IRENA
International Renewable Energy Agency

RENEWABLE ENERGY POLICIES FOR CITIES

POWER SECTOR

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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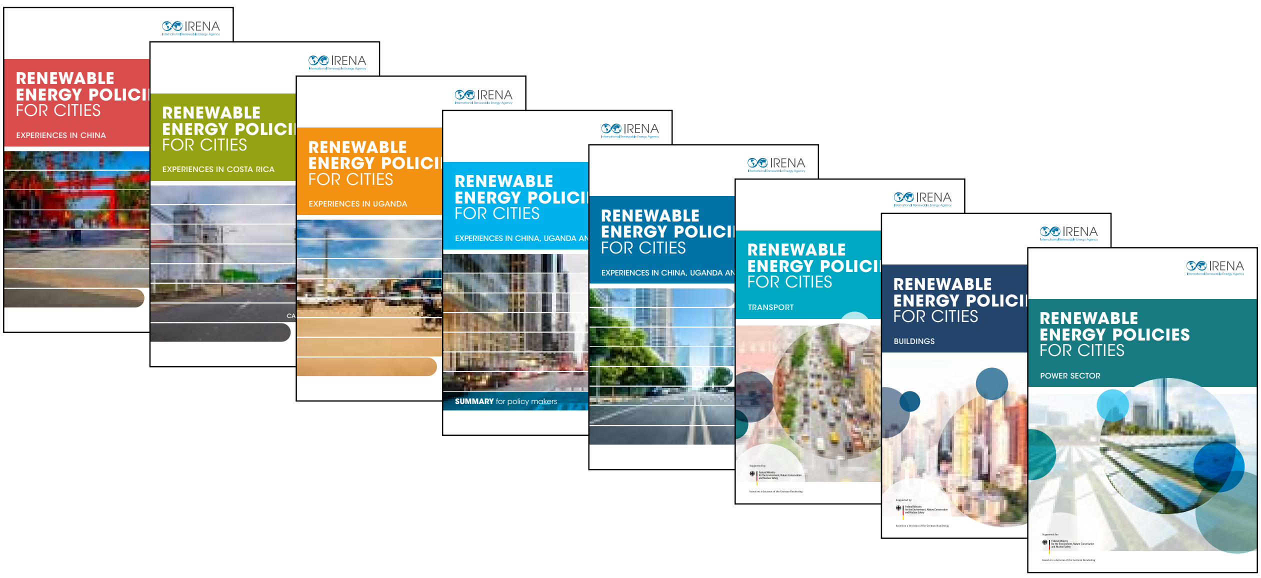
ABOUT THE RENEWABLE ENERGY POLICIES FOR CITIES SERIES

Renewable Energy Policies for Cities: Power Sector is one of several briefs intended to help policy makers accelerate efforts to create sustainable cities powered by renewable energy. The series includes briefs focused on the transport and buildings sectors, and this one, on power. In addition, IRENA has produced a larger analytical report with case studies from three countries and an executive summary. The case studies are also available as stand-alone reports.

The series recognises that cities are critical actors in energy and climate policy making, complementing actions taken at the national and state/provincial levels of government. Cities are home to an ever increasing share of the world's population and are economic engines that use a large share of the energy consumed in the world. Thus, municipalities will play a major role in advancing and shaping the global energy transition. These briefs focus on actions that may be undertaken independently by cities or in combination with initiatives at higher governmental levels.

The briefs carry a common understanding that the energy transition in cities is really a story of urban transformation. Renewables have impacts that extend well beyond the energy sector; they shape transport, buildings, land use and a host of other sectors critical to cities' functioning. Even within the energy sector, adoption of renewable energy involves more than a shift in energy sources; it includes an emphasis on greater energy efficiency and changed consumption patterns as well, both of which can change the face of a city. In sum, the energy transition is an opportunity to remake cities in a variety of ways that are better for people and the planet alike.

In addition, the *Renewable Energy Policies for Cities* series supports the International Renewable Energy Agency's (IRENA's) urban policy guidelines toolkit, an online resource that may be of particular interest to staff of municipal-level entities but is open to any interested individuals who want to strengthen their knowledge of options to facilitate the deployment of renewable energy in the urban environment. Part of IRENA's Policy Framework for the Energy Transition (PFET) (see Box), this innovative toolkit centres on the same areas of city-level action as IRENA's series of sectoral briefs: that is, renewable energy in (1) the power sector, (2) transport and (3) buildings. Based on a series of yes/no questions about basic circumstances in a city of interest (such as basic policy-making objectives, settlement density or the availability of public transit), the toolkit offers basic policy recommendations, and points to case studies and examples of how policies have been implemented in cities across the world. These recommendations are intended to offer a broad orientation; specifically tailored advice requires detailed assessments of a given city.



BOX IRENA'S POLICY FRAMEWORK FOR THE ENERGY TRANSITION (PFET)

The PFET aims to translate the knowledge products developed by IRENA's Knowledge, Policy and Finance Centre on policy, socio-economic benefits and finance into actionable advice, and to bring the messages and recommendations to policy makers on the ground to create impact. The PFET includes a set of **packages** that synthesise the knowledge products of IRENA and proposes different **tools** to deliver the capacity building to policymakers. These tools may include but are not limited to: presentations that can serve to deliver capacity building exercises; interactive exercises to conduct during the trainings; and short videos to convey key messages. PFET materials have been prepared or are under development for IRENA's work on cities, auctions, targets, and heating and cooling policies.

PFET
Policy Framework for the Energy Transition

IRENA
International Renewable Energy Agency

THE RENEWABLE ENERGY POLICIES FOR CITIES SERIES INCLUDE THE FOLLOWING REPORTS AND AN ONLINE TOOL

- Renewable Energy Policies for Cities: **TRANSPORT**
- Renewable Energy Policies for Cities: **BUILDINGS**
- Renewable Energy Policies for Cities: **POWER SECTOR**

INTRODUCTION

If cities can be said to be the heart of human activity, energy is what keeps the urban heart pumping. Cities are engines of the economy, accounting for more than 80% of global gross domestic product. Urban energy powers transport, industrial production, commerce, building construction, public works, lighting, air conditioning and countless other human activities. Accounting for about 75% of global primary energy use, cities have a major role to play in advancing and shaping the global energy transition, including with their choice of energy (IRENA, 2016, 2021). And increasingly, cities seek to supply energy that is clean and renewable, and therefore sustainable. Cities play a multitude of roles in the energy sector, and although their needs and opportunities vary as much as their capacities to act, they can undertake a variety of measures to support renewable energy (see Box 1).

To date, the fastest uptake of renewable energy globally has occurred in electricity generation (IRENA, 2019a), and cities have played a key role in accelerating the transition of the urban electricity mix to one that is based on renewable energy. Municipal authorities may also adopt clean energy guidelines governing their purchases of energy. By setting targets, adopting labelling schemes or requiring "green" certificates, they can influence what kinds of energy sources private providers develop and offer to local households and businesses. Some cities have put in place feed-in tariffs or net metering for renewable power. Cities that own utilities can directly shape their energy offerings and may consider, for example, green premium products or tailored renewable energy contracts for urban customers.

Outlining a number of specific approaches and experiences in cities around the world, this brief discusses urban policies for power generation through both utility-scale operations and decentralised options.[1]

Section 1 of this brief starts with efforts by cities to formulate broad visions and targets for renewables to play a much larger role in electricity generation. One important urban power need is for street lighting, and a number of cities are promoting solar photovoltaic (PV) panels combined with light-emitting diode (LED) bulbs as an alternative to conventional lights. The section next discusses the use of biogas from municipal landfills and from food waste for power generation.[2]

Turning to decentralised applications of renewables, Section 2 of the brief discusses efforts to promote rooftop solar PV panels, including net metering. Promoting renewables in the urban context is about more than just facilitating the application of cleaner energy technologies. It is also concerned with the question of who can drive the energy transition forward.

Thus, Section 3 discusses the role of publicly owned utilities (as contrasted with private providers); the importance of community energy initiatives; and, finally, the role that peer networks can play in enhancing cities' knowledge and capacity to act, and in sharing lessons learned.

1 The brief highlights a few selected examples, but experiences are multiplying around the world. REN21's *Renewables in Cities Global Status Report* (REN21, 2020) offers a broader catalogue of targets and policies that cities pursue in the power, heating and cooling, and transport sectors.

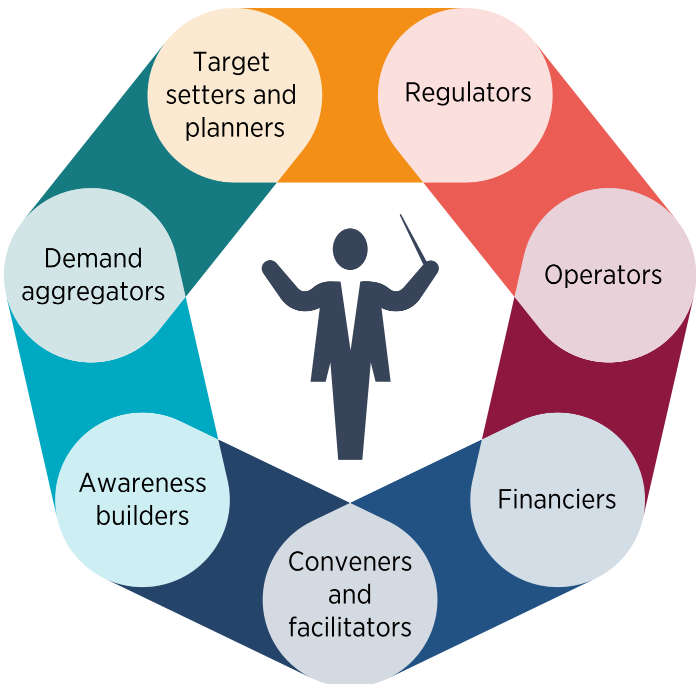
2 Biogas can also be used for other purposes, such as an alternative fuel for municipal bus fleets, something discussed in another brief in this series, *Renewable Energy Policies for Cities: Transport*.

BOX 1 THE SIGNIFICANCE OF CITIES IN DEPLOYING RENEWABLE ENERGY

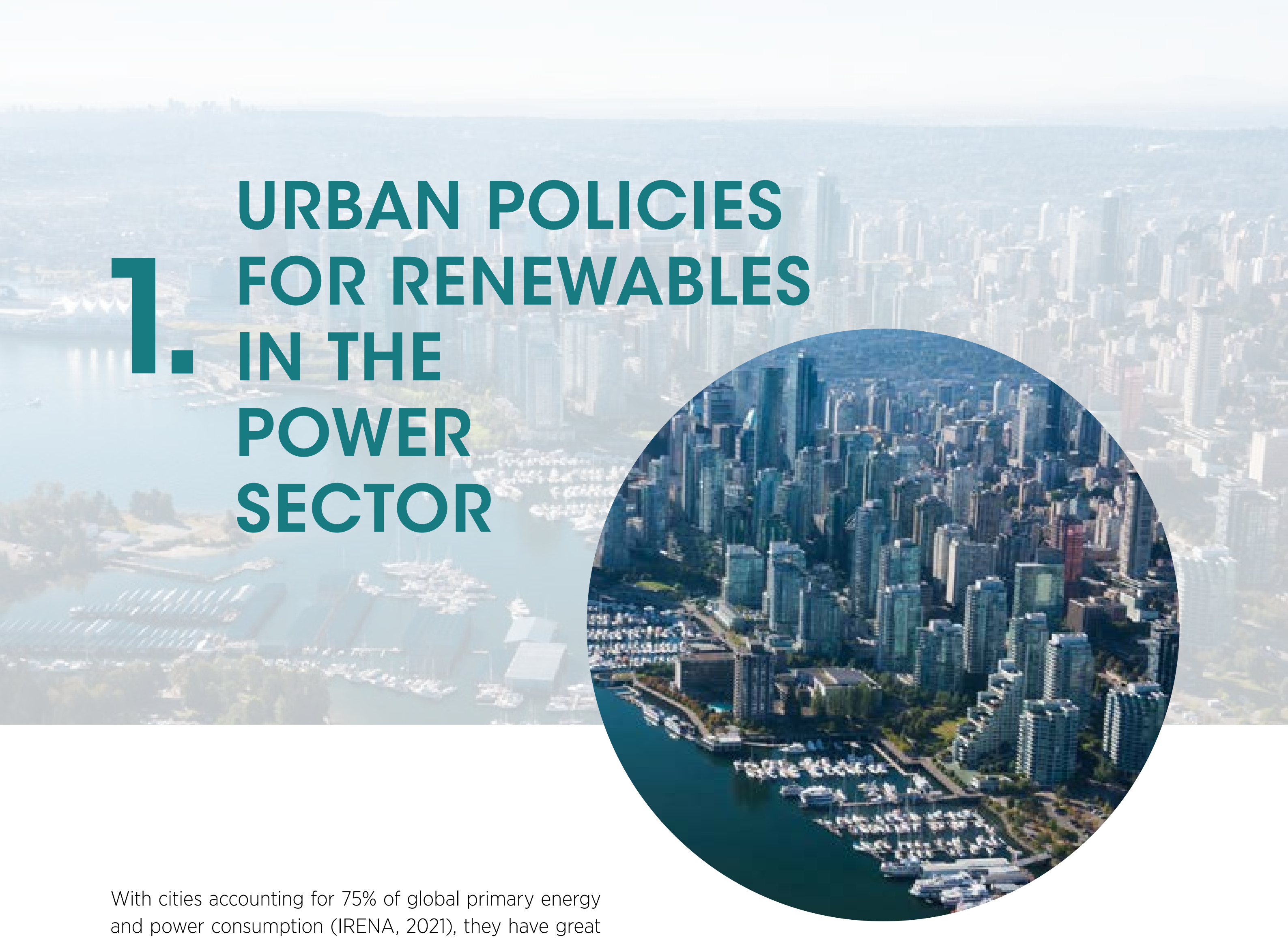
The boundaries of urban policy making are defined by the legal and regulatory authority vested in governments not only at the municipal level but also at the state, provincial and national levels. These boundaries are drawn in different ways across countries; some are governed in a highly centralised way while in others there is a considerable degree of devolution of authority.

IRENA's continuing work on renewable energy in cities (IRENA, 2016; 2021) has identified several dimensions of cities' roles in shaping climate adaptation and mitigation efforts, and as such in accelerating the deployment of renewable energy solutions as a key pillar of national sustainable energy targets (see Figure 1). Cities can be target setters, planners and regulators. They are often owners and thus operators of municipal infrastructure. Cities are always direct consumers of energy and therefore aggregators of demand, and can be conveners and facilitators and financiers of renewable energy projects. Finally, local authorities can play an important role in raising awareness by informing citizens of target setting and planning, and also by giving citizens an opportunity to provide comments and other inputs.

Figure 1 Roles of municipal governments in the energy transition



Source: IRENA urban policy analysis (based on IRENA 2021).



1. URBAN POLICIES FOR RENEWABLES IN THE POWER SECTOR

With cities accounting for 75% of global primary energy and power consumption (IRENA, 2021), they have great incentive to produce or procure their own electricity from renewable sources, rather than continuing to rely on the polluting fuels that today are generating the majority of power supplies. Municipalities can play a proactive role in a variety of ways, explored in this section.

1.1. SOURCING MUNICIPAL POWER FROM RENEWABLES

Urban energy supply and electrification are often under the purview of national energy utilities and regulatory authorities. In some countries, however, municipalities have a strong role to play, though the privatisation of utilities has altered the policy-making landscape in recent decades. In Nordic countries, for example, cities that own their utilities have developed wind, hydro and bioenergy generation capacities (including for methane capture from wastewater, sludge and landfills) in their capacity as planners, financiers and operators. Germany is another country where local utilities, owned by municipalities (so-called Stadtwerke), as well as community-based energy co-operatives, play a significant role in electricity generation and distribution. In the United States, the cities and counties with 100% clean energy all have local, public control over electricity procurement (UCLA Luskin Center for Innovation, 2019).

Growing numbers of cities are attempting to source more of their energy supply from renewables and to increase the role of local generation. The degree of ambition varies as well, both in terms of the scope of planned actions and their time horizon. As the following examples from around the world indicate, while cities play important roles in articulating a vision for their energy transitions and adopting overall plans and targets in pursuit of it, they face different types of challenges, at different scales, in greening their energy supply. Some cities have a head start, such as where clean energy supplies are already abundantly available. **Vancouver** (Canada), for example, gets 94 percent of its power from renewables, largely from hydropower. This large share reflects long-standing policy choices (CER, 2021).

Where national governments have not already taken action, municipal authorities may do so in their function as local electricity regulators. In the United Arab Emirates, the Shams Dubai programme adopted by the **Dubai** Electricity and Water Authority led to the installation of 30–40 megawatts (MW) of solar capacity on the premises of the Dubai Ports Authority (REN21, 2020). The ambitious strategy of the Dubai Emirate, that aims to provide 25% of Dubai's total power output from clean energy by 2030 and 75% by 2050, includes other projects such as the Al Maktoum Solar Park, which is the largest single-site solar energy project in the world, with a planned total production capacity of 5 000 MW by 2030, with a total investment of AED 50 billion (DEWA, 2019).

Cities vary in their ability to generate their own renewable energy. Those that have limited capacity can join together to transform the energy market and lower costs through a joint procurement process (auctions). The city of **Boston** (United States) launched a multi-city initiative in mid-2018 to issue a request for information for the competitive pricing of large-scale renewable energy projects. The request pools demand from 20 participating US cities representing about 5.7 terawatt hours, or enough to power half a million homes. The initiative requests price estimates from renewable energy developers for projects to meet this collective demand (City of Boston, 2018a; 2018b).

Small municipalities do not have purchasing power at levels anywhere near that of large cities. But they may still be able to generate workable solutions together. For example, in Germany's Oberpfalz (Upper Palatinate) region, 17 towns and communities across three counties with a combined population of 270 000 formed a co-operative association known as Neue Energien West, with offices in **Grafenwöhr**, a town of just 6 300 inhabitants. The association pursues the planning and operating of joint renewable energy projects, with an eye towards regional value creation, and offers membership to residents of the region (Neue Energien West EG, n.d.).

1.2. DEPLOYING SOLAR STREET LIGHTING

Lighting of streets and public spaces can account for as much as 40% of a city's energy budget (IRENA, 2016). Electricity for such uses can be provided more sustainably through solar power. Street lights represent a significant share of urban energy use. Conventional lights are inefficient and need to be replaced often. By contrast, solar lights with LED bulbs offer energy and cost savings of 50% or more and, because they have life spans of up to 20 years, greater durability. Solar LED lights offer even more benefits if they are networked and combined with smart grid development (Silver Spring Networks, 2013). However, of the approximately 300 million streetlights globally, only about 10% are LEDs, and only 1% are networked (Rondolat, n.d.).

Cities possess varying degrees of control over decision making related to street lighting. In **Sydney**, Australia, many municipally owned streetlights have been upgraded to energy-efficient LEDs, powered by the sun. Of the 22 000 public lights in the city, the municipality itself maintains 8 500 and Ausgrid, a privately owned utility, the remainder. A three-year project that began in 2012 saw a total of about 6 600 lights replaced, resulting in close to 50% reduction in energy use and carbon dioxide (CO_2) emissions and substantial monetary savings (ICLEI and IRENA, 2018a).

In **Pittsburgh**, (United States), a collaborative project between city authorities and members of the SmartPGH consortium of corporations, universities and civic groups was instrumental in converting some 36 365 streetlights to LED technology. The consortium worked with the state of Pennsylvania's Department of Transportation. Energy savings were estimated at 60% or about USD 650 000 a year (Riley, 2017).

In summer 2020, the Nepalese city of **Lalitpur** announced an initiative to install smart, electrically powered streetlamps along three main routes. With the technical support of the Nepal Electricity Authority, the project is designed to benefit from past experiences with solar street lighting, by using a centralised control system that helps minimise electricity use and alerts the operator to any faulty lights. This system is the first of its kind in Nepal, which has already gained extensive experience with decentralised street lighting, and could be expanded to other parts of the country depending on interest (The Kathmandu Post, 2020).

Lugazi is one of several Ugandan cities to benefit from the construction of solar-powered streetlights in 2016. The project was financed through development aid as well as local funds and was initiated through the World Bank's Uganda Support to Municipal Infrastructure Development Programme. About two dozen streetlights were installed in a previously unlit area, providing an important pilot for future scaling up. Funds were channelled through the Ministry of Lands, Housing and Urban Development (IRENA, 2021).

1.3 CAPTURING METHANE FROM LANDFILLS AND TURNING FOOD WASTE INTO POWER

Power generation using bioenergy produced from municipal waste reduces problems stemming from waste flows, mitigating the pressure on urban land management from expansion of landfills, and avoids greenhouse gas (GHG) emissions from landfill methane.

Urban waste generation is a large and growing problem. From 1.3 billion tonnes in 2012, municipal solid waste volumes worldwide rose to 2 billion tonnes in 2016 and are projected by the World Bank to increase to 3.4 billion tonnes by 2050 (World Bank, 2019). The depositing of waste in unregulated dumps or its open burning entails serious health and environmental consequences. But even where solid waste is placed in regulated landfills that meet certain safety specifications, one unintended consequence is anaerobic digestion, which produces methane that may be released into the atmosphere. Methane is a far more potent greenhouse gas than CO_2. Often, the methane is flared, a wasteful and environmentally questionable practice.

A growing number of cities are capturing landfill methane to produce biogas for power generation. Such efforts are part of a wider waste-to-energy strategy. According to Bloomberg New Energy Finance (BNEF, 2018), at least 978 waste-to-energy plants worldwide use either municipal or industrial waste as feedstock. Collectively, these facilities have a power-generating capacity of 13.7 gigawatts (GW). However, by far the largest share, at 11.6 GW, belongs to incineration plants, which cannot be considered renewable; concerns about incineration's impacts on human health have at times sparked community protests. The remainder of the plants are mostly landfill gas capture and anaerobic facilities.

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Though European cities are in the lead, methane capture is spreading to other continents as well.

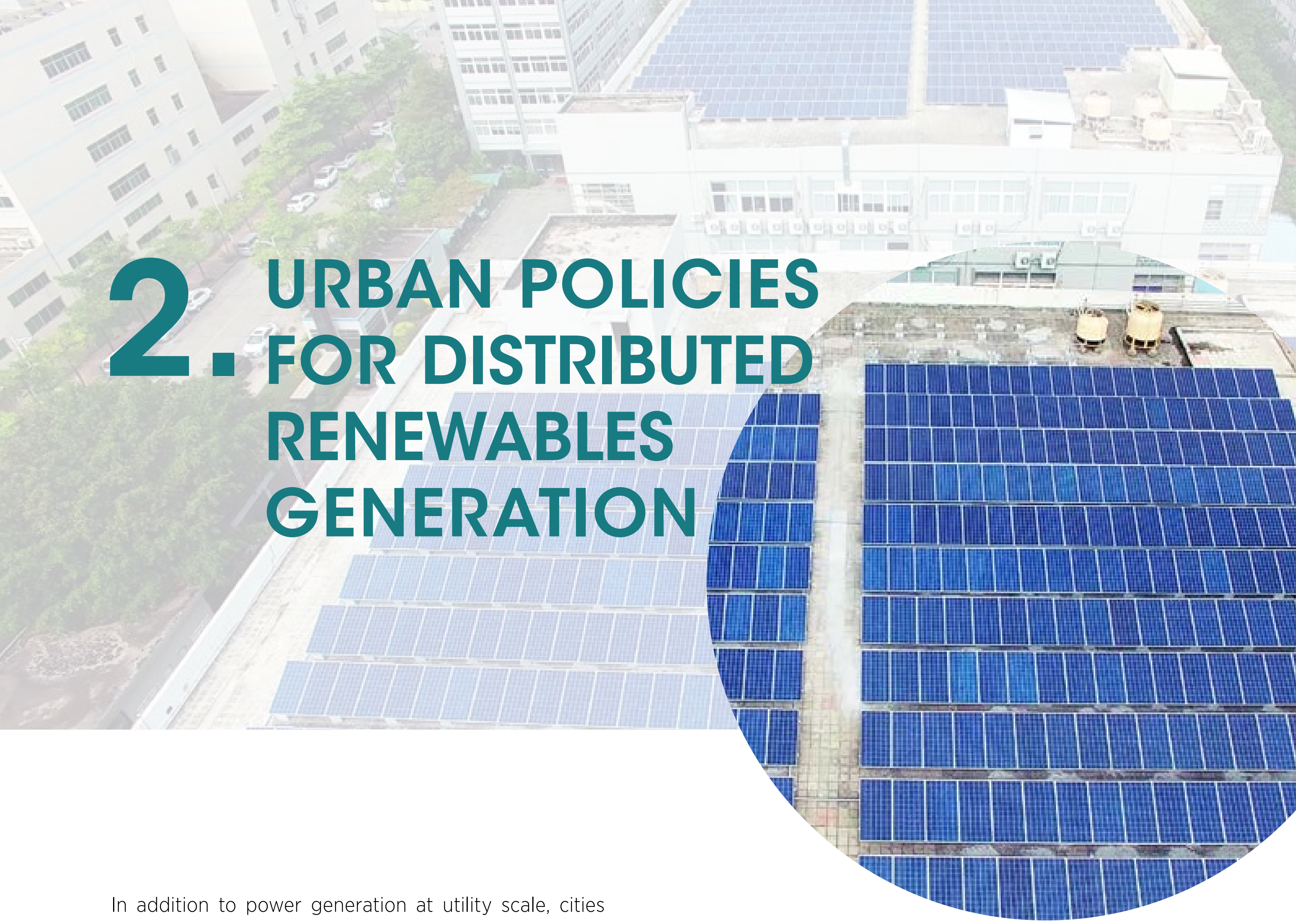
The United States has seen a rapid increase in the use of methane capture from local landfills since the 1990s, owing to a combination of factors that include federal legislation to implement the Clean Air Act for landfills, economic incentives and other national and state-level programmes to help encourage GHG reductions and renewable energy. As of August 2020, the US Environmental Protection Agency counted 565 operational landfill gas energy projects that use methane captured from waste, as well as 475 "candidate" landfill sites that could turn their methane into an energy resource, by generating electricity, for direct use, or for further processing into vehicle fuel (EPA, 2020). Redwood Landfill in **Novato**, California, exemplifies some of these projects. In 2017, a local community energy partnership initiative opened a landfill gas energy plant that provides renewable electricity to more than 5 000 customers (Patch, 2017).

Waste-to-energy plants are also beginning to appear in various parts of Asia and Africa. Palava City in **Mumbai** (India) began using landfill gas for power generation and biofertiliser in 2017 (Rege, 2017). Work has begun on an 8.6 MW power plant in **Chonburi** (Thailand) that will run on some 100 000 tonnes of industrial waste per year. In **Addis Ababa** (Ethiopia), construction started in 2017 on a facility that will turn more than half a million tonnes of municipal waste into 185 gigawatt hours (GWh) of electricity annually, enough to power 25% of urban households (REN21, 2018).

Johannesburg (South Africa) offers lessons in two innovative approaches to generate energy from local waste flows. The city is home to the country's largest waste-to-energy project. Methane from five landfills generates enough power for 16 500 medium-sized residential houses (Climate Neutral Group, n.d.). Since 2012, Johannesburg has also produced sewage gas at its Northern Works wastewater treatment facility. The sewage gas is fed into a combined heat and power plant. The plant's heat output is used to improve sludge management, which reduces waste volumes, produces valuable compost for farmers and increases biogas production. The electricity produced reduces the need to purchase power from the utility, Eskom, mitigating the impact of escalating electricity prices. However, technical problems have kept biogas and electricity production substantially below projections (GIZ, SALGA and SEA, n.d.).

While waste-to-energy strategies show promise, a note of caution is in order. Such strategies are predicated on an unabated continuation of waste flows, and so reliance on waste energy for heat and electricity could ultimately be at odds with waste avoidance strategies such as recycling, reuse and composting. These waste reduction objectives need to be prioritised.

As a way to avoid landfilling, a number of cities are also turning to anaerobic digestion and composting of food wastes, which enables local renewable energy generation. For example, **Milan** (Italy) has been a pioneer of segregated food waste collection since 2012. About 140 000 tonnes are collected annually from all inhabitants and businesses. The food waste is transported to an integrated anaerobic digestion and composting facility near the city of Bergamo, about 60 kilometres northeast of Milan. It generates biogas, some of which is used for power generation (with a capacity of 9 megawatts electric [MW_{el}]) while some is fed into the national gas grid (World Biogas Association, 2018).



2. URBAN POLICIES FOR DISTRIBUTED RENEWABLES GENERATION

In addition to power generation at utility scale, cities can encourage and enable distributed renewables generation. Solar PV panels,[3] in particular, can be installed at different scales and configurations on public and private buildings, in parking lots and at a variety of urban structures and locations. A growing number of cities around the world are formulating ambitious goals for deploying solar PV on rooftops and other spaces. In addition to panel installations that may be undertaken by municipalities directly, facilitating the uptake of PV panels by households or commercial enterprises requires supportive policies. These may include feed-in tariffs (FITs) which are typically implemented by national authorities, and also measures such as net metering that can be put in place by municipal authorities. The section first offers examples of broad solar PV plans in a number of selected cities before discussing net metering policies in various locations.

2.1. ROOFTOP SOLAR PV

Solar PV costs have come down markedly (IRENA, 2020a). For many cities, encouraging the deployment of rooftop solar PV through regulatory measures helps achieve multiple objectives. It benefits local consumers as well as governments and integrates well with parallel local and national efforts to increase energy efficiency (IRENA, 2021).

As owners of large rooftop areas on public buildings, and regulators of roof space on private buildings, cities are well positioned to deploy rooftop PV programmes for their power supply. The metropolitan government of **Seoul** (Republic of Korea) is using this approach in its "Solar City Seoul" programme, part of the national government's plan to generate 20% of the country's electricity from renewable energy by 2030 (Bellini, 2019). Announced in late 2019, Solar City Seoul aims to quintuple the city's total installed rooftop PV capacity in just three years, from around 200 MW to approximately 1 GW. It will distribute solar panels to 1 million households—two thirds in the form of mini-solar PVs, which are installed on apartment balconies,

3 Other renewables can be decentralised but may not be fit for high-density urban environments. For example, modern wind turbines require more space and thus are more likely to be deployed at the urban perimeter or outside of city areas entirely. Similarly, bioenergy harvesting, hydropower and geothermal systems are most common in the least-dense parts of a municipality.

and the remainder as rooftop PVs (Kim and Gim, 2021). The process is expected to create 4 500 new jobs and cost nearly USD 1.5 billion. Residents who install mini-solar PVs receive a subsidy covering more than 60% of the total cost from the Seoul Metropolitan Government and district governments. Return on invested capital is expected in less than three years (Kim and Gim, 2021).

Tokyo (Japan) similarly plans to install 1 GW of rooftop systems by 2024, including 22 MW on publicly owned buildings and facilities. The city aimed to have renewables contribute 20% of total power generation by the time of the 2020 Summer Olympics[4] (the Games were ultimately postponed due to the COVID-19 pandemic). In support of this effort, Tokyo developed a roof rental scheme under which residential or commercial building owners can rent out their roofs to project developers for a fee. A city web portal matches and connects interested parties (Movellan, 2015). The city also created Japan's first solar map, the "Tokyo Solar Register", which calculates suitable solar PV system size (kilowatt, kW) and potential electricity generation (kilowatt hours, kWh) by assessing solar insolation, roof-top space, roof tilt and shading for each specific home or building (Movellan, 2015).

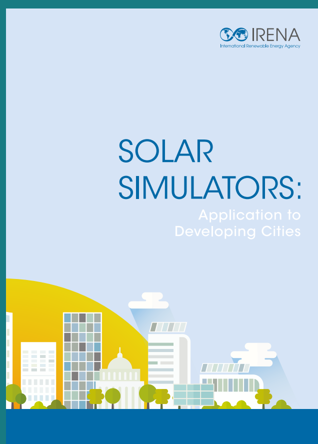
Solar simulator tools (see Box 2) are playing an increasingly important role in helping many cities assess their PV potential and move forward. A more sophisticated understanding of this potential equips local policy makers with the tools they need to formulate ambitious yet realistic plans.

BOX 2 USING SIMULATING TOOLS TO ASSESS THE SOLAR PV POTENTIAL OF A CITY

Given their rapidly declining costs, decentralised rooftop photovoltaic (PV) technologies are becoming increasingly appealing options for many cities. This is of particular relevance in developing countries, where many residents need more accessible, affordable and reliable electricity options. Solar PV rooftop simulator tools are already available to support municipal decision making in the cities of many developed economies, especially in Europe and North America. Simulators help to determine the optimal power mix and ensure its long-term viability in the context of urban energy planning processes and existing rules and regulations such as tariffs, tax credits and other incentives.

In a recent report, the International Renewable Energy Agency (IRENA, 2019b) examines the evolution of simulators for urban PV deployments ranging from the household level to large-scale arrays undertaken by municipal authorities and other large entities. In the past, the significant costs and need for expertise to develop such simulators limited their use to advanced economies with well-established electricity markets and appropriate research and development capabilities. However, due to an evolving technology landscape, solar simulators can now be deployed to maximum benefit anywhere in the world at an affordable cost.

IRENA is currently designing a pilot solar city simulator – called the "SolarCityEngine" – in the Ugandan city of **Kasese** and in **Zhangjiakou** (China). The solar simulator for Kasese addresses purchase and lease financing options for three situations: individual homeowners seeking to compare rooftop PV to alternatives; estate promoters examining the prospects for a small community (with a group of buildings); and municipalities investigating the cost of different policy options across the entire city.



4 At 10%, Tokyo's share of renewables in the power generation mix (ISEP, 2019) is still considerably lower than in the country as a whole. Nationwide, Japan's share of renewables rose from 12.1% of electricity generation in 2012 to 18.5% in 2019 (ISEP, 2020).

In North America, **San Francisco** became the first major US city, in April 2016, to require all new buildings to install rooftop solar PV (IRENA, 2016). **New York City** has a goal of installing 100 MW of solar power on public buildings and spurring the installation of 250 MW on private buildings by 2025. This is supported by the city's target for energy storage, aiming for 100 megawatt hours (MWh) by 2020 (Roselund, 2016). However, the city's stringent rules for permitting have slowed the pace of adding energy storage capacity substantially. The city has demanding safety standards governing the installation of lithium-ion batteries. Furthermore, the large number of city agencies with authority over the permitting process has slowed progress. Only 4.8 MWh of storage were installed in the city at the beginning of 2017 (Maloney, 2018).

A unanimous vote by the **Atlanta**, Georgia, city council in 2017 put this large metropolis on the road to attaining 100% renewable power by 2035. This goal is built on three pillars: enhancing energy efficiency through better insulation, LED lighting and other measures; promoting renewable energy generated from local sources; and purchasing additional renewable electricity from beyond Atlanta, including from out-of-state sources like wind power from Oklahoma. Developing locally generated solar energy is seen as the most cost-effective option. The city's rooftops add up to more than 17 square kilometres (km^2), an area that could accommodate solar capacity of up to 4 GW. At present, less than 10% of this potential has been tapped (Smith, 2018).

It is clear from these examples that while goal setting, planning tools and financing are important, actions such as streamlining permitting processes and improving the co-ordination of different municipal agencies are critical in achieving ambitious goals.

Europe has been a pioneer of renewable energy deployment: solar PV panels are a common sight and many small and large cities are introducing ambitious solar programmes. European municipalities can indeed do more to exploit their potential, given that 90% of the European Union's rooftop area is currently not used for solar PV purposes. A study by the European Commission's Joint Research Centre (Bodis *et al.*, 2019) found that this unused area could generate 680 terawatt hours of renewable energy, or almost a quarter of total EU electricity use, at a lower cost than current retail electricity prices.

2.2. NET METERING AND NET BILLING

Through net metering or net billing, local or national authorities can encourage solar PV deployment, allowing households or businesses that generate their own electricity to feed any surplus back to the grid, thus turning them from consumers into "prosumers".

Under different approaches, private generators can be compensated in energetic terms (*i.e.*, credit in kWh), to be offset within the current billing cycle (*e.g.*, one month); this solution is called net metering. The alternative is to be compensated in monetary terms (*i.e.*, credit in monetary units), with all net energy exports being metered and credited at a predetermined selling rate the moment they are injected into the grid; this is known as net billing (IRENA, IEA and REN21, 2018).

In most countries, the policy lead on net metering lies with national-level authorities. In Pakistan, for example, net metering has been expanded from a few cities to the entire country. From a still small number of 150 solar installations with a total capacity of 4 MW at present, the aim is to reach 1 000 MW by 2021 and 4 500 MW by 2025 (GeoTV, 2017).

In South Africa, **Cape Town's** net metering programme does not offer payment for excess generation but rather provides credits to offset later consumption. The city is one of only a few municipalities in the country that support feed-in, i.e., the export of excess electricity generation by private users to the grid, and has taken a number of other measures to support local market creation, such as defining installation guidelines (ESI Africa, 2020). By 2016, this had led to the commissioning of more than 4.5 MW of grid-connected small-scale solar PV capacity, most of it in commercial and industrial buildings (IRENA, 2016). Some 274 such projects, with a peak generation capacity of 247 kW, had been approved as of early 2018, and more than 2 MW of additional capacity were in the planning pipeline (ICLEI and IRENA, 2018b).

Net metering was introduced in India's capital, **New Delhi**, in 2014. Homeowners can choose to either own or lease a solar system set up by project developers (Times of India, 2017). In India's state of Karnataka, **Bangalore** is struggling to meet its energy needs as demand rises yet droughts diminish power generation from hydro-electric facilities. After the city introduced its net metering programme in 2014, deployment of rooftop solar panels by residents, business owners, schools and other public institutions expanded rapidly. Solar capacity connected to the grid of city utility BESCOM expanded from 5.6 MW in 2016 (Martin and Jairaj, 2016) to 98 MW in the fall of 2018 (New Indian Express, 2018).

As cities proceed with such policies, a note of caution is in order. Net metering benefits homeowners but not necessarily renters, who do not have their own house at their disposal. In addition to this distinction, people's ability to afford buying or leasing such systems varies tremendously. Net metering could, on its own, lead to uneven outcomes and social inequities. Also, to the extent that stand-alone residential PV systems can lead to grid defection, an unintended consequence may be that utilities end up with a reduced customer revenue base while grid maintenance and operating costs remain high. This may in turn drive up rates, which would fall disproportionately on grid customers – typically those who cannot afford to install their own power systems (IRENA, 2020b). It is important, therefore, that local governments find ways to make distributed renewable energy solutions available and accessible to lower-income households. Community energy projects, discussed in the next section, offer potential solutions (IRENA, 2020b).

3. EMPOWERING COMMUNITIES AND PEOPLE

Achieving a high rate of renewable energy in the urban power mix requires a concerted strategy that is supported by city administrations, energy suppliers and the residents of a given city (IRENA Coalition for Action, 2020). Where municipalities do not own energy generation and distribution assets, and where private utilities are hesitant to invest sufficiently in renewable energy, progress towards clean energy can also be advanced if cities pursue awareness-raising programmes and if policy makers ensure that local citizens can play an active role in formulating and implementing municipal policies, and that all urban residents, rich and poor, benefit from the move to renewable energy. The social equity dimension is thus crucial (IRENA, 2021).

This section first considers cities' moves to set up new public utilities and to remunicipalise existing enterprises that had previously been privatised. It then examines ways to strengthen community projects, particularly in the solar PV field. Although the precise sets of opportunities and challenges vary, cities have much to learn from one another. The section concludes with some notable examples of peer-to-peer networks and initiatives intended to promote the uptake of renewable energy generation in the urban context.

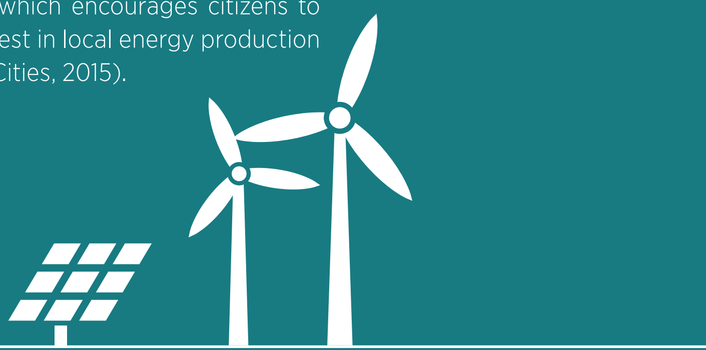
3.1. STRENGTHENING PUBLIC OWNERSHIP OF GENERATING FACILITIES

Public ownership is an effective lever for driving local energy transitions and for channelling funding to renewables. In a number of countries, municipalities are setting up new city-run companies to generate renewable power, such as in Japan where the government aimed to have 1000 companies established by 2021 (Wall Street Journal, 2015), or in the United Kingdom, where new public companies and community owned enterprises have been set up in places like **Aberdeen, Bristol** (see Box 3), **Nottingham** and **Woking** (Cumbers, 2016). In the capital of Spain's Catalonia province, **Barcelona**, Energía began its role as operator of the metropolitan electricity system in July 2018. Its responsibilities are to supply electricity and to provide public lighting. In 2018, 41 solar PV systems on municipal buildings were already operational, along with an energy recovery plant and landfill biogas generation. The intended benefits include economic savings and helping the city in its transition to greater energy sovereignty (Sánchez Molina, 2018).

Many municipal energy utilities were privatised during the 1980s and 1990s. However, promised cost efficiencies, performance improvements and infrastructure investment often failed to materialise. This experience triggered subsequent efforts in a number of cities in Europe and the United States to return these facilities to public ownership. Known as "remunicipalisation", such efforts are foremost aimed at regaining control of revenue-producing assets at a time of fiscal austerity but are also motivated by an interest in greater local value retention and driven by energy and climate considerations (Cumbers, 2016). Of an estimated 311 cases of energy utilities' remunicipalisation worldwide, most are in Europe (REN21, 2020).

BOX 3 BRISTOL RETROFITTING – INNOVATIVE TECHNOLOGIES FOR EVERYONE

Bristol City Council in the United Kingdom developed a programme named "Bristol Retrofitting – Innovative Technologies for Everyone" (BRITE) to articulate both climate and energy targets and social priorities. BRITE was supported financially by the European Investment Bank's European Local Energy Assistance facility. Bristol was the first British city to develop its own municipal energy company, Bristol Energy, with the goal of providing local, low-cost and low-carbon energy to residents and improving building energy efficiency (Energy Cities, 2015). It was, accordingly, the first UK local authority to invest in its own large-scale wind turbines in 2015. Since 2017, the City Council also owns the 4.2 megawatt Avonmouth solar photovoltaic park. Together, these facilities can supply more than 4000 homes with energy and avoid over 7000 tonnes of carbon dioxide emissions. In addition, Bristol Energy procures renewable energy from more than 140 generators across the country. Renewable electricity accounts for about 60% of the city's overall fuel mix (Pratt, 2018). The city council also supported the development of the Bristol Energy Co-operative, which encourages citizens to collectively invest in local energy production units (Energy Cities, 2015).



Germany, where locally owned energy systems have played a prominent role in facilitating the growth of renewable energy, is home to the majority of remunicipalisation initiatives. Still one of the most noted examples is a 2013 referendum in **Hamburg**. A grassroots campaign led to a decision to buy back the city's grid (Cumbers, 2016). The municipal entity, Hamburg Energie GmbH, has installed 10 MW of wind farms and 11 MW of solar PV within the city's boundaries. These initiatives are intended to facilitate Hamburg's planned shift to a 100% renewable energy supply (Renewable Energy Hamburg, n.d.).

As the experience of **Boulder**, Colorado (United States), shows, remunicipalisation processes can be difficult if private owners of a utility are not amenable to the terms for a takeover. Initially, the city sought to convince Xcel Energy (a private-investor-owned utility that operates in multiple municipalities) to agree to transition from a heavy reliance on coal and natural gas to low-carbon energy. Xcel's reluctance led Boulder to develop plans, in 2010, for a municipal utility to help achieve its goals of 100% clean energy, an 80% cut in carbon emissions by 2050 and 100 MW of local renewable energy generation by 2030, principally from solar PV (City of Boulder, n.d.). Two-thirds of local voters supported this plan, but legal battles over the pricing of assets and compensation delayed a resolution (Cumbers, 2016). In 2017, voters reaffirmed their support through a ballot measure to provide the necessary funding (Burness, 2017). However, prompted by tightening municipal finances, the city struck a deal with Xcel in 2020, abandoning the municipalisation effort on condition of the company reaching agreed benchmarks. Renewables now account for 28% of Xcel's power mix, up from 13% in 2010, with a binding goal of 60% by 2030, and GHG emissions are to be cut by 80%. Voters ratified the deal in late 2020 (Castle, 2020; Sakas, 2020).

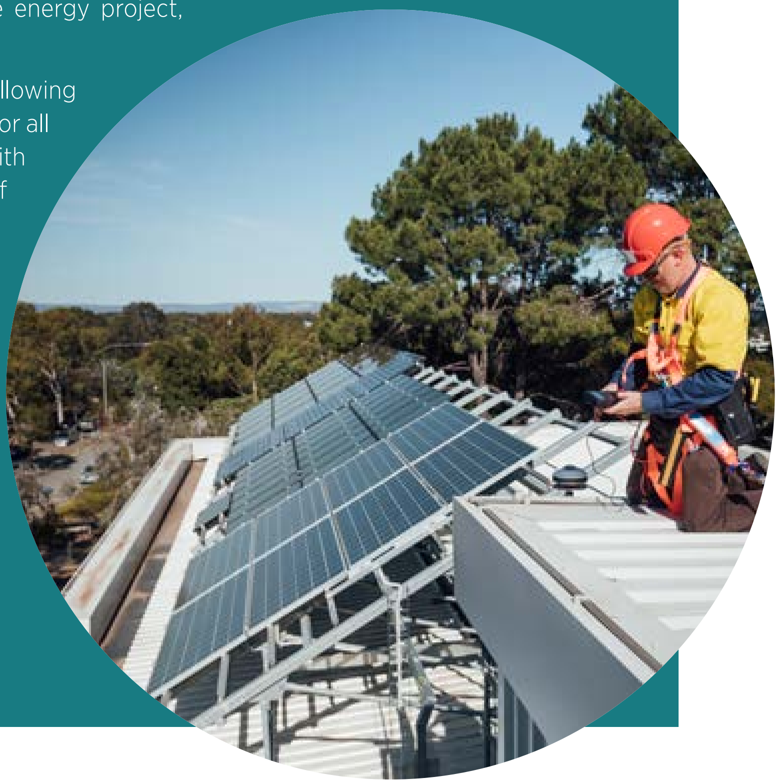
BOX 4 DEFINING COMMUNITY ENERGY

The IRENA Coalition for Action defines community energy as the "economic and operational participation and ownership by citizens or members of a defined community – be it at the village, city or regional level – in a renewable energy project, regardless of the size and scope of the project".

Community energy involves at least two of the following three elements: local stakeholders own the majority or all of a renewable energy project; voting control rests with a community-based organisation; or the majority of social and economic benefits are distributed locally.

Among the diverse approaches around the world, successful models emphasise a project's local, social and economic benefits, including job creation along the value chain, revenue flows, improved energy access and other contributions to human welfare. Greater citizen participation, awareness and acceptance of renewables represent other benefits. Political frameworks, ownership models and other factors such as access to financing shape the extent to which communities can secure tangible benefits.

Source: IRENA Coalition for Action, 2018, 2020.



3.2. SUPPORTING COMMUNITY RENEWABLES

Around the world, community energy is an increasingly popular solution to local energy supply challenges (see Box 4). Such projects can be initiated by municipalities, or citizens' grassroots groups may be the driving force, while local or national governments can pass legislation that facilitates such projects.

A number of ownership models exist for community energy projects, depending on the extent of local capacity and resources and on whether investor profit or broad community benefits are the primary objective. They include co-operatives, non-profits, private associations, community trusts, partnerships, and corporations and limited liability companies (IRENA Coalition for Action, 2020). Co-operative structures allow urban residents to participate directly and actively. But it is essential that citizens acquire the knowledge and capacity to act as informed participants in energy decision making (Roberts, Bodman and Rybski, 2014).

Much of the activity undertaken by citizens and communities has been local in focus, with the result that the exchange of experiences and best practices across the world remains limited. Policy support, including through regulatory and administrative frameworks, and better financing mechanisms can help communities acquire the skills, knowledge and funds needed to accelerate community renewable energy development (IRENA Coalition for Action, 2020).

An array of support measures have been implemented in a number of different countries. As discussed by the IRENA Coalition for Action (2020), *regulatory tools* include setting quotas for community energy, quotas for local ownership of renewable energy projects and virtual net metering rules. They can also include a tailoring of national-level policies such as FITs or a move towards auctions. In the absence of specific measures to support small players, auctions can pose a challenge for community energy since bidding procedures and requirements may increase their financial risks and administrative burdens. With regard to financial and fiscal measures, city and other authorities can offer grants and loans, revolving credits and tax incentives. Finally, local governments can set up *administrative structures* to reduce burdens and increase transparency.

In Germany, some 880 energy co-operatives were in existence as of 2019, most in the solar PV field. The number of co-operatives grew strongly under national FITs, but in 2018–19 the pace of new community initiatives sharply declined, to two dozen. Following regulatory changes and the move to auctions, momentum shifted to large investors that are better able to handle financial risks and complex procedures (IRENA Coalition for Action, 2020).

Several local governments in Japan have worked to encourage community energy projects. For example, **Nagano** Prefecture's Profit Repayment Subsidy for Community Power Planning and Development programme provided financial support for a total of 33 community-based projects, covering a portion of feasibility study costs and installation costs between 2014 and 2019 (IRENA Coalition for Action, 2020). In **Tokyo's** western suburbs, community start-up Tama Empower pioneered DiO (Do it Ourselves) in September 2016. It is a rooftop PV installation model intended to provide owners and tenants of commercial and apartment buildings with a sense of community ownership. DiO is based on four pillars: (1) customer training and participation in installations, (2) cost reduction efforts, (3) focus on equipment durability and (4) support for operation and maintenance (Furuya, 2017).

In Canada's Ontario province, Sun Co-operative Inc. is a community-owned non-profit organisation in the **Greater Sudbury** area, set up with assistance from reThink Green, a network of local environmental community organisations. Sun Co-operative plans to build solar energy projects and invest the proceeds in reThink Green and into a Community Environmental Fund for a variety of local community environmental projects (bike paths, tree planting, river restoration, a community garden and other activities). The co-operative has signed a contract with the Ontario government to buy the power generated by its first project over a 20-year period. Long-term community bonds will finance the project, and residents can become members and investors (SUN Co-operative Inc., 2018).

In the United States, community solar projects had installed close to a cumulative 1.4 GW by the end of 2018 (SEIA, n.d.), a number that almost doubled to 2.6 GW by mid-2020 (IRENA Coalition for Action, 2020). Several models have been developed by a variety of actors ranging from co-operatives to utilities, to other private entities. Municipalities can support them financially and through regulations. Such models include:[5]

- *Community solar power purchase agreements*, under which a project developer owns, operates and maintains PV systems on building rooftops or elsewhere on a property, and the owner of the building purchases the electricity produced, rather than the PV system itself.
- The *utility-sponsored model*, whereby a utility provides customers with the option to purchase renewable energy from a shared facility. The utility owns the array and sells or leases shares to customers.
- *On-bill crediting*, which relies on projected future electricity bill savings as a revenue stream to fund investments in renewables or energy efficiency, enabling people who have few assets or savings to invest in energy alternatives. This approach is also known as *virtual net metering*. It allows a person or household to buy or lease a portion of a renewable energy project and receive bill credits for the share of electricity generated.
- A *special purpose entity*, which involves individuals or companies joining in a business enterprise to develop a community solar project. Participants may be allowed to take advantage of incentives and tax credits.
- The *non-profit "buy a brick" model*, in which donors contribute to a shared installation owned by a charitable non-profit organisation.
- *Solar purchasing co-operatives*, which bring together several households to negotiate affordable prices with solar installation firms. In the United States, solar worker co-operatives such as Evergreen Energy Solutions in **Ohio**, Namasté Solar in **Colorado** and PV Squared in **Massachusetts** have a strong focus on the local communities in which they operate.
- The *community choice aggregation* model, in which an entity known as a community choice aggregator procures electricity in bulk from independent power producers on behalf of interested residents and businesses in a given municipality (or in a group of like-minded regional municipalities). Bundling demand and striking long-term power purchase agreements allows cities to negotiate competitive rates and makes the electricity supply more affordable. Community choice is not necessarily focused on renewables exclusively, but many of the existing policies in the United States offer customers the option of buying electricity with greater renewable energy content than what is available from utilities. **Athens, Ohio**, offers an interesting example (see Box 5).

BOX 5 COMMUNITY CHOICE IN ATHENS, OHIO (UNITED STATES)

Residents of Athens, Ohio, have access to a community choice programme offered by the Southeast Ohio Public Energy Council (SOPEC). SOPEC is a council of regional governments that provides public energy services to the region. The City of Athens' 2017 Sustainability Action Plan includes a goal of reducing municipal energy use by 20% by 2020. UpGrade Ohio (which used to be a part of SOPEC) launched the Solar ACCESS programme to help bring solar electricity to low- and moderate-income households. The programme sought to meet the US Department of Energy's Solar in Your Community Challenge. Further, in May 2018, Athens residents approved a ballot initiative in favour of a carbon fee of 0.2 cents per kilowatt hour. The fee will be routed through the community choice programme (and translate into a USD 1.60 to USD 1.80 monthly cost per household, though residents are allowed to opt out). The revenues will be used to purchase solar panels for public buildings in the city. Community choice aggregation is seen in Athens as a way to help local utility dollars stay local (Farrell, 2018).

5 The list of example models draws on the following sources: SEIA, n.d.; Duda, 2015; Agar and Renner, 2016; IRENA, 2016; IRENA Coalition for Action, 2020.

Some of these approaches have also been tried in other countries. For example, some Australian and Japanese cities are adopting community choice. Bringing together local governments, cultural institutions, universities and companies, the **Melbourne** Renewable Energy Project (MREP) marks the first such attempt in Australia. Members of the procurement consortium committed to buy 88 GWh of electricity per year from a wind farm, enough to power 17 600 households, under a long-term power purchase agreement. MREP provides electricity supply security, generates local jobs and assists Melbourne in meeting its CO_2 reduction targets (MREP, 2017). Among several municipalities in the Japanese prefectures of Gunma and Yamagata, **Nakanojo** owns 60% of Nakanojo Electric, which purchases power from publicly owned PV systems and distributes it to schools and community centres at rates below those available from the Tokyo Power Electric Company (Movellan, 2015).

Although renewable energy costs have fallen tremendously, the up-front costs may still keep clean energy out of reach of poorer people. Some projects have focused on overcoming this obstacle. In the United States, the single-largest low-income community solar project is the Coyote Ridge Community Solar Farm in **Fort Collins**, Colorado, with 1.95 MW capacity (SEIA, n.d.). In Massachusetts, **Boston** Community Capital (BCC, a private non-profit community development agency) has since 2008 developed a programme to bring solar power to organisations serving low-income individuals and communities in a number of cities and towns. Through its affiliate, Solar Energy Advantage (BCC SEA), it develops, owns and operates solar PV projects on the properties of "host customers". Host customers purchase the electricity BCC SEA generates through power purchase agreements at a fixed rate (PD&R Edge, n.d.). In the city of Gardner, for example, BCC SEA developed a 986 kW ground-mounted PV system with some 3 300 panels on a formerly vacant brownfield site. Over a period of five years, BCC SEA installed 17 600 solar panels totalling 4 MW (PD&R Edge, n.d.).

Another example is the Community Renewable Energy (PCRE) Programme in Princeton, New Jersey. Initiated in November 2019 and implemented in June 2020, it offers electricity with a larger renewables share (50% versus 24% under existing arrangements with the utility company PSE&G), yet at a slightly lower price. This programme was developed under New Jersey State Law and allows municipalities to leverage the bulk purchasing power of all residents for electricity supplies at lower prices and on better terms (Municipality of Princeton, 2020).

3.3. COLLABORATIVE INITIATIVES

Municipalities can greatly benefit from sharing experiences with partner cities around the world because of similarities in opportunities and challenges. More and more cities are taking action in peer-to-peer networks and like-minded voluntary coalitions, some closely focused on promotion of renewable energy, while others have a broader focus, including the climate and related issues.

At the level of megacities, the C40 Cities group is a prominent network; at present, it encompasses 97 cities around the world that together represent a quarter of global gross domestic product and 1 in 12 people on the planet. But many smaller cities are also increasingly active. Several initiatives bring cities and other actors together in support of clean energy and climate objectives (see Table 1).

The community choice model is spreading from North America to cities in Australia and Japan.

Melbourne, Australia

Table 1 Collaborative initiatives to promote renewable energy and climate action in urban areas

Initiative (year founded)	Members/Initiators	Objectives and achievements
Energy Cities (1990) www.energy-cities.eu/	European association of local authorities in energy transition, with more than 1 000 cities and towns in 30 countries.	Representing cities' interests and influencing European Union energy, environmental and urban policies; developing and promoting initiatives through exchange of experiences, transfer of know-how and implementation of joint projects. Among other projects, the initiative co-ordinates the European City Facility to provide towns with financial support and services for local sustainable energy projects. Some of these include the European Structural and Investment Funds, H2020 Project Development Assistance and EIB-ELENA (European Local Energy Assistance). In addition, Energy Cities is part of several permanent advocacy groups driving forward the energy transition political agenda.
The Cities Climate Finance Leadership Alliance (CCFLA) (2014) www.citiesclimatefinance.org/	Sixty-four organisations as of 2021, including United Nations (UN) agencies, multi-lateral development banks, governments and donor agencies, banks and financial institutions, non governmental organisations and academic institutions.	Catalysing and accelerating investment in low-carbon and climate-resilient infrastructure in cities and urban areas. Through the Green City Finance Directory, the Alliance helps sub-national governments and stakeholders identify project preparation facilities that can support them in developing green and resilient infrastructure, including implementing more efficient heating and cooling systems, building renewable energy, setting up sustainable transit and climate-proofing resilient infrastructure.
Global District Energy in Cities Initiative (2014) www.districtenergyinitiative.org	Co-ordinated by UN Environment, with local and national governments in 14 countries, as well as private sector companies and industry associations.	Supporting national and municipal governments to develop, retrofit or scale up district energy systems (assessing potential, demonstration projects, best-practice dissemination). One example of the initiative's success is an assessment of district cooling in five Indian cities, identifying at least USD 600 million worth of opportunities in the next decade. The initiative supports the pilot city of Thane (within the Mumbai Metropolitan Region), to deliver India's first district cooling project. Following Thane, the initiative will assist in creating a pipeline of district cooling investments for other Indian cities such as Rajkot and Pune.

Table 1 Collaborative initiatives to promote renewable energy and climate action in urban areas (continued)

Initiative (year founded)	Members/Initiators	Objectives and achievements
Transformative Actions Programme (TAP) (2015) http://tap-potential.org	Managed by ICLEI in collaboration with networks of local and sub-national governments, including R20 – Regions of Climate Action, United Cities and Local Governments (UCLG) and C40. Working in synergy with members of CCFLA.	Catalysing and improving capital flows to cities, towns and regions. Intended to strengthen their expertise and capacity to create local climate projects. TAP serves as a matchmaker, connecting to other project preparation facilities and platforms, as well as an advocacy tool that shows the demand and diversity of local needs while promoting multi-level governance.
100% Renewable Energy Cities and Regions Network (2015) https://iclei.org/en/100RE.html	Initiated by ICLEI.	Supporting ambitious lead cities striving for a 100% renewable future, through expert guidance, peer-to-peer exchanges, leadership recognition and global visibility. With this network, ICLEI and its partners aim to equip local governments with the knowledge and capacity to bring renewable energy to their communities. Local and regional governments in the network drive uptake of renewables in their territories – especially in electricity, heating and cooling – and transport in community and government operations in order to commit to 100% renewable energy.
Global Covenant of Mayors for Climate & Energy (2016) www.globalcovenantofmayors.org	As of early 2021, about 10 600 cities representing one billion people in 138 countries in all continents.	Mobilising and supporting ambitious, measurable climate and energy action, working with city/regional networks, national governments, etc. Through various initiatives, the covenant increases the flow of public and private sector investment in support of urban climate change mitigation and resilience projects; defines and addresses cities' knowledge and innovation opportunities; creates partnerships between the scientific and academic community, businesses and governments; and gathers data to measure and manage cities' and local governments' climate ambition and progress.

Source: IRENA urban policy analysis.

Note: ICLEI = Local Governments for Sustainability, a global network of more than 1 750 local and regional governments in more than 100 countries focused on sustainable urban development.

SUMMARY

Because they represent the bulk of global energy and power use, cities are critical actors in the global energy transition. They fulfil a range of roles from target setters, regulators and facility operators to financiers, facilitators and awareness builders. Cities need to formulate long-term plans for their energy transition pathways, as many lead cities are already doing, with a variety of targets for increasing the share of renewables in the power mix (as well as in the overall energy mix). Ambitious goals for clean electricity sources need to be underpinned with practical measures to facilitate such outcomes.

Most directly, renewable power generation in the urban context can be done at utility scale, such as through solar PV, wind or geothermal facilities. Increasingly, methane from landfills and other sources such as food waste are also being exploited to generate power for cities. Cities can also remake their own infrastructure to achieve high levels of energy efficiency or to use renewables. Streetlights, for example, can be upgraded to use high-efficiency technologies such as LED bulbs powered by solar energy.

Utility-scale renewable energy could be operated either by municipally-owned companies or by private sector firms. The arrangements vary widely from city to city (and from one country or region of the world to another). Some cities are legally empowered to own and run their own power generation facilities. Others never had this power or lost it in the wake of privatisation, but a rising number of them have sought to

regain ownership through remunicipalisation efforts. Particularly in parts of Europe, numerous cities – in some cases, driven by citizens' grassroots campaigns – have sought to take back ownership of previously privatised utilities. Often, this was done in a bid to gain more direct influence over the future direction of power supply systems and specifically the choice of energy sources used.

Unlike in the age of fossil fuels, decentralised energy supply is now an additional and cost-competitive option, principally in the form of solar PV rooftop deployment. Solar PV panels can be installed at different scales and thus provide a high degree of flexibility and versatility in complex urban landscapes that other technologies may not be able to match. Among policy measures to promote rooftop solar PV, net metering allows homeowners to manage their own energy supply, and even to generate additional income.

Net metering policies (and other measures often taken at the level of national government authorities, such as FITs) provide incentives to homeowners or businesses. But renters (or owners with limited financial means) typically cannot avail themselves of such opportunities. Therefore, community energy initiatives carry great significance and can spread the benefits of renewable energy. An array of existing models and approaches can be replicated in many locations. Understanding what works well and what is required for success – technically, financially, institutionally and socially – is key to scaling up the use of renewables in cities' power systems. Therefore, it is important that cities exchange experiences and lessons learned, as many of them increasingly do by way of peer-to-peer networks.

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