unit within the lead department that can drive the process over the short, medium and long terms. This unit must steer the critical stakeholder collaboration and establish fora for information exchange and action plan collaboration, including guidance and feedback.[131] A particular challenge in many cities is interdepartmental collaboration.[132] Because energy projects are often cross-cutting in nature, the lead department or unit must overcome the lack of communication and co-ordination that often prevents departments from working together.

i A local intermediary organisation such as a non-governmental organisation, academic institution or civil society organisation with experience in energy research, implementation and capacity building is important, as it gives rise to capacity building beyond municipal staff and ensures that the approaches and solutions are locally appropriate, rather than being generated solely from foreign expertise that may lack the deeper local context.

ii The Urban Energy Network is a 20-year-old learning partnership for cities in South Africa run by Sustainable Energy Africa, the South African Local Government Association and the South African Cities Network. The network aims to build municipal staff capacity on current sustainable energy issues, to enable lesson sharing and co-ordination among municipalities and to develop relationships and facilitate information flow between different levels of government.

REFERENCE TABLES

Tables R1-R5: see data online at: **www.ren21.net/cities/datapack**

TABLE R6. Selected Cities with High Shares of Electricity Generation from Solar PV and Wind, 2019

City	Population	Wind and solar share of electricity mix (2019)	Renewable* share of electricity mix (2019)	Renewable energy and emission reduction targets
Örebro, Sweden	156,000	100%	100%	Carbon neutral by 2050
Georgetown, Texas, United States	50,000	100%	100%	100% local renewable energy generation (achieved in 2018)
Diu, India	52,000	100% (during day)	100% (during day)	N/A
Denton, Texas, United States	139,000	83%	83.8%	100% renewable electricity by 2020
Gladsaxe, Denmark	70,000	52%	77%	100% renewable energy by 2035
Adelaide, Australia	1,300,000	51%	51%	100% renewable electricity in municipal operations (achieved in mid-2020)
San Diego, California, United States	1,400,000	33%	35%	100% renewable electricity by 2035
Madrid, Spain	3,260,000	24%	41%	N/A
London, United Kingdom	8,980,000	21%	23%	1 GW solar by 2030 and 2 GW solar by 2050; carbon neutral by 2050
Birmingham, United Kingdom	1,100,000	21%	33%	60% emission reduction by 2027 (from 1990 baseline); national carbon neutral target by 2050
Los Angeles, California, United States	3,990,000	21%	34%	100% renewable energy by 2045; carbon neutral by 2050
Jaipur, India	3,070,000	20%	45%	N/A
Hamburg, Germany	1,850,000	15%	30%	100% renewable electricity by 2035; 55% emission reduction by 2030 (from 1990 baseline); carbon neutral by 2050
Toronto, Canada	2,930,000	13%	37%	75% renewable energy by 2050
Bangalore, India	11,440,000	10%	25%	N/A
Nelson Mandela Bay, South Africa	1,150,000	10%	10%	N/A
Santiago, Chile	7,300,000	9%	51%	100% renewable electricity by 2040
Zaragoza, Spain	7,000,000	8%	14%	N/A
Paris, France	2,300,000	7%	21%	Carbon neutral and 100% renewable energy by 2050
Seoul, Republic of Korea	10,300,000	7%	8%	Carbon neutral by 2050
Barcelona, Spain	1,600,000	7%	18%	45% emission reduction by 2030 (from 2005 baseline); carbon neutral by 2050
Manchester, United Kingdom	2,800,000	6%	13%	Carbon neutral by 2038

■ TABLE R6. Selected Cities with High Shares of Electricity Generation from Solar PV and Wind, 2019 (continued)

City	Population	Wind and solar share of electricity mix (2019)	Renewable* share of electricity mix (2019)	Renewable energy and emission reduction targets
Calgary, Canada	1,300,000	5%	10%	80% emission reduction by 2050 (from 2005 baseline)
eThekwini, South Africa	3,900,000	5%	5%	40% renewable electricity by 2030 and 100% by 2050; 40% emission reduction by 2030 and 80% by 2050 (from 2015 baseline)
Tainan, Chinese Taipei	1,900,000	5%	7%	20% renewable electricity and 20 GW cumulative installed solar PV capacity by 2025
Buenos Aires, Argentina	15,100,000	4%	32%	20% renewable electricity for the city's largest public sector users by 2025
Singapore	5,600,000	4%	4%	50% reduction in the city's 2030 peak greenhouse gas emissions by 2050
Istanbul, Turkey	15,500,000	4%	32%	33% emission reduction by 2030 (from 2015 baseline)
Taoyuan, Chinese Taipei	2,200,000	3%	5%	850 MW cumulative installed renewable power capacity by 2021
Chicago, Illinois, United States	2,700,000	3%	5%	100% renewable energy for municipal buildings by 2025
Berlin, Germany	3,600,000	1%	3%	Carbon neutral and 25% solar electricity by 2050
Tokyo, Japan	14,000,000	1%	9%	30% renewable energy by 2030
Hyllie, Sweden	700,000	N/A	N/A	100% renewable or recycled** energy by 2030

Notes:

* Includes solar, wind, biomass, geothermal and hydropower. City-level targets for renewables are listed unless otherwise noted.

** Energy recycling from waste and wastewater to generate district heating, electricity and biogas.

N/A = data not available.

Source: Deloitte analysis and REN21 Policy Database (2020), available at www.ren21.net/cities/datapack and Reference Table R1. Data are compiled by REN21 and based on CDP-ICLEI Unified Reporting System, CDP Open Data, The Global 100% Renewable Energy Platform, Climate Action Network, ICLEI, C40, IRENA, Sierra Club, UK100 and REN21 data collection. Some research is based on voluntary reporting and therefore may not be exhaustive. For a list of cities with over 1 million people, see United Nations, *The World's Cities in 2018* (New York: 2018), https://www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in_2018_data_booklet.pdf; for shares of wind and solar power, see CDP, "CDP Open Data Portal", https://data.cdp.net, updated November 2020. City-level targets for renewables are listed unless otherwise noted. Deloitte, "Smart Renewable Cities", from https://www2.deloitte.com/content/dam/insights/us/articles/4971_Smart-renewable-cities/DI_Smart-renewable-cities.pdf. It identifies and classifies cities globally that are deploying solar and/or wind power in connection with their smart city plans. This requires that cities have a publicly available city plan that presents a vision integrating renewables and smart city initiatives. In addition, the city must have already deployed solar and/or wind power (at least 1% of its energy mix) and plan to deploy more.

DATA COLLECTION AND VALIDATION

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, and the following text explains some of REN21's key processes for data collection and validation in the context of the *Renewables in Cities Global Status Report* (REC).

DATA COLLECTION

Production of REN21's REC begins with an Expression of Interest form to mobilise contributors. The data collection process then involves the following elements:

1. **Global tracking database.** The REC team compiles data on city-specific indicators, especially targets and policies, building mostly on existing consolidated datasets at the global or regional level.
2. **Open city questionnaire.** In the city questionnaire, contributors from around the world submit data on renewable energy in their respective cities or cities of interest. This covers information about technology and market trends, targets and policy developments, investment, citizen participation and other local developments. Each data point is provided with a source and verified independently by the REC team.
3. **Regional contributors.** For each world region, REN21 appoints one principal data contributor to provide city-specific data regarding renewable energy across different sectors and to share an overview of general trends and developments in cities in the respective region. The contributions of other organisations and individuals in each region also are collected, mostly through the questionnaire and peer review feedback.
4. **Open peer review.** To further collect data and project examples and to ensure that significant developments have not been overlooked, REC-GSR contributors and reviewers participate in an open peer review process that typically occurs halfway through the report's production cycle. Peer review is open to all interested experts.
5. **Expert interviews.** REN21's global community consists of a wide range of professionals who provide their expert input on renewable energy trends ad hoc in specific topics, including through interviews and personal communication with the REN21 REC team and chapter authors. The vast majority of the information is backed up by primary sources.
6. **Desk research.** To fill in remaining gaps in the report and to pursue new topics, the REN21 REC team and chapter authors conduct extensive desk research. Topics of research can vary among REC editions and depend on emerging topics, important trends and annual availability of relatively recent formal or informal data in cities.
7. **Data sharing agreements.** REN21 holds several data sharing agreements with some of the largest and most reliable data providers/aggregators in the energy sector. These formal data are used exclusively in some cases or, in others, form the foundation of calculations and estimations presented in the REC.

DATA VALIDATION

REN21 ensures the accuracy and reliability of its reports by conducting data validation and fact-checking as a continuous process. Beginning during the first submission of the country questionnaires, data are continually verified up through the design period and until the final report is published. **All data provided by contributors, whether written or verbal, are validated by primary sources, which are published alongside the full report.**

METHODOLOGICAL NOTES

This 2021 report is the second edition of the *Renewables in Cities Global Status Report*. Readers can see the previous REC edition for additional details.

Most 2019 and 2020 data[i] for national and global capacity, output, growth and investment provided in this report are preliminary. Where necessary, information and data that are conflicting, partial or older are reconciled by using reasoned expert judgment. Endnotes provide additional details, including references, supporting information and assumptions where relevant.

Each REC edition draws from thousands of published and unpublished references, including: official government sources; reports from international organisations and industry associations; input from the REN21 community, including questionnaires submitted by regional and technology contributors as well as feedback from several rounds of formal and informal reviews; additional personal communications with scores of international experts and special advisors, including an international advisory committee created specifically to support the production of each report; and a variety of electronic newsletters, news media and other sources.

Much of the data found in the REC is built from the ground up by the authors with the aid of these resources. Other data, often very specific and narrow in scope, come more-or-less prepared from third parties. The REC attempts to synthesise these data points into a collective whole for the focus years.

The REC endeavours to provide the best data available in each edition; as such, data should not be compared with the previous version of this report to ascertain year-by-year changes.

i For information on city-level renewable energy data and related challenges, see Box 1 on Page 30.

NOTE ON ESTABLISHING RENEWABLE ENERGY SHARES OF TOTAL FINAL ENERGY CONSUMPTION (TFEC)

For methodology related to calculating renewable energy shares of TFEC see methodological notes in REN21's *Renewables 2020 Global Status Report*.

DEFINITION OF HEATING AND COOLING AND THERMAL APPLICATIONS

In the REC, the term "heating and cooling" 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.

OTHER NOTES

This report includes data on projects, policies and other information prior to 31 December 2020. Editorial content of this report closed by 31 January 2021. Data provided for 2020 in the figures, tables and reference tables are as of the end of 2020, unless indicated otherwise. Growth rates in the REC are calculated as compound annual growth rates (CAGR) rather than as an average of annual growth rates. All exchange rates in this report are as of 31 December 2020 and are calculated using the OANDA currency converter (http://www.oanda.com/currency/converter). Corporate domicile, where noted, is determined by the location of headquarters.

GLOSSARY

Absorption chillers. Chillers that use heat energy from any source (solar, biomass, waste heat, etc.) to drive air conditioning or refrigeration systems. The heat source replaces the electric power consumption of a mechanical compressor. Absorption chillers differ from conventional (vapour compression) cooling systems in two ways: 1) the absorption process is thermochemical in nature rather than mechanical, and 2) the substance that is circulated as a refrigerant is water rather than chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs), also called Freon. The chillers generally are supplied with district heat, waste heat or heat from co-generation, and they can operate with heat from geothermal, solar or biomass resources.

Auction. See Tendering.

Bagasse. The fibrous matter that remains after extraction of sugar from sugar cane.

Behind-the-meter system. Any power generation capacity, storage or demand management on the customer side of the interface with the distribution grid (i.e., the meter).

Biodiesel. A fuel produced from oilseed crops such as soy, rapeseed (canola) and palm oil, and from other oil sources such as waste cooking oil and animal fats. Biodiesel is used in diesel engines installed in cars, trucks, buses and other vehicles, as well as in stationary heat and power applications. Most biodiesel is made by chemically treating vegetable oils and fats (such as palm, soy and canola oils, and some animal fats) to produce fatty acid methyl esters (FAME). (Also see Hydrotreated vegetable oil (HVO) and hydrotreated esters and fatty acids (HEFA).)

Bioenergy. Energy derived from any form of biomass (solid, liquid or gaseous) for heat, power and transport. (Also see Biofuel.)

Biofuel. A liquid or gaseous fuel derived from biomass, primarily ethanol, biodiesel and biogas. Biofuels can be combusted in vehicle engines as transport fuels and in stationary engines for heat and electricity generation. They also can be used for domestic heating and cooking (for example, as ethanol gels). Conventional biofuels are principally ethanol produced by fermentation of sugar or starch crops (such as wheat and corn), and FAME biodiesel produced from oil crops such as palm oil and canola and from waste oils and fats. Advanced biofuels are made from feedstocks derived from the lignocellulosic fractions of biomass sources or from algae. They are made using biochemical and thermochemical conversion processes, some of which are still under development.

Biogas/Biomethane. Biogas is a gaseous mixture consisting mainly of methane and carbon dioxide produced by the anaerobic digestion of organic matter (broken down by microorganisms in the absence of oxygen). Organic material and/or waste is converted into biogas in a digester. Suitable feedstocks include agricultural residues, animal wastes, food industry wastes, sewage sludge, purpose-grown green crops and the organic components of municipal solid wastes. Raw biogas can be combusted to produce heat and/or power; it also can be transformed into biomethane through a process known as scrubbing that removes impurities including carbon dioxide, siloxanes and hydrogen sulphides, followed by compression. Biomethane can be injected directly into natural gas networks and used as a substitute for natural gas in internal combustion engines without risk of corrosion.

Biomass. Any material of biological origin, excluding fossil fuels or peat, that contains a chemical store of energy (originally received from the sun) and that is available for conversion to a wide range of convenient energy carriers.

Biomass, traditional (use of). Solid biomass (including fuel wood, charcoal, agricultural and forest residues, and animal dung), that is used in rural areas of developing countries with traditional technologies such as open fires and ovens for cooking and residential heating. Often the traditional use of biomass leads to high pollution levels, forest degradation and deforestation.

Biomass energy, modern. Energy derived from combustion of solid, liquid and gaseous biomass fuels in high-efficiency conversion systems, which range from small domestic appliances to large-scale industrial conversion plants. Modern applications include heat and electricity generation, combined heat and power (CHP) and transport.

Biomass gasification. In a biomass gasification process, biomass is heated with a constrained amount of air or oxygen, leading to partial combustion of the fuels and to production of a mix of combustion gases that, depending on the conditions, can include carbon monoxide and carbon dioxide, methane, hydrogen and more complex materials such as tars. The resulting gas can be either used for power generation (for example, in an engine or turbine) or further purified and treated to form a "synthesis gas". This then can be used to produce fuels including methane, alcohols, and higher hydrocarbon fuels, including bio-gasoline and jet fuel. While gasification for power or heat production is relatively common, there are few examples of operating plants producing gas of high-enough quality for subsequent synthesis to more complex fuels.

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.

Biomethane. Biogas can be turned into biomethane by removing 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. Biomethane is often known as renewable natural gas (RNG), especially in North America.

Blockchain. A decentralised ledger in which digital transactions (such as the generation and sale of a unit of solar electricity) are anonymously recorded and verified. Each transaction is securely collected and linked, via cryptography, into a time-stamped "block". This block is then stored on distributed computers as a "chain". Blockchain may be used in energy markets, including for micro-trading among solar photovoltaic (PV) prosumers.

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. See Renewable building codes.

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 (for example, 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.

Carbon neutrality. The achievement of a state in which every tonne of carbon dioxide emitted to the atmosphere is compensated for by an equivalent tonne removed (e.g., sequestered). Emissions can be compensated for by carbon offsets. Carbon neutrality refers to net zero emissions of only carbon dioxide, whereas **climate neutrality** indicates a broader focus on net-zero emissions of all greenhouse gases.

Circular economy. A closed-loop system in which the waste from one process is a resource that can be used as input for another. By having a flow of resources that is circular rather than linear, the production of waste is minimised.

City. No international criteria or standards exist to determine what a city is. Most definitions of "cities" rely on settlement density and/or population numbers, although the criteria vary widely across countries. Generally, the term "urban area" refers to settlement areas that are more densely populated than suburban or peri-urban 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". Throughout the report, municipal and city government refers to the local decision-making bodies and government authorities (the mayor's office, city council, etc.), unless noted otherwise. "Local government" is a more generic term that can refer to different sub-national levels of public administration, including also counties, villages and other intermediate levels of government. In addition to municipal governments, 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.

City-wide. Extending or happening in all parts of a city.

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 choice aggregation (CCA). Under a CCA, municipalities themselves (independently or in partnership with an agency running the CCA) aggregate their residents' and businesses' electricity demand and set out to procure electricity for all participating customers city-wide through direct contracts with energy producers or through third-party energy providers. By enabling local communities to procure their own electricity, CCAs can be an attractive option for cities that want more local control over their electricity mix, for instance to increase the share of renewable electricity.

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 (for example, schools, neighbourhoods, partnering city governments, etc.); similarly, projects vary in technology, size, structure, governance, funding and motivation.

Competitive bidding. See Tendering.

Concentrating solar collector technologies. Technologies that use mirrors to focus sunlight on a receiver (see Concentrating solar thermal power). These are usually smaller-sized modules that are used for the production of heat and steam below 400°C for industrial applications, laundries and commercial cooking.

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.

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. The use of market signals such as time-of-use pricing, incentive payments or penalties to influence end-user electricity consumption behaviours. Demand response is usually used to balance electrical supply and demand within a power system.

Digitisation. The conversion of something (for example, data or an image) from analogue to digital.

Distributed generation. The 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 this report, "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 areas.

Distribution grid. The portion of the electrical network that takes power off the high-voltage transmission network via sub-stations (at varying stepped-down voltages) and distributes electricity to customers.

Ecodistrict. A district relying on integrated urban planning that encompasses the objectives of sustainable development and social equity and is aimed at reducing the ecological footprint of a neighbourhood, urban area or region.

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. Also see Plug-in hybrid electric vehicle.

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 audit. Analysis of energy flows in a building, process or system, conducted with the goal of reducing energy inputs into the system without negatively affecting outputs.

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 intensity. Primary energy consumption per unit of economic output. Energy intensity is a broader concept than energy efficiency in that it is also determined by non-efficiency variables, such as the composition of economic activity. Energy intensity typically is used as a proxy for energy efficiency in macro-level analyses due to the lack of an internationally agreed-upon high-level indicator for measuring energy efficiency.

Energy poverty. In poor countries, the term refers to the lack of access to modern energy services (for example, electricity and clean cooking). In wealthier countries, fuel poverty is associated with having energy costs above typical levels and mostly affects low-income households.

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 the 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 building. A building that (in its construction or operation) reduces or eliminates negative impacts and can create positive impacts on the climate and natural environment. Countries and regions have a variety of characteristics that may change their strategies for green buildings, such as building stock, climate, cultural traditions, or wide-ranging environmental, economic and social priorities – all of which shape their approach to green building.

Green energy purchasing (also called green tariffs). 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.

Hydrotreated vegetable oil (HVO) and hydrotreated esters and fatty acids (HEFA). Biofuels produced by using hydrogen to remove oxygen from waste cooking oils, fats and vegetable oils. The result is a hydrocarbon that can be refined to produce fuels with specifications that are closer to those of diesel and jet fuel than is biodiesel produced from triglycerides such as fatty acid methyl esters (FAME).

Inverter (and micro-inverter), solar. Inverters convert the direct current (DC) generated by solar PV modules into alternating current (AC), which can be fed into the electric grid or used by a local, off-grid network. Conventional string and central solar inverters are connected to multiple modules to create an array that effectively is a single large panel. By contrast, micro-inverters convert generation from individual solar PV modules; the output of several micro-inverters is combined and often fed into the electric grid. A primary advantage of micro-inverters is that they isolate and tune the output of individual panels, reducing the effects that shading or failure of any one (or more) module(s) has on the output of an entire array. They eliminate some design issues inherent to larger systems, and allow for new modules to be added as needed.

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).

Investment tax credit. A fiscal incentive that allows investments in renewable energy to be fully or partially credited against the tax obligations or income of a project developer, industry, building owner, etc.

Joule. A joule (J) is a unit of work or energy equal to the work done by a force equal to one newton acting over a distance of one metre. One joule is equal to one watt-second (the power of one watt exerted over the period of one second). The potential chemical energy stored in one barrel of oil and released when combusted is approximately 6 gigajoules (GJ); a tonne of oven-dry wood contains around 20 GJ of energy.

Light commercial vehicle. Vehicle used for commercial purposes that has a gross vehicle weight of less than 3,500 kilograms.

Low-emission vehicle zone. A type of vehicle restriction that limits or prohibits the access of certain types of fossil fuel vehicles in defined city areas.

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.

Market concession model. A model in which a private company or non-governmental organisation is selected through a competitive process and given the exclusive obligation to provide energy services to customers in its service territory, upon customer request. The concession approach allows concessionaires to select the most appropriate and cost-effective technology for a given situation.

Micromobility. A range of small, lightweight vehicles such as bicycles and scooters often used by individuals to travel short distances in cities.

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.

Monitoring. Energy use is monitored to establish a basis for energy management and to provide information on deviations from established patterns.

Municipal operations. Services or infrastructure that are owned and/or operated by municipal governments. This may include municipal buildings and transport fleets (such as buses, police vehicles and refuse collection trucks).

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.

(Re-)Municipalisation. Legal process by which municipalities assume control of their electricity procurement and distribution assets, generally through purchase from private entities.

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.

Net-zero carbon building / Net-zero energy building / Nearly zero energy building. Various definitions have emerged of buildings that achieve high levels of energy efficiency and meet remaining energy demand with either on-site or off-site renewable energy. For example, the World Green Building Council's Net Zero Carbon Buildings Commitment considers use of renewable energy as one of five key components that characterise a net-zero building. Definitions of net-zero carbon, net-zero energy and nearly zero energy buildings can vary in scope and geographic relevance.

Net-zero strategy. Policy or plan to achieve carbon neutrality by a certain date. In most cases, this involves reducing community-wide emissions as much as possible, for instance through improvements in energy efficiency and a transition to renewable energy, while investing in carbon mitigation options or offsets elsewhere in the world.

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.

Off-take agreement. An agreement between a producer of energy and a buyer of energy to purchase/sell portions of the producer's future production. An off-take agreement normally is negotiated prior to the construction of a renewable energy project or installation of renewable energy equipment in order to secure a market for the future output (e.g., electricity, heat). Examples of this type of agreement include power purchase agreements and feed-in tariffs.

Off-taker. The purchaser of the energy from a renewable energy project or installation (e.g., a utility company) following an off-take agreement.

Pay-as-you-go (PAYGo). 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.

Plug-in hybrid electric vehicle. This differs from a simple hybrid vehicle, as the latter uses electric energy produced only by braking or through the vehicle's internal combustion engine. Therefore, only a plug-in hybrid electric vehicle allows 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.

Positive energy district (PED). An area within a city that is capable of generating more renewable energy than it consumes.

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).

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.

Property Assessed Clean Energy (PACE) financing. Provides access to low-interest loans for renewable energy that can be repaid through increases on property taxes.

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 building codes. Building energy codes that mandate that a certain amount of energy demand be met by renewable energy (e.g., solar obligations). They differ from green building codes, which tend to focus on improving the performance of buildings by using materials, equipment and components that enhance energy efficiency. See Green building.

Renewable energy. This includes all forms of energy produced from renewable sources, including solar, wind, ocean, hydropower, biomass, geothermal resources and biofuels.

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 hydrogen (also referred to as green hydrogen). Hydrogen produced from renewable energy, most commonly through the use of renewable electricity to split water into hydrogen and oxygen in an electrolyser. The vast majority of hydrogen is still produced from fossil fuels, and the majority of policies and programmes focused on hydrogen do not include a focus on renewables-based production.

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.

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.

Shore power (also called cold ironing). This entails connecting a maritime vessel to the power grid while at berth in a port so that the electricity demand from the vessel while hotelling is supplied directly by the grid rather than by the generator on the vessel, which typically is diesel powered.

Smart charging. Optimisation of the charging process of an electric vehicle according to external inputs (e.g., user requirements, power system characteristics, grid constraints and renewable energy availability). Smart charging includes unidirectional controlled charging (V1G), bi-directional vehicle-to-grid (V2G) and vehicle-to-home/building (V2H/B). Developing smart charging brings several advantages for balancing the grid, also helping to integrate renewables into the system and possibly improving operating expenses for consumers. Also see Vehicle-to-grid.

Smart city. A city that utilises digital technologies to collect data that is then used to manage assets, resources and services more efficiently, improve operations across the city and generally increase the quality of life of citizens.

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 non-electrical (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.

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 and 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 home system. 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 also is 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 façade.

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. 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 sub-stations, 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.

Urban form. Refers to a city's physical characteristics, including size, shape and population density.

Urban freight transport. The movement of goods in to, out from, through or within the urban area made by light or heavy vehicles, including but not limited to service transport, construction material transport and reverse logistics for waste removal.

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 sub-hourly 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-to-grid (V2G). A system in which electric vehicles – whether battery electric or plug-in hybrid – communicate with the grid in order to sell response services by returning electricity from the vehicles to the electric grid or by altering the rate of charging.

Virtual net metering. Virtual (or group) net metering allows electricity utility consumers to share the output of a renewable power project. By receiving "energy credits" based on project output and their ownership share of the project, consumers are able to offset costs on their electricity utility bill.

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.

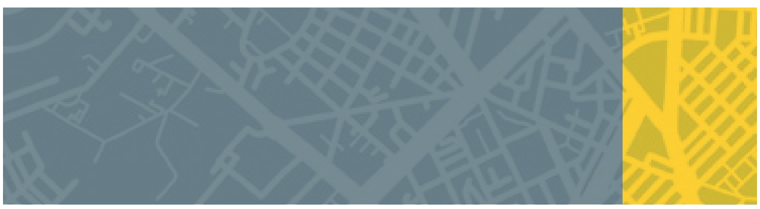
Watt. A unit of power that measures the rate of energy conversion or transfer. A kilowatt is equal to 1 thousand watts; a megawatt to 1 million watts; and so on. A megawatt-electrical (MW) is used to refer to electric power, whereas a megawatt-thermal (MW_{th}) refers to thermal/heat energy produced. 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.

Wheeling. Refers to the transport of electric energy from within an electrical grid from one party (the seller) to another party (the buyer). Wheeling deals with the use of the network and the cost of delivering the energy.

Zero-emission vehicle. A vehicle that does not produce tailpipe emissions (the air pollutants emitted during the operation of a vehicle). These emissions often include greenhouse gases, particulate matter, volatile organic compounds, nitrogen oxides, carbon monoxide and sulphur dioxide. The term zero-emission vehicle typically refers to an electric vehicle, although the charging of the vehicle is not necessarily linked with renewable energy.

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
AUD	Australian dollar
BRL	Brazilian real
CCA	Community choice aggregation
CDP	Carbon Disclosure Project
CHP	Combined heat and power
CNG	Compressed natural gas
CNY	Chinese yuan
CO_2	Carbon dioxide
COP26	26^{th} Conference of the Parties
COVID	Coronavirus disease
CSP	Concentrating solar thermal power
DHC	District heating and cooling
EBRD	European Bank for Reconstruction and Development
EDGE	Excellence in Design for Greater Efficiencies
EJ	Exajoule
ESCO	Energy service company
ESG	Environmental, social and corporate governance
EU	European Union
EUR	Euro
EV	Electric vehicle
FIT	Feed-in tariff
GBP	Pound sterling
GDP	Gross domestic product
GJ	Gigajoule
GO	Guarantee of origin
GSR	Global Status Report
GW/GWh	Gigawatt/gigawatt-hour
GW_{th}	Gigawatt-thermal
HEFA	Hydrotreated esters and fatty acids
HVO	Hydrotreated vegetable oil
ICCT	International Council on Clean Transportation
ICE	Internal combustion engine
ICLEI	International Council for Local Environmental Initiatives
IDR	Indonesian rupiah
IEA	International Energy Agency
INR	Indian rupee
IPP	Independent power producer
IPVA	Vehicle Property Tax
IRP	Integrated Resource Plan
JPY	Japanese yen
KCCA	Kampala Capital City Authority
km^2	Square kilometre
KPLC	Kenya Power and Lighting Company
kW/kWh	Kilowatt/kilowatt-hour
LED	Light-emitting diode
LEZ	Low-emission zone
LPG	Liquefied petroleum gas
MENA	Middle East and North Africa
MSW	Municipal solid waste
MW/MWh	Megawatt/Megawatt-hour
MW_{th}	Megawatt-thermal
MXN	Mexican peso
NDC	Nationally Determined Contribution
NEV	New Energy Vehicle
NUP	National urban policy
OECD	Organisation for Economic Co-operation and Development
PACE	Property Assessed Clean Energy
PAYGo	Pay as you go
PCET	Plan Climat-Energie Territorial
PHEV	Plug-in hybrid electric vehicle
PLN	Polish zloty
$PM_{2.5}$	Fine particulate matter
PPA	Power purchase agreement
PPI	Private participation in infrastructure
PPP	Public-private partnership
PV	Photovoltaic
REC	Renewable energy certificate
REIPPP	Renewable Energy Independent Power Procurement Programme
SDG	Sustainable Development Goal
SEA	Sustainable Energy Africa
SEED	Sustainable Energy for Environment and Development
SEK	Swedish krona
SPV	Special purpose vehicle
SSA	Sub-Saharan Africa
TW/TWh	Terawatt/Terawatt-hour
UK	United Kingdom
UN	United Nations
URBACT	Urban development network programme
US	United States
USD	United States dollar
WHO	World Health Organization
ZAR	South African rand



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GLOBAL OVERVIEW OF RENEWABLES IN CITIES

1 REN21 Policy Database (2020) and Tables R1-R5, available at www.ren21.net/cities/datapack. Data are compiled by REN21 and based on CDP-ICLEI Unified Reporting System, CDP Open Data, The Global 100% Renewable Energy Platform, Climate Action Network, C40, ICLEI, IRENA, Sierra Club, UK100 and REN21 data collection. Some research is based on voluntary reporting and may not be exhaustive. **Figure 1** and **Table 1** from Ibid; Fossil Free Divestment, "Divestment commitments overview", https://gofossilfree.org/divestment/commitments, viewed 14 December 2020.

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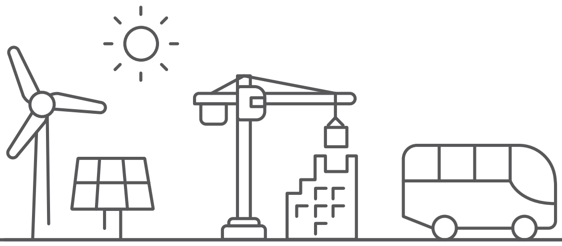

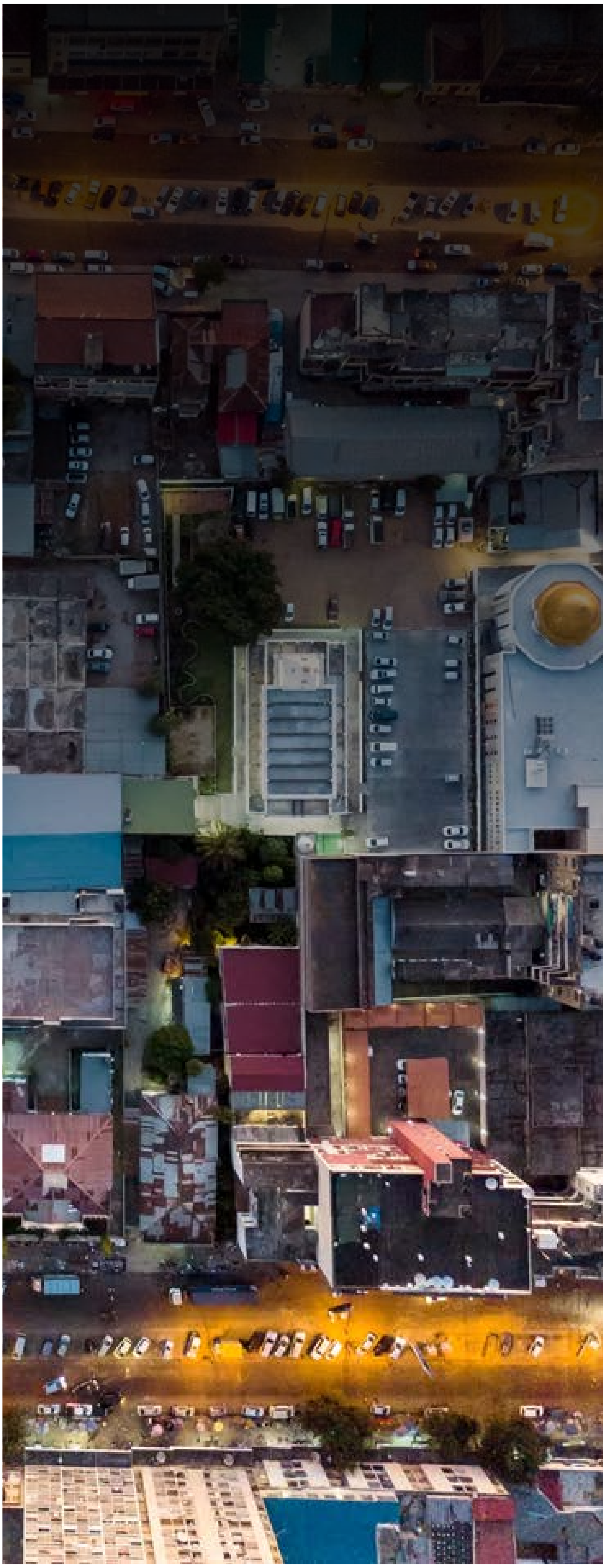

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