Planning 100% Renewable Energy Urban Cities

Global Status and Solutions

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Abstract

Transitioning to renewable energy is understood as an effective strategy to stay within 1.5°C average global temperature rise (IEA, 2017). Cities occupy two percent of the world's landmass in size, consume over two-thirds of the world's energy demand, and account for over 70% of global carbon dioxide emissions (C40 Cities, 2019a). Technologically, it can be difficult to transition to a significant share of renewable energy in cities. Energy demand is expected to grow, particularly in urban centers and renewable energy power generation requires more land compared to traditional, centralized thermal generation (Hoicka & MacArthur, 2019). This study investigates *the status of renewable energy transitions in urban cities, and how to achieve 100% renewable energy in urban cities.* The study documents urban cities currently achieving or planning to achieve 100% renewable energy, each city's current stage of the local energy planning process, and investigates the proposed solutions in city plans including policy instruments, technological and innovative solutions and stakeholders involved to achieve 100% renewable energy urban cities. Globally, 276 urban cities were found to have committed to or achieved various levels of 100% renewable energy; no 'urban city' has successfully achieved 100% renewable energy or carbon neutrality city-wide; and 17 urban cities have achieved 100% renewable electricity. Over half of the commitments have not developed a plan yet, and only six urban cities have adopted plans towards 100% renewable energy city-wide (Paris, Malmö, Frankfurt, Saanich, Vancouver, Victoria). Of these six cities' plans, many include reducing energy demand, and adding local, on-site, or neighbourhood scale energy generation. None of the urban cities' high power densities of demand can be met with renewable energy production within the city alone. Benefits and motivations will not be entirely local. The cities will work with other neighbouring municipalities, levels of government, and stakeholders outside the city to achieve 100% renewable energy. The three Canadian (BC) plans rely on the centralized regional utility for importing electricity, the European plans rely on a decentralized approach, focusing on neighbouring authorities. Surprisingly, none of the plans discuss the need for access roads, transmission right-of-way, and buffer zones in their plans despite needing to import energy.

Introduction

On December 12, 2015 at Conference of Parties (COP) 21 in Paris, countries around the world reached a landmark agreement to combat climate change known as the Paris Agreement. The main aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping global temperature rise this century well below 2°C above pre-industrial levels and pursue efforts to further limit the increase to 1.5°C (UNFCCC, n.d.). Countries were then required to put forward nationally determined contributions and later strengthen these efforts. The Paris Agreement was eventually signed by 197 countries, although the United States has since withdrawn under President Donald Trump (Denchak, 2018).

The United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) assesses the science related to climate change. The IPCC's most recent report showed the benefits of limiting global warming to 1.5° to 2°C above pre-industrial levels to avoid catastrophic disruption such as increasing and more intense weather and storms, and negative impacts to water supply and agriculture (IPCC, 2018). There is an urgent need to reduce greenhouse gas emissions globally and mitigate climate change. The majority of global greenhouse gas emissions come from energy (ClimateWatch, 2020; IEA, 2019b). Transitioning to a significant proportion of renewable energy is understood as an effective strategy to greatly reduce emissions (IEA, 2017).

Globally, total primary energy is mainly supplied by oil (32%), coal (27.1%), and natural gas (22.2%) while nuclear (4.9%); and renewables such as hydro (2.5%); biofuels and waste (9.5%); and solar, wind, etc. (1.8%) make up much less of the supply (IEA, 2019c). It is necessary to shift away from fossil fuels and towards renewable energy to cut

down greenhouse gas emissions and mitigate climate change (Bazaz et al., 2018). For example, renewables supply will need to be at least 70-85% of electricity by 2050 to keep within 1.5°C and the share of low carbon fuels in the transport sector will need to be 12% by 2030 and 55% in 2050 (Bazaz et al., 2018).

Sixty eight percent of the world's population is expected to live in urban areas by 2050 (United Nations, 2018). Cities occupy only two percent of the world's landmass in terms of size, but enormously impact the climate (C40 Cities, 2019a). Cities both contribute to and are impacted by climate change. Cities account for over 70% of global carbon dioxide emissions and over two-thirds of the world's energy is consumed by cities (C40 Cities, 2019a). In addition, 90% of the world's urban areas are located on coastlines, making them highly vulnerable to the devastating impacts of climate change, including rising sea levels and intense storms (C40 Cities, 2019a).

Energy demand is expected to grow, especially in urban areas (Hoicka and MacArthur 2019). It is imperative that cities play a role in fighting to solve climate change through improving energy efficiency and reducing greenhouse gas emissions and transitioning to renewable energy. There is often an assumption that this includes a shift toward more local, distributed energy (Hoicka & MacArthur, 2019, p. 24; Kuzemko et al., 2017, p. 62) involving locally-oriented motivations, benefits, and actors (Lowitzsch & Baigorrotegui, 2019). However, technologically, it can be difficult to transition to a significant share of renewable energy in cities. Energy demand is expected to grow particularly in urban centers, while at the same time, renewable energy power generation requires more land when compared to traditional, centralized thermal generation (Hoicka & MacArthur, 2019). Renewable energy has a low power density of supply, requiring more land than traditional energy sources to meet the same energy demand. Less land is available in dense urban cities compared to other areas. There are implications on spatial organization, land uses, and the location of planning to lower energy use and greenhouse gas emissions (Hoicka & MacArthur, 2019, p. 10). Low-carbon energy transitions are part of a geographical process that involves a reconfiguration of current spatial patterns of economic and social activity (Bridge et al., 2013). It is unclear how dense 'urban cities' can transition to renewable energy.

The United Nations provides the framework for climate change and sustainable development commitments. The United Nations introduced the Sustainable Development Goals (SDGs) in its 2030 Agenda for Sustainable Development (2015). There are 17 goals and 169 targets which are meant to stimulate action in areas of critical importance for humanity and the planet. SDG goals 7, 13 and 11 are relevant to addressing renewable energy in cities. Goal 7 is to "ensure access to affordable, reliable, sustainable and modern energy for all" which includes to "increase substantially the share of renewable energy in the global energy mix" and "double the global rate of improvement in energy efficiency" (United Nations, 2015). Goal 13 is to "Take urgent action to combat climate change and its impacts" (United Nations, 2015). Goal 11 is to "make cities and human settlements more inclusive, safe, resilient and sustainable" which includes targets for sustainable, accessible and affordable transport; increasing adoption of policies for climate mitigation and adaptation, etc. (United Nations, 2015).

It is important for cities to pursue climate change mitigation strategies, as they both contribute to and are affected by climate change. Many cities and communities have made commitments to address climate change adaptation and/or mitigation through policies and planning. In terms of renewable energy commitments specifically, 77 countries and more than 100 cities have committed to net zero carbon emissions by 2050 at the Climate Action Summit in September of 2019 (Kosolapova, 2019). In the United States, 28% of the population lives in a place committed to transitioning to 100% clean energy (Rohrbach, 2019).

There are several organizations and consortiums of member cities which have goals to be more 'climate friendly', carbon neutral or 100% renewable energy. For example, C40 Cities is a network of 97 global cities committed to bold climate action (C40 Cities, 2020). Carbon Neutral Cities Alliance (CNCA) is a collaboration of global cities which have formally set a goal to cut greenhouse gas emissions by 80% to 100% by 2050 or sooner (CNCA, n.d.). UK100 is another

network of local government leaders who pledged to shift to 100% clean energy by 2050 (Billington, 2017). Within this context, cities tend to be pursuing different types of climate change and renewable energy goals. These include:

1. *100% renewable energy*, where the amount of energy generated from renewable energy sources in the area (or brought into it) equals or exceeds 100% of the annual energy consumed within that area (Sierra Club, 2016).
2. *Carbon neutral,* where the city's A carbon neutral city has *net* greenhouse gas emissions of zero associated with the city (Plastrik & Cleveland, 2018, p. 31). Carbon neutral cities aim to cut their carbon pollution through means including adopting more widespread renewable energy use and energy efficiency policies and programs (C40 Cities, 2019b).
3. *100% Renewable Electricity*, which means a city that is committed to sourcing 100% of its electricity from renewable energy sources.

In a context of climate change, and where most people live in urban settings requiring energy, where renewable energy requires more land area and is more location specific than traditional historical sources, and where a renewable energy transition involves a spatial and social shift, this study seeks to understand *what is the status of renewable energy transitions in urban cities, and how do we achieve 100% renewable energy in urban cities?* This has been done by documenting urban cities currently achieving or planning to achieve 100% renewable energy, each city's current stage of the local energy planning process, and investigating the proposed solutions in city plans to identify the policy instruments, technological and innovative solutions and the stakeholders involved to achieve 100% renewable energy urban cities.

Climate Change Solutions for Urban Areas

Cities can participate in a range of climate solutions. These include clean energy, transportation, building energy efficiency, climate action plans and inventories, social equity and climate change, sustainable communities, finance and economic development, adaptation in action, solid waste, and adaptation plans and assessments (Brown & Sako, 2016). Clean energy solutions include using policy to promote widespread adoption of renewable energy, increasing use of data for energy efficiency rollouts, and using new technologies to increase the viability of waste to energy systems at a large scale (Brown & Sako, 2016, p. 13). Another way to reduce emissions is through moving to zero carbon built form – buildings that do not use carbon for heating, lighting, cooling or electricity – through becoming more energy efficient and using cleaner energy resources like renewables (Milhahn, 2019). Solutions in the building energy efficiency sector include building refurbishments that improve energy efficiency, upgrading residential buildings, and encouraging greener building regulations (Brown & Sako, 2016, p. 83). Cities can mitigate climate change through planning well designed, compact, walkable cities with good public transportation (Milhahn, 2019). Transportation solutions include switching to clean fuelled-vehicles, and better integrating mobility into urban planning and development for reducing emissions (Brown & Sako, 2016). Cities also need to transition away from gas-powered cars to zero-carbon public transport powered by renewable energy which could prevent 250 million tonnes of carbon emissions by 2030 while improving health, noise and air pollution conditions (Milhahn, 2019). IRENA's "Renewable Energy in Cities" report outlines that the priority areas for a transition to renewable energy use in cities include renewable energy in buildings, sustainable options for transport, and creating smart integrated urban energy systems (IRENA, 2016).

Local Energy Planning

Local energy plans are expected to help with the transition from large, centralized energy systems to more decentralized and distributed energy focused on sustainable energy (St. Denis & Parker, 2009; Wyse & Hoicka, 2019, p. 887) and municipalities are expected to be important actors in climate change mitigation and local energy planning

(Wyse & Hoicka, 2019, p. 887). Local energy planning is relatively new in practice and has emerged as a localized response to address climate change. This is despite the longstanding recognition that energy use is determined in large part by planning practice and the relationships between built form, land use, renewable energy, energy efficiency and energy use (Owen 1985, 1992). Energy has traditionally been managed by individual customers or by regional or national utilities (St. Denis & Parker, 2009, p. 2088). However, more recently the trend of local energy plans has emerged and "decisions that used to be left to regional level energy agencies or private individuals are now being considered at the community level" (St. Denis & Parker, 2009, p. 2088). Traditional urban planning provides a spatial structure of activities or land uses (Hall, 2002, p. 3). Environmental planning is the "theory and practice of making good, interrelated decisions about the natural environment (natural resources, wildlife, and natural hazards), working landscapes (farms, forests, and lands from which minerals are extracted), public health (air and water pollution, toxics, and waste disposal), and the built environment" (Daniels, 2009, p. 178). The objective of *energy-conscious planning* is to "plan for a physical environment which permits people to carry out their daily activities using energy as efficiently as possibly, subject to other reasonable constraints" (Owens, 1992, p. 89). For example, Community Energy Management combines land use planning with energy management (Jaccard et al., 1997). It can be used in neighbourhoods, cities, or small regions to create liveable cities that minimize emissions. CEM encompasses measures such as: land use planning, transportation management, site design and fostering environmentally benign energy supply and delivery systems (such as district heat and power) which decreases energy consumption and service costs compared to business as usual (Jaccard et al., 1997, p. 1066).

Local Energy Plans

Local energy plans provide a process to develop strategic vision documents that outline the energy goals of a local context or community (Wyse & Hoicka, 2019). Within local energy plans, goals and expected outcomes are generally articulated as actions (Wyse & Hoicka, 2019). There are varying definitions of local energy plans. Tozer (2013) defines local energy plans as "community-led plans that aim to increase and improve local energy management" and are employed largely as climate change mitigation policy (Tozer, 2013, p. 20). The U.S. Department of Energy (2010) defines a strategic energy plan as "a roadmap to achieving community energy goals in both the near and long term" (U.S. Department of Energy, 2010, p. 1). The plans are "inherently local" because their goals are determined by stakeholder input and have stakeholder buy in (U.S. Department of Energy, 2010, p. 1). Plans can be "brief documents to inform decisions in city and utility planning or "detailed guidebooks with goals, implementations plans, measurement and verification procedures, and reporting requirements" (U.S. Department of Energy, 2010, p. 1). Strategic energy plans can include the entire community or one part such as municipal buildings (U.S. Department of Energy, 2010, p. 1). Some cities may choose to focus on municipal energy (i.e. energy in municipal buildings or operations only) first before expanding to community-wide goals (U.S. Department of Energy, 2010, p. 4). Intelligent Energy Europe states that the local action plan for sustainable energy is a document that "systematically organizes all the strategies, objectives, and priority actions that the local administration will undertake to develop the local energy system" (Intelligent Energy Europe, 2012, p. 14). According to QUEST, a local energy plan is "a comprehensive, long-term plan to improve energy efficiency, reduce greenhouse gas emissions and foster local sustainable energy solutions in the community" (QUEST, 2013, p. 2). ICLEI[1], through its Building Adaptive & Resilient Communities (BARC) program, offers a comprehensive way for cities and communities to respond to the impacts of climate change, develop and implement an adaptation plan, and protect people, property and prosperity of communities (ICLEI, n.d.). A local action plan "outlines how the municipality will achieve its emissions reduction target through municipal operations and community-based initiatives" (Federation of Canadian Municipalities, 2020; ICLEI, 2019).

[1] Previously called International Council for Local Environmental Initiatives and now called Local Governments for Sustainability.

The Benefits of Local Energy Plans

There are many different reasons to plan energy locally. The goals and benefits of environmental, community and local energy plans include: reducing greenhouse gas emissions (Neves & Leal, 2010; QUEST, 2013; Wyse & Hoicka, 2019); enhancing or improving energy efficiency in the municipal corporation or community-wide (QUEST, 2013); broader community sustainability (QUEST, 2013); minimizing environmental impacts (QUEST, 2013; U.S. Department of Energy, 2010); increasing share of renewable energy in energy, electricity, and household energy use (Neves & Leal, 2010; Wyse & Hoicka, 2019); diversifying energy supply (U.S. Department of Energy, 2010); reducing climate change impacts from the community (U.S. Department of Energy, 2010) and integrating energy planning into the municipal planning process (i.e. land use, transportation, economic development) (QUEST, 2013).

Social goals and benefits of local energy plans include to improving energy reliability, affordability, comfort for consumers, resilience, energy services, and the response to local community needs (QUEST, 2013; U.S. Department of Energy, 2010). This can be done, for example, by encouraging energy efficiency and understanding the local context and responding to local community needs (QUEST, 2013). Local energy plans can also contribute to a community's capacity, such as addressing local goods and labour, skill and knowledge development (Wyse & Hoicka, 2019).

The economic benefits and goals of local energy planning include the optimization of infrastructure redevelopment costs (U.S. Department of Energy, 2010), strengthening and generating economic development opportunities and investment (QUEST, 2013; U.S. Department of Energy, 2010), building a "green" workforce (U.S. Department of Energy, 2010), and using local resources (U.S. Department of Energy, 2010).

Stages and Stakeholder Involvement

Local energy plans have various stages and types of stakeholder engagement, for the articulation and implementation of local energy goals.

ICLEI's framework to help local governments create adaptation plans to address climate change impacts in their communities consists of five milestones that guide cities and communities to take climate action. The iterative milestones are: 1) Create a GHG emissions inventory and forecast; 2) Set an emissions reduction target; 3) Develop a local action plan; 4) Implement the Local Action Plan; and 5) Monitor progress and reporting results (Federation of Canadian Municipalities, 2020; ICLEI, 2019). According to a report from the U.S. Department of Energy on how to develop a strategic energy plan, there are nine steps to the strategic planning process. These include 1) identify and convene stakeholders; 2) establish a leadership team; 3) develop a common energy vision; 4) develop a community energy baseline; 5) based on the vision and baseline, develop energy goals; 6) identify and evaluate supply and demand policy and program resource options, matching these to the goals and ranking overall program options; 7) find and secure funding sources; 8) compile the plan (including objectives, goals, baseline, program options, analysis, and recommended options for policy makers); and 9) measure and evaluate, altering the plan (U.S. Department of Energy, 2010). QUEST provides three phases of community energy plan development: 1) stakeholder engagement, 2) baseline energy study and energy mapping, and 3) community energy plan development (QUEST, 2013). Intelligent energy Europe also outlines four macro stages of local energy planning that are interwoven and complementary founded based on four pilot local energy planning experiences in Mediterranean cities. The EASY model consists of 1) assessment (i.e. analyzing the energy system of the area and the local conditions) 2) planning (developing a local action plan), 3) implementation (project development and action), 4) evaluation and reporting (i.e. monitoring and checking results, etc.) (Intelligent Energy Europe, 2012).

All these methods agree there need to be a involvement of a range of stakeholders at various stage of the plan, however, the extent of their involvement varies. Planners are often required by law to offer opportunities for public

participation during the planning process (Levy, 2013, p. 96). However, there are various forms of citizen participation which range from direct citizen control to manipulation (Arnstein, 1969).

A stakeholder is a "group of parties interested in the activity of an institution, an organization, and an area" (Intelligent Energy Europe, 2012, p. 18). "Stakeholder mapping" is identifying the different parties involved or that should be involved in the development and requalification of the local energy system (Intelligent Energy Europe, 2012, p. 18). Examples of stakeholders groups include utilities, government (city council, mayor's office), community businesses and industry, nongovernmental organizations (NGOs), residents, and champions (U.S. Department of Energy, 2010). 'macro' categories of stakeholders include local institutions (regions, provinces, municipalities, etc.); functional agencies (consortiums, chambers of commerce, energy-saving agencies, research agencies, etc.); private organizations (companies, energy service suppliers, etc.); learning institutions (schools, universities, etc.); organized groups (association categories, environmental associations, etc.); the local community (citizen organizations and single citizens) (Intelligent Energy Europe, 2012, p. 18). They may also include strategic partners, park institutions, local operators, tourists, energy experts, universities, citizens, co-ops, market operators, NGOs, energy service companies, and other institutions (Intelligent Energy Europe, 2012, p. 19). The US Department of Energy defines critical stakeholders as "anyone who generates, controls the sale of, sells, or uses electricity and gas" (U.S. Department of Energy, 2010, p. 3). critical stakeholders, which include "anyone who generates, controls the sale of, sells, or uses electricity and gas" (U.S. Department of Energy, 2010, p. 3). QUEST recommends the municipality involve stakeholders such as elected officials, staff from a range of departments, gas utilities, government and its agencies, nongovernmental groups (NGOs), environmental and community organizations and the public (QUEST, 2013, p. 7). Community-led energy seeks to both incorporate citizens' ideas and opinions and "engage them as active stakeholders in the multiple areas of energy production, delivery and consumption" (St. Denis & Parker, 2009, p. 2089).

Ideally, stakeholders are involved throughout the planning process. For example, ICLEI advises that a range of municipal and community stakeholders should be involved in every step of the framework to ensure success (Federation of Canadian Municipalities, 2020; ICLEI, 2019). A leadership team should be set up to guide the plan's development such as a community task force or technical advisory committee (Federation of Canadian Municipalities, 2020). Stakeholder engagement is critical to plan development and municipalities must describe the public or internal stakeholder participation activities for developing a local action plan. Cities need to report on how stakeholders and decision makers were included throughout the milestone process (Federation of Canadian Municipalities, 2020; ICLEI, 2019). In order to confirm that an emissions reduction target is set, cities must demonstrate that a council resolution has been adopted with the target, baseline year, target year, and percentage change from baseline year (Federation of Canadian Municipalities, 2020; ICLEI, 2019). ICLEI states that plan implementation involves creating a "clear implementation schedule" (Federation of Canadian Municipalities, 2020; ICLEI, 2019). Finally, monitoring progress and reporting results helps communities check whether the initiatives are working and whether the municipality is on track to meet their target.

Intelligent Energy Europe recommends/requires participatory process of local stakeholder involvement across all stages. Methods to engage stakeholders, include workshops, conferences, seminars, focus groups, newsletters, exhibitions and info-days, info points at urban centers, local media relations, flyers, leaflets, website for internet tools and networking, information and training, and gadgets (Intelligent Energy Europe, 2012, p. 21).

QUEST recommends engagement in a local energy plan that provides the opportunity for the community to ask questions, provide feedback, and an opportunity to collect information from the community about local priorities, opportunities and considerations (QUEST, 2013, p. 7).

While stakeholder involvement is noted as an important part of local energy planning that should be conducted throughout the energy planning process, Wyse and Hoicka (2019) demonstrate that this is not always the case through their study of 77 local energy plans. The authors evaluate the participation of actors who were involved in the various stages of plan development by examining who wrote the plans, who participated in plan development, how they participated, at what stage they participated, and barriers to participation. Actors identified included community members / general public / residents; community staff/elected officials; consultant/consulting firms; non-profit organizations; public sector (education, health, policy); private business; provincial/territorial department; utilities, and unknown. The paper revealed that the plan development process did not go far enough to treat community members and residents as active stakeholders (Wyse & Hoicka, 2019, p. 896).

Policy Instruments for Renewable Energy in Cities

According to IRENA (2016), cities can accelerate the transition to renewable energy through many different policies and actions as they are "uniquely positioned to integrate renewable applications across their various functions" (IRENA, 2016, p. 38). For example, cities can work as planners, regulators, tax collectors, financiers, and owners and operators of urban infrastructure (IRENA, 2016, p. 38). Cities can influence citizens, local businesses, organizations, and other governments to do more. Cities can also disseminate knowledge through demonstration projects, feasibility studies, media campaigns and education programs (IRENA, 2016, p. 38).

IRENA (2016) identifies multiple policy instruments that can enable a shift to renewable energy in cities. 'Remunicipalisation' involves bringing back municipal utilities into public and collective ownership, which also brings local jobs (IRENA, 2016). For example, community choice aggregation (CCA) involves a municipality forming a new entity called a community choice aggregator, which procures electricity in bulk to cover the combined load of interested residents and businesses within the municipality. This way, cities can negotiate competitive electricity rates with power suppliers and developers and save residents and businesses money on energy, while allowing the choice of renewable energy (IRENA, 2016, p. 47). Net metering is a regulation in the electricity sector that allows consumers who generate their own electricity to get credit on their bill for the amount of electricity they generate (IRENA, 2016, pp. 46–47). Cities can promote renewable energy through investing in city-owned renewable energy power plants, district energy networks, transportation infrastructure, public engagement, consultations, and demonstrations (IRENA, 2016).

Policy mixes have the potential to contribute to the advancement of renewable energy transitions for local communities and citizens (Burke & Stephens, 2017). These policy instruments include regulatory measures such as net metering, renewable energy standards, community benefit agreements, and community choice aggregation; financial inclusion measures such as feed-in tariffs, green subsidies, public bonds, cap-and-dividend, etc.; new socioeconomic institutions such as community energy, renewable energy cooperatives, remunicipalization; and new energy system institutions such as energy investment districts, energy utilities, and energy regions (Burke & Stephens, 2017).

Decarbonization in cities shows plans use a "complicated suite" of technologies, innovations, and policy instruments to reach their goals (Tozer & Klenk, 2019, p. 18). Their study included hydropower, biofuels, heat pumps, solar energy, offsets, waste heat, district energy, reduced energy demand behaviour, waste to energy, natural gas, combined heat and power, climate districts, nuclear power, smart city technology, and energy efficient technology (Tozer & Klenk, 2019, p. 10).

Tozer & Klenk (2019) identify mixes of policy instruments in support of carbon neutrality in cities. Ten policy instrument categories include benchmarking and reporting; building standards; capacity building; financial incentives; financial penalties; lead by example; lobby authorities; municipal energy supplier; private sector engagement; and public sector engagement (Tozer & Klenk, 2019, p. 12). Capacity building, financial incentives,

leading by example, building standards, and benchmarking and reporting were found to be important policy instruments in carbon neutral governance (Tozer & Klenk, 2019, p. 12). District energy, energy efficiency technology, and solar power are emphasized as important "objects of governance" (urban elements to achieve carbon neutrality) in the decarbonization planning documents (Tozer & Klenk, 2019, p. 17).

Spatial and Technological Barriers to Transitioning to 100% Renewable Energy in Urban Areas

Despite the well-meaning goals of local energy plans to involve stakeholders in all stages of planning and meet net-zero emissions targets, there are many spatial and technological barriers to transitioning to a significant proportion of renewable energy for urban areas. These challenges can be encapsulated in the concept of power density, which is the amount of energy produced or consumed per unit horizontal area of land or water and is often measured in watts per meter squared: W/m^2 (Smil, 2010). The gap between the high power density consumption of cities and the low power density production of renewables (Smil, 2015) is an important technological challenge of cities transitioning to a substantial portion of renewable energy.

Cities have developed based on the high-energy density provided by fossil fuels and nuclear power (Owens 1985, 1992). By definition, urban areas are densely built. Due to population density and the built environment, the power density of energy use is highest in urban areas. The mean power density that urban areas use globally ranges between 10 and 100 W/m^2, and hourly extremes often reach and substantially surpass 1,000 W/m^2 (Smil, 2015, p. 200). Single and multi-family housing in temperate climates require power densities of 20-30 W/m^2 of floor area (Smil, 2015, p. 200). Final energy uses of modern high energy societies have power densities between 10 and 100 W/m^2 for homes, commercial buildings, industrial enterprises, and densely populated urban areas (Smil, 2015, p. 205).

Fossil fuels and nuclear power have high power densities and can be sited or transported in or near urban areas. Natural gas and crude oil extraction have power densities of mostly between 1,000 and 10,000 W/m^2 and up to 50,000 W/m^2 in the Dutch supergiant field of Groningen (Smil, 2015, p. 197). Nuclear power generation has power densities of between 100 and 1,000 W/m^2 (Smil, 2015, p. 204). Renewable energy sources have much lower power densities of production. Hydropower projects have wide ranging power densities of between 0.1 and 500 W/m^2 (Smil, 2015, p. 192). Large geothermal projects, when accounting for all affected land, have power densities of mostly between 50 and 80 W/m^2, while supplies of geothermal heat for individual houses have power densities between 40 and 100 W/m^2 (Smil, 2015, pp. 194–195). Large ground-mounted PV projects can now generate electricity with power densities of 3 to 7 W/m^2 in less sunny locations and 7 to 11 W/m^2 in sunny regions (all rates are for the total plant area) (Smil, 2015, p. 191). Power densities of large wind farms in America range between 1 and 11 W/m^2, with most projects between 2.5 and 4 W/m^2 (Smil, 2015, p. 192). Power densities of biofuels and biodiesel are the lowest, ranging from 0.1 to 0.6 W/m^2 (Smil, 2015, p. 194). Table 1 summarises the wide range in power density between different energy sources and uses.

Future renewables-based societies will require two or three orders of magnitude more space to secure the same amount of useful energy as existing power arrangements (Smil, 2015, pp. 205–208). The shift would require construction and maintenance of access roads to wind turbines; buffer zones between areas of human habitation; and extensive transmission rights-of-way to export electricity from sunny or windy areas (for example) to major urban and industrial areas (Smil, 2010, p. 17). This means it will require more land to meet the same amount of production as traditional energy supply, and this transition will create spatial pressures, requiring spatial planning and energy planning to be combined (Ramirez Camargo & Stoeglehner, 2018). It is unclear whether renewable energy can be generated within city boundaries, such as on-site or neighbourhood scale generation, imported from other areas, or a combination.

Table 1: Size and Power Density Characteristics of Electricity Installations and Uses

Installation Type	Range of Sizes	Power Density (W/m^2)
Fossil-fueled electricity plant	1–3,500 MW (order of magnitude)	300–3,000
Nuclear electricity plant	500 to 4,000 MW	500
Hydroelectricity plant	0.1–1,500 (MW) (run of river) 1 MW to 20 GW (reservoir)	3
Solar electricity plant	< 1kW to 100 MW	5
Wind power plant	5–300 MW 2–4 MW (turbine)	1 (turbine), 50 (footprint)
Electricity transmission	100–800 kV	30
Modern economy (use)	—	3
Urban area	—	10–30
City downtown	—	100
House	—	10–50
High-rise building, city downtown, factory, supermarket	—	300–1000
Motor	5–400 kW	
Refrigerator	120 W	
Laptop	30 W	
Central air conditioning	2–5 kW	
Room air –conditioning	1 kW	
Light bulb (incandescent)	40–150W	
Light bulb (compact fluorescent)	23 W	
Light bulb (LED)	8–25 W	
Clothes dryer	1.8–5 kW	
Dishwasher	1.2–2.4 kW	
Portable heater	750–1100 kW	

(Adopted from Hoicka & MacArthur, 2019)

Renewable Energy and Societal Transformation

Energy production in the fossil fuel era has typically involved centralized ownership and control. The shift away from the dominant fossil fuel regime toward distributed generation requires social acceptance as distributed generation is a very different form of technology from the dominant centralized energy generation (Wolsink, 2012). Actors must be willing to become part of this new system, as governance shifts to more polycentric decision making and more local involvement in energy governance (Wolsink, 2012).

The transition to a low-carbon economy can also be a social shift involving more local involvement in energy production and management (Burke & Stephens, 2017, 2017; van Veelen & van der Horst, 2018). Two literatures that address this are energy democracy and energy citizenship, and these concepts are increasingly being adopted in government policies, for example through feed-in-tariff laws and renewable energy communities (Lowitzsch et al., 2020).

Energy democracy is a social movement that "recognizes that replacing fossil-fuel-based infrastructure with renewables is much more than a technological substitution; the social changes associated with this transition could be transformative" (Stephens, 2019, p. 4). Through more distributed, locally based energy, the energy transition

offers a way to redistribute political and economic power. It is argued that energy democracy is fundamentally different than fossil-fuel-based energy, in part because renewable energy can be deployed in small-scale, dispersed, and distributed way, which allows individual, household, community, and organizational involvement in energy ownership and management; and there is widespread opportunity for local control because renewable resources are available everywhere (Stephens, 2019, pp. 5–6).

Energy citizenship is created through public participation in low-carbon energy transitions viewing "people as active participants to be democratically engaged in sustainable energy transitions" (Ryghaug et al., 2018, p. 288). While the role of people in energy systems has largely been as passive energy users and customers, policies are shifting toward creating 'active consumers' through better information and price signals such as demand side management (Ryghaug et al., 2018, p. 284). Energy citizenship allows people to take on multiple roles as users, consumers, protestors, supporters and prosumers and entails energy consciousness and literacy (Ryghaug et al., 2018, p. 288). Prosumership, when consumers are also partly owners and generators of renewable energy installations, is expected to increase with the growing complexity of the energy sector as energy production and consumption become more decentralized and embedded in communities (Lowitzsch et al., 2020).

Local ownership of community energy, energy democracy and community energy, requires the overlap of renewable energy sources, technology, and demographics of use and investment, which may be a technological and spatial challenge. The literature on community energy, one form of energy democracy, tends to assume a connection between the renewable energy transition and an increase in place-based, locally oriented, distributed energy, which can all also be considered characteristics of "communities of place".

Communities of place, or the term "community" in popular usage and culture, "usually implies a set of social relationships embedded in a particular locality—the idea of territorial community or community of locality" (Walker, 2011, p. 778). This term "community" is also often carried into environmental and carbon applications, for example, in the notion of a village or town becoming a low-carbon community" (Walker, 2011, p. 778).

Community defined as "communities of interest" challenges the local orientation. While community energy is usually associated with local participation, Creamer et al. (2018) argue that community energy projects are not necessarily place-based and involve a variety of actors and institutions operating at and across multiple scales. Communities of interest are often understood to be when communities are "formed by networks and social relationships, but these can extend beyond specifically place-based networks" (Bauwens & Devine-Wright, 2018, p. 613; Walker, 2011, p. 778). These include a network of investors in a 'community' renewable energy project, or climate justice activists connected over virtual networks, and these networks are considered communities of interest (Bauwens & Devine-Wright, 2018, p. 613; Walker, 2011, p. 778). Energy projects are entangled with actors such as the community, state (including the central government and local government) and private sector (such as energy utilities, developers, and independent consultants) (Creamer et al., 2018). The involvement of the local community in "community" energy is perhaps taken for granted (Creamer et al., 2018). Municipalities as local governments are believed to play an important commitment to locality and place, being the scale of government which interacts most with civil society (Creamer et al., 2018, p. 6). "communities, however defined, cannot achieve large-scale, socio-technical reconfiguration single-handedly, but must be facilitated by a mixture of top-down policy and bottom-up initiatives" (Creamer et al., 2018, p. 8).

Energy projects can therefore be organized by communities of interest, communities of place, or both. In renewable energy projects, there are differences with respect to the participation of local people, distribution of benefits, motivation, technology and geography (Lowitzsch & Baigorrotegui, 2019). Communities of place typically have strong engagement of local people, and emphasize local and collective ownership (Lowitzsch & Baigorrotegui, 2019). Communities of interest focus on benefits secondary to the local community and are funded by various private or

public funds, and communities of place and interest are a combination of the two. Communities of place involve more local, small-scale, tailor made, locally managed renewable and distributed energy systems that focus on self-consumption and increase awareness of energy efficiency and conservation (Lowitzsch & Baigorrotegui, 2019, p. 668). Technologies for communities of interest are typically "market or incentive driven and more often installed by international, large-scale companies and therefore standardized and scalable" (Lowitzsch & Baigorrotegui, 2019, p. 668).

In a comparison of the attitudes toward renewable and wind energy technologies between communities of place and communities of interest, individuals who were more spatially concentrated were considered communities of place while the members who were part of a more broadened geographical scope of operations were considered communities of interest (Bauwens & Devine-Wright, 2018, p. 614). Communities of place developed more favourable attitudes toward renewable and wind energy technologies than communities of interest because of the higher level of social interaction facilitated within communities of place (Bauwens & Devine-Wright, 2018).

The localized perspective depends on the spatial convergence of investor demographics, resource potential, and energy use. It is not always clear whether renewable energy results in energy decentralization, distributed energy, locally oriented energy and it is unclear how these assumptions of local, distributed energy and associated benefits might play out for dense urban cities. While renewable energy projects that are small-scale and oriented to smaller communities are assumed to have locally oriented benefits and participation, this level of place-based local participation may be more challenging in dense urban city environments. Therefore, this paper investigates the extent to which urban city energy plans rely on stakeholders in local communities, communities outside of the city, or a combination.

Methodology

To understand the status of renewable energy transitions in urban cities, and how to achieve 100% renewable energy in urban cities, the methodological approach was to document urban cities currently achieving or planning to achieve 100% renewable energy, each city's current stage of the local energy planning process, and to investigate the proposed solutions in city plans to identify the policy instruments, technological and innovative solutions and the stakeholders involved to achieve 100% renewable energy urban cities.

The first stage of research was to identify a sample: urban cities that are pursuing 100% renewable energy. The identified plans were categorized by level of ambition, and the most ambitious (adopted) plans were coded for policy tools, technological solutions and stakeholder involvement in plan implementation.

Sample

The first step was to find a global sample of urban cities which were found to have committed to or are already achieving different forms of 100% renewable energy.

To create the global list of cities achieving or committed to achieving forms of 100% renewable energy, organizations which could potentially provide information on cities committed or achieving 100% renewable energy was compiled. Organizations in the fields of environmental issues, climate change, renewable energy, energy, and/or cities were selected if they potentially provided lists, case studies and/or articles identifying cities pursuing 100% renewable energy. Academic databases were searched for any articles that could identify cities committed to or achieving 100% renewable energy. Reference lists of relevant articles were checked for organizations. Overall, 44 organizations were found. However, not all these organizations were useful in determining specifically cities that are committed to or achieving 100% renewable energy or carbon neutrality. Thirty organizations were selected to come up with the list of cities, shown in Table 2.

The searches were done in English, which could potentially limit the results to English countries. However, many of the organizations and websites used were global and included many non-English towns and cities pursuing or achieving renewable energy. Therefore, it was assumed that the global list was as comprehensive as possible despite being an English search.

Table 2: Organizations Used to Determine Sample of Urban Cities

Organization	Website
100 percent.org	https://www.100-percent.org/
100% RE Ontario	http://www.100reontario.org/
American Cities Climate Challenge Renewables Accelerator (City Renewables .org)	https://cityrenewables.org/city-stories/
Bluedot	https://bluedot.ca/wp-content/uploads/2017/06/Municipal-Toolkit-Guide-8.pdf
C40 Cities	https://www.c40.org/why_cities
Carbon Disclosure Project (CDP)	https://www.cdp.net/en
Carbon Neutral Cities Alliance (CNCA)	https://carbonneutralcities.org
Cities100	https://www.cities100report.com/about
David Suzuki Foundation	https://davidsuzuki.org/our-work/cities/
Energy Cities	https://energy-cities.eu/join-us/
Global Covenant of Mayors for Climate and Energy (GCoM)	https://www.globalcovenantofmayors.org/
Go 100% RE	https://www.global100re.org/index.php/about-us/
Go 100% Renewable Energy	http://www.go100percent.org/cms/index.php?id=3
ICLEI (governments for sustainability)	https://iclei.org/en/100RE.html
International Renewable Energy Agency (IRENA)	https://www.irena.org/
National Renewable Energy Laboratory (NREL)	https://www.nrel.gov/
National Resources Defence Council (NRDC)	https://www.nrdc.org/about
Partners for Climate Protection (PCP) program by Federation of Canadian Municipalities (FCM)	https://fcm.ca/en/programs/partners-climate-protection
Ren 21: Renewables Now!	https://www.ren21.net/
Renewable Cities	https://www.renewablecities.ca/
Renewables Networking Platform	https://www.renewables-networking.eu/cities
Rocky Mountain Institute (RMI)	https://rmi.org/impact/carbon_free_pathways/
Sierra Club	https://www.sierraclub.org/?_ga=2.209885845.103570318.1575916697-1943657938.1575916697
Smart Cities Info System (SCIS)	https://smartcities-infosystem.eu/
The Atmospheric Fund (TAF)	https://taf.ca/about-us/
The Solutions Project	https://thesolutionsproject.org/
Track0	http://track0.org/cities-regions/
UK100	https://www.uk100.org/
We Are Still In	https://www.wearestillin.com/about
Zero Energy Project	https://zeroenergyproject.org/our-mission/

The next stage of developing the sample was to remove all locations that did not meet the definition of urban city.

'Urban city' is not clearly defined. Attempts have been made to harmonize definitions of cities and urban by the 'new degree of urbanization (DEGURBA) and the Atlas of Urban Expansion. For this research, 'urban city' was defined by examining the various definitions of 'urban' and 'city' from the United Nations, DEGURBA (the 'new degree of urbanization') and the Atlas of Urban Expansion (Dijkstra & Poelman, 2014; Schlomo et al., 2016b; United Nations, 2019). According to the Atlas, there is "near universal agreement that a settlement of 100,000 people or more constitutes a city" (*The City as a Unit of Analysis and the Universe of Cities*, 2016). The United Nations determined

that no international standard definition of urban was possible and defines urban based on national census definitions, which vary greatly and use both quantitative and qualitative criteria (United Nations, 2019). Density is a recurring quantitative determinant of 'urban', with density criteria ranging from a minimum of 200 to 500 persons per square kilometer (United Nations, 2019). DEGURBA defines urban clusters (cities) using a density of at least 300 inhabitants per square kilometer (Dijkstra & Poelman, 2014). Based in these definitions, for this study, a city is defined as the lowest tier or level of local government responsible for planning, and an urban city is defined a minimum population size of at least 100,000 and a minimum population density of at least 200 persons per square kilometer. To leave a margin of error for any out-dated population data, cities were included if they have a minimum population size of 90,000 persons and minimum population density of 180 persons per square kilometer.

Cities are not necessarily comparable just because they meet certain population and density criteria. For the purposes of this research, an assumption has been made that cities are 'urban' cities based on meeting specific population size and density criteria. However, density is a rough indicator of urban. Caution should be taken going forward in comparing varying cities based on population size and density alone.

The webpage www.citypopulation.de was used for compiling population data because it was identified by the Atlas of Urban Expansion as a useful source for global city populations and densities (Schlomo et al., 2016a). The website uses national statistics offices for each country to provide the population and land area data (*References and Links*, 2020). Because not all population data has been updated recently and varies by country, a margin of error has been used and cities with a population of at least 90,000 and a population density of at least 180 persons per square kilometre were included as 'urban cities'.

All places which that did not meet the definition of urban city were eliminated. Eighty-one places were removed because they did not meet the first criteria for being a city, which is being the lowest tier/level of government responsible for planning. For example, potential cities were removed if they were found to be neighbourhoods, regions, provinces, prefectures, districts, villages, a network of municipalities, research centre, resort town, townships, counties, states, countries, islands, or a planned city project. Also, for the cases from the organization UK100, places were removed from being 'cities' when they were deemed to be a county council or county borough, which is not the lowest tier of government. District councils are located within county councils and manage the planning for the district. The list of councils in the United Kingdom was provided by the organization UK100 through email in May 2020. Four places were excluded from the list of cities because it is unclear which location or city the reference refers to, and the population size and land area information needed to determine if the place is a city or not was missing and could not be obtained. Finally, 278 places were excluded for not meeting the minimum population size and/or density criteria to be an urban city. The final sample includes 276 urban cities.

Table 3 describes the information collected about each urban city in the sample. The goals and plans were only gathered for the final sample of 276 cities.

Table 3: Information Collected on Sample of Urban Cities

Coding Title	Categories, Thresholds and Definitions
Urban City Name + Country	
Source of Identification	Organizations that identified the city as having 100% renewable energy commitments or achievements
Population Size + Source	Urban City criteria: Minimum population size of 90,000 persons.
Land Area of City (Sq Km) + Source	This was used to determine population density.
Population Density (Persons per sq km)	Urban City criteria: Minimum population density of 180 persons per square km.
Tier of Government	Lowest tier or level of local government responsible for planning
Level of Ambition	100% Renewable Energy; Carbon Neutral; 100% Renewable Electricity; 100% Renewable Energy (city operations only); Carbon Neutral (city operations only); 100% Renewable Electricity (city operations only); Unknown
Achieved or Commitment	Achieved: The city has successfully achieved the renewable energy goal. Commitment: The city has stated their desire to a goal for example through a non formal/ nonbinding or formal/binding commitment, pledge, target, goal, or aspiration.
Plan Located (Yes/No)	Yes: A plan was found (Adopted or Draft Released); No: No plan found (N/A) or plan is In Process but not developed yet.
Stage of Planning Process (Adopted; Draft Released; In Process; or Not Found)	Adopted: A plan has been adopted / approved by council for publication or has been published in its final form Draft Released: The city has released a draft version of their plan towards their commitment; In Process: No plan was found but information regarding progress on the plan was found (such as consultation) and it was determined that a plan toward the respective renewable energy goal is underway; Not Found: A plan was not located, and no information was found regarding progress on forming a plan.
Plan Name(s) + Source (Link)	
Notes / Sources	Notes and further links to return to for checking progress.

Level of Ambition

The sample of urban cities was coded for each cities' level of ambition towards renewable energy. The six categories for level of ambition include: *100% renewable energy; carbon neutrality; 100% renewable electricity* (city-wide); and *100% renewable energy; carbon neutrality; and 100% renewable electricity* (for city operations only), respectively. Table 4 presents the categories for level of ambition, along with their respective definitions.

Using renewable energy for all energy is more ambitious than carbon neutrality or 100% electricity because electricity is only one type of all energy carriers, making up approximately 20% of the share of final energy consumption globally in 2017 (IEA, 2019d). Carbon neutrality is less ambitious than 100% renewable energy because carbon neutrality can involve the use of offsets, which allow cities to buy their use of carbon through ensuring activities that reduce carbon elsewhere. The categories for city operations only are less ambitious than city-wide

commitments or achievements because city operations make up a smaller portion of energy use and emissions of the cities they inhabit.

Table 4: Defining Level of Ambition

Level of Ambition	Definition
100% Renewable Energy	*Highest level of ambition.* The amount of energy generated from renewable energy sources in the area (or brought into it) equals or exceeds 100% of the annual energy consumed within that area (Sierra Club, 2016) including buildings, transport, heating, cooling, and waste. In this case, the area meets our definition of "urban city".
Carbon Neutral	*Net* greenhouse gas emissions of zero associated with the city (Plastrik & Cleveland, 2018, p. 31). *Carbon neutrality* can be achieved through carbon reduction/mitigation measures (i.e. renewable energy; energy efficiency, eliminating use of fossil fuels, etc.) and carbon offsets (European Parliament, 2019). Carbon offsets are credits for greenhouse gas reductions achieved by one party that can be purchased to compensate (offset) emissions of another party. Carbon offsets are usually measures in tonnes of CO2 equivalents (CO2e) (David Suzuki Foundation, 2017). *Carbon neutral* cities aim to cut their carbon pollution through means including adopting more widespread renewable energy use and energy efficiency policies and programs (C40 Cities, 2019b).
100% Renewable Electricity	Urban city that is committed to sourcing 100% of its electricity from renewable energy sources. Electricity is used for lighting, cooling, heating, refrigeration and appliances, computers, electronics, machinery, and public transportation (EIA, 2019a). This does not necessarily address end uses fueled by other carriers, such as natural gas, or oil.
100% Renewable Energy (City operations only)	The city has targeted or achieved 100% renewable energy for its municipal/corporate operations only. These targets focus on emissions under the direct control, influence, or accountability of the local government as a corporate entity. 'Traditional local government services' may include administration and governance; drinking, storm and waste water; solid waste collection, transportation and diversion; roads and traffic operations; arts, recreation and cultural services; and fire protection (Federation of Canadian Municipalities & ICLEI, n.d., pp. 5–7). The local government is determined to have operational control over a facility or operation if it has the full authority to introduce and implement operating policies at the operation.
Carbon Neutral (City Operations only)	The city has targeted or achieved carbon neutrality (same definition as above) for its municipal/corporate operations only.
100% Renewable Electricity (City operations only)	The city has targeted or achieved 100% renewable electricity for its municipal/corporate operations only.
Unconfirmed	An urban city was identified to have a goal toward one of the ambition categories. However, the category was vaguely outlined and it could not be confirmed which specific level of ambition will be pursued for now. For example, the urban city will pursue carbon neutrality, but it is unclear if carbon neutrality will be pursued for city operations only or city-wide.

Commitments and Achievements

The commitments and achievements were identified for all of the urban cities in the sample. Some cities may have made the commitment or pledge to 100% renewable energy and/or carbon neutrality but have not yet started on a plan. Some cities may have made a pledge and indicated that they are currently creating or updating their plan to include their commitment to 100% renewable energy or carbon neutrality. Others may have drafted or adopted a plan towards their goal. Each urban city in the list of urban cities was coded for its stage of the planning process of preparing a plan. Identifying whether a plan has been prepared determines whether a plan was available to study.

Content Analysis

Six cities adopted plans toward achieving the most ambitious goal of *100% renewable energy*. These plans were selected for a more detailed content analysis to investigate the proposed solutions in city plans to identify the policy instruments, technological and innovative solutions and the stakeholders involved in achieving 100% renewable energy urban cities. The coding categories are presented in Table 5.

Content analysis involves examining documents and texts. It is the "study of recorded human communications" including books, websites, paintings, and laws (Babbie, 2008, p. 350). The unit of analysis for this study is plans adopted by urban cities toward achieving 100% renewable energy. The research approach is to study existing documents for their substantive content, such as which solutions are identified towards achieving 100% renewable energy.

Content analysis has been used for similar research studying publicly available local energy plans, such as St. Denis and Parker (2009), Tozer (2013), Tozer and Klenk (2019), and Wyse and Hoicka (2019). St. Denis and Parker analysed 10 of the first community energy plans in Canadian communities for their approaches to reducing greenhouse gas emissions and becoming more energy self-sufficient. Tozer (2013) employed interviews and document analysis to analyse community energy plans and implementation documents to assess progress in implementation of the plans. Tozer & Klenk (2019) draw on discourse analysis and textual network analysis to study climate governance policy documents, and unpack the sociotechnical configurations planned in carbon neutral built environments. Wyse and Hoicka (2019) identified 244 Canadian local energy plans and evaluated the 77 plans that were obtained to understand how the plans contributed to the goals of community energy of participation, ownership, and capacity.

Coding categories were determined through conceptualization of the theoretical literature (Babbie, 2008, p. 357), and open coding was also used as some emergent categories were added during the coding process (Babbie, 2008, p. 423). The predetermined categories were derived from the presented literature review, as well as an in-depth literature review of technical reports and sources (Bruckner et al., 2014; Canada & NRCan, 2020; Davis et al., 2018; IEA, 2017, 2019d, 2019b; IRENA, n.d.-d, n.d.-c, n.d.-a, n.d.-b, n.d.-e, n.d.-f; Martinot, 2016; NRCan, 2017; Palensky & Kupzog, 2013; Rezaie & Rosen, 2012; U.S. Department of Energy, n.d.).

Table 5: Coding Categories

No.	Question/Category	Codes	Relevant Literature
1a	Publication/ approval date	Date (Day, month, year) of adoption if available.	
1b	What is the expected timeframe to reach the renewable energy goal?	Target year Interim targets (and what are they?)	Climate change requires urgent action (IPCC, 2018).
2a	What types of energy end uses does 100% renewable energy implemented or target include?	Space Heating Water Heating Cooling (Space) Street Lighting Lighting Major/Large Appliances Other Appliances/Electronic Devices (televisions, radios, computers, toasters, etc.) Personal / Passenger Transportation (cars, buses, bicycles, motorcycles, passenger rail, air, boats, ships) Commercia/Freight Transportation (trucks, trains, planes, boats/ships/barges) Cooking Industrial Processes (grinders, refiners, thermal reducers, etc.) Industrial Motors	(Canada & NRCan, 2020; IEA, 2017, 2019a; IRENA, 2016; Jaccard et al., 1997; Smil, 2006)
2b	Which energy end-use sectors are targeted?	Residential (low-medium density, high density) Commercial (offices, malls, stores, hotels, warehouses, restaurants, places of worship) Institutional (Schools, hospitals, government, university campuses) Industrial (mining, quarrying, oil and gas extraction, pulp and paper, iron and steel, smelting and refining, cement, chemicals, petroleum refining, other manufacturing, forestry, construction) Transportation (commercial/freight, personal/passenger) Agriculture	(Canada & NRCan, 2020; Davis et al., 2018; EIA, 2019b; IRENA, 2016)
3	What are the proposed energy sources and technologies?	Solar Photovoltaic (PV) rooftop/ ground-mounted, Solar Hot Water, Concentrated Solar Power (CSP) Wind Onshore/ offshore Hydro Run of River/Diversion, Reservoir / Impoundment, Pumped Storage Biofuels, Biomass, Biogas / renewable natural gas Geothermal Ocean energy – wave energy / tidal energy/ salinity gradient energy/ thermal energy conversion Nuclear Waste-to-energy / Waste heat / Excess industrial heat Natural Gas, Coal, Oil Emergent categories	(Barron et al., 2013; Bruckner et al., 2014; Hoicka & MacArthur, 2019; IRENA, n.d.-d, n.d.-c, n.d.-a, n.d.-b, n.d.-e, n.d.-f; NRCan, 2017, 2017; Smil, 2015; Tozer & Klenk, 2019; U.S. Department of Energy, n.d.)

No.	Question/Category	Codes	Relevant Literature
4	Which technological and innovative solutions are being used?	Community design Retrofits (reductions of up to 50%) Deep energy retrofits (reductions of 50-80%) Behaviour / reducing demand Energy efficiency Smart meters (also called advanced metering) Smart grids Demand-response Energy storage District heating and cooling Electric Vehicles Combined heat and power (CHP) Offsets Heat pumps Prosumership Microgrids Hydrogen Distributed Generation Carbon capture and storage Emergent categories	(Barron et al., 2013; Martinot, 2016; Palensky & Kupzog, 2013; Rezaie & Rosen, 2012; Sovacool et al., 2017; Tozer & Klenk, 2019)
5	Where will the energy be generated?	Imported from outside city limits On-site Neighbourhood scale Within city limits Emergent categories	(Hoicka & MacArthur, 2019, p. 15; Kuzemko et al., 2017, p. 59; Wolsink, 2012).
6a	Within which climate does the city exist?	Dry Tropical Temperate Continental Polar	(Arnfield, 2016; NOAA SciJinks, 2020; Pidwirny, 2006)
6b	What are the landforms within and around the city?	Emergent Categories (For example: Volcanos; Ocean; Mountain; Desert)	(Wikipedia, 2020; WorldLandForms, 2015)
7	Which policy instruments are proposed in plans?	Capacity Building Building Standards Lobby Authorities Public Sector Engagement Private Sector Engagement Benchmarking and Reporting Urban Planning Tools Financial Incentives Financial Penalties Lead by Example Municipal Energy Supplier Emergent Categories	(Burke & Stephens, 2017; Fouquet, 2013; IRENA, 2016; IRENA et al., 2018; REN21, 2019; Sarti, 2018; Tozer & Klenk, 2019)
8	Who are the intended stakeholders involved in implementing the plan?	Community Members / General Public / Residents Elected Officials Non-profit / Community Organizations Public Sector (Education, Health, Police) Provincial / Territorial / State Government Federal Government Utilities Indigenous Communities Private Businesses Emergent categories	(Burke & Stephens, 2017; Lowitzsch & Baigorrotegui, 2019; Stephens, 2019; van Veelen & van der Horst, 2018; Wyse, 2018)

No.	Question/Category	Codes	Relevant Literature
9	Who is intended to benefit from the plan?	Citizens / Individuals / Residents Private Businesses Public Sector Institutions (e.g., universities and hospitals) Indigenous communities Emergent Categories	(Berka & Creamer, 2018; Wyse, 2018)
10	What are the expected benefits of the plan?	Revenue – city, businesses, individuals Cleaner air Reduced noise pollution Health Quality of Life Empowerment Democracy Social Capital Socio-economic regeneration Affordable energy Knowledge and Skill development / Energy literacy Environmentally benign lifestyles Branding / Eco-tourism/optics Emergent Categories	(Berka & Creamer, 2018; Stephens, 2019; van Veelen & van der Horst, 2018; Wyse, 2018)
11	What are the other related plans identified in the plan? (by Sector)	Buildings Transportation Comprehensive land use plan (Official Plan) Municipal Strategic Plan Sustainability/Environment Climate Change Plan Economic Development Waste Emergent Categories	
12a	Is a funding/revenue source identified?	Yes No	
12b	If yes, what is the funding source?	Emergent categories	

Results

A total of 30 organizations (Table 2) were used to source the list of cities, of which, an initial 639 cities were identified. The results of the analysis described in Table 3 are that 276 cities met the criteria for an urban city. A total of 342 commitments and achievements were identified (Table 6). Some urban cities had multiple achievements and/or commitments for different ambition categories, for example, a commitment to be 100% renewable energy for city operations, followed by a carbon neutral city-wide goal. The population, land area and population density for the 276 cities is described in Table 7. Table 8 describes the remaining results, of level of ambition, whether a goal was achieved or committed, whether the plan was located, and the stage of the planning process, all of which are defined in Table 3. Of the 23 achievements, 17 are for 100% renewable electricity city-wide, one is for 100% renewable energy (city operations only), one is for carbon neutral city operations only, and four are 100% renewable electricity (city operations only). A total of 110 adopted plans were found out of all achievements and commitments. Forty-eight of the plans adopted are in the carbon neutral category. No cities have achieved 100% renewable energy city-wide.

The 342 commitments and achievements are in cities in 52 different countries (Figure 1). The countries with the most cities with commitments and achievements are the United States (84), and the United Kingdom (78), followed by Canada (12), Germany (11), and Brazil (11). One underlying factor is that many American cities pledged to continue to pursue climate action once Donald Trump was elected through the organization "We are Still In" (We Are Still In, 2017). Many of the US commitments or achievements focus on 100% renewable electricity, which is more achievable for smaller or remote cities. Councils in the United Kingdom are pursuing different forms of 100% renewable energy through the UK100 pledge (Billington, 2017).

Three of the most ambitious urban cities are located in British Columbia, Canada, which is an area known to be environmentally-focused, and supported by BC Hydro which provides mainly clean hydroelectricity to the region.

Figure 2 provides a closer look at the urban cities by country without the United States and United Kingdom commitments and achievements.

Table 6: Breakdown of Exclusions and Urban Cities Included

Total number of potential cities identified	**639**
Total excluded for not meeting lowest planning tier criteria	81
Total excluded for not meeting population size and density criteria	278
Total number of exclusions due to lack of information	4
Total Exclusions	**363**
Total Number of Cities Included	**276**
Total Number of Commitments and Achievements	**342**

Table 7: Population, Land Area, and Population Density for all Urban Cities Included (n=276)

Population	
Population Size Range	91,350 - 14,916,456
Population Size Average	1,170,158
Population Size Median	297,387
Land Area (Square Km)	
Land Area (Sq Km) Range	15 - 14,378
Land Area (Sq Km) Average	544
Land Area (Sq Km) Median	160
Land Area (Sq Km) Mode	160
Population Density (Persons per Sq Km)	
Population Density Range	181 - 55,318
Population Density Average	3,714
Population Density Median	2,108

Table 8: Sample Description (n=342)

City Achievements and Commitments by Ambition Category								
	City-Wide			City Operations Only			Unconfirmed	Total
	100% Renewable Energy	Carbon Neutral	100% Renewable Electricity	100% Renewable Energy	Carbon Neutral	100% Renewable Electricity		
Achieved	0	0	17	1	1	4	0	23
Commitment	20	109	80	5	40	24	41	319
Total	**20**	**109**	**97**	**6**	**41**	**28**	**41**	**342**
Planning Process by Ambition Category								
	City-Wide			**City Operations Only**			**Unconfirmed**	**Total**
	100% Renewable Energy	**Carbon Neutral**	**100% Renewable Electricity**	**100% Renewable Energy**	**Carbon Neutral**	**100% Renewable Electricity**		
Plans Adopted*	6	48	26	3	11	16	0	110
Plans with Draft Released*	1	7	2	0	4	0	0	14
Total Plans Located*	7	55	28	3	15	16	0	124
Plans in Process	0	16	3	0	4	2	0	25
Plans Not Found	13	38	66	3	22	10	41	193
Total Commitments & Achievements	**20**	**109**	**97**	**6**	**41**	**28**	**41**	**342**

*Includes non-English plans

Figure 1: Number of Commitments and Achievements by Country and Level of Ambition

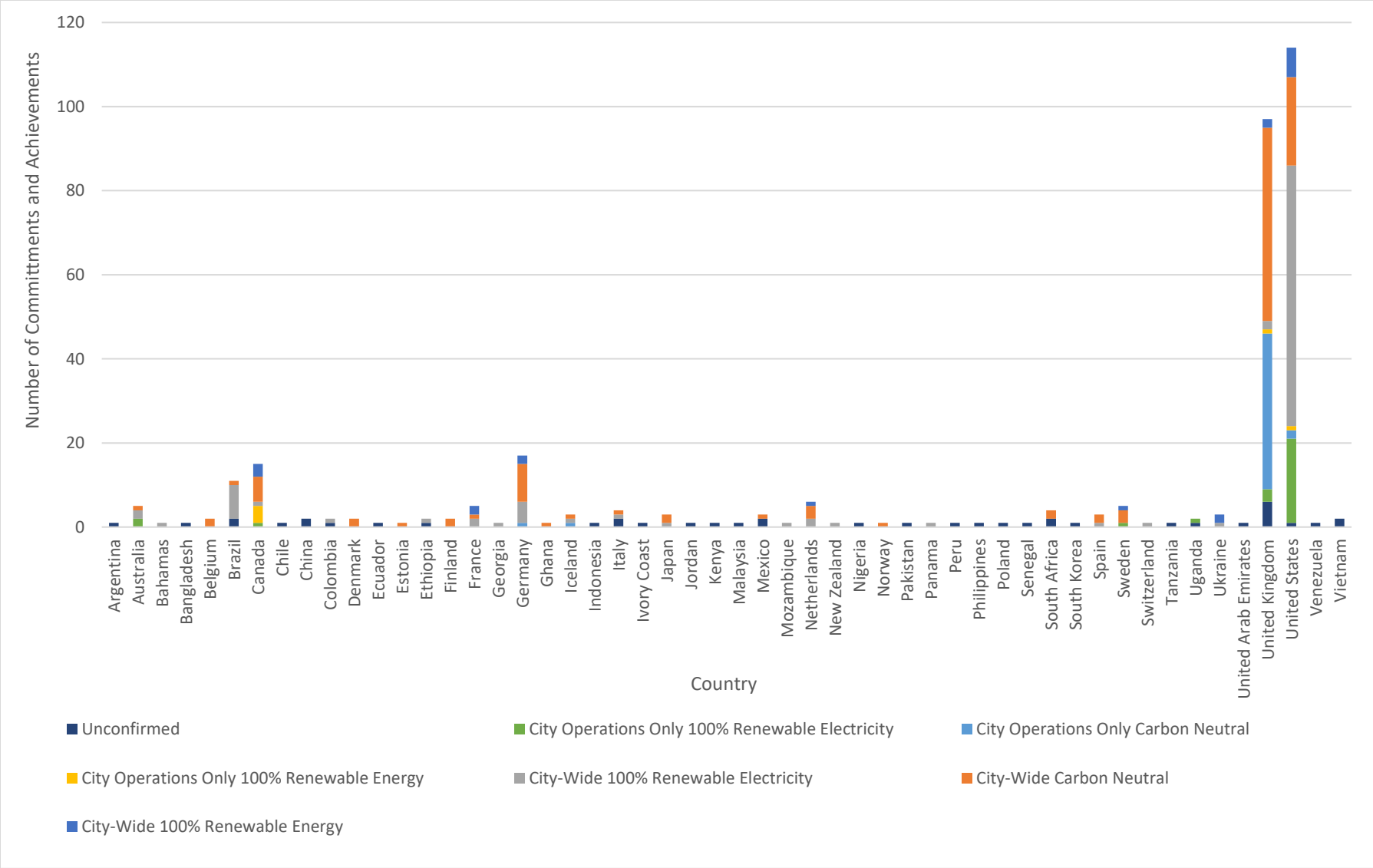
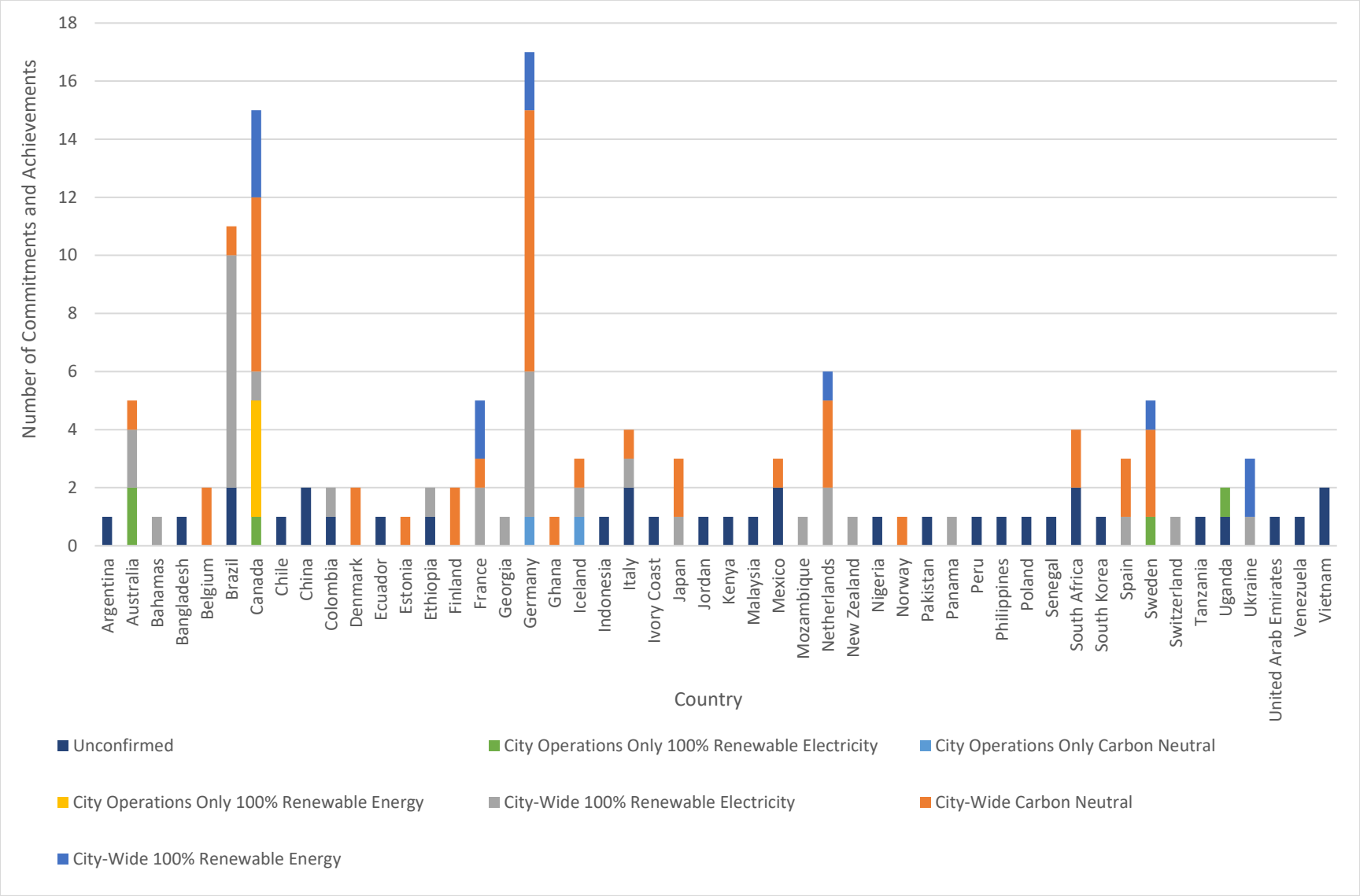


Figure 2: Commitments and Achievements by Country (without United States and United Kingdom)



For better visualization, the population size and densities of urban cities with city-wide plans are plotted in Figure 3. Most of these cities have population sizes of less than 3,000,000, and population densities of less than 10,000 persons per square km. There are some outliers, such as

- Paris (population density of 20,834 persons per square km), which has adopted a plan towards *100% renewable energy*;
- Barcelona (population density of 16,516 persons per square km) which has adopted a plan toward *carbon neutrality*;
- Islington, UK (population density of 16,050 persons per square km) which has adopted a plan towards *carbon neutrality;*
- Tokyo (population size of over 14,000,000) which has adopted a plan toward *carbon neutrality*;;
- London (population of 8,992,166) which has adopted plan toward *carbon neutrality*;
- New York City (population 8,398,748) which has adopted a *carbon neutral* plan;
- Los Angeles (population 3,990,456) which has adopted a *carbon neutral plan*; and
- Yokohama (population 3,740,172) which adopted a *carbon neutral* plan.

Figure 4 shows the population density versus population size for the 17 plans with city-wide achievements. which are all in the 100% renewable electricity level of ambition category.

Figure 3: Population Density versus Population Size for 74 Urban Cities with City-Wide Plans

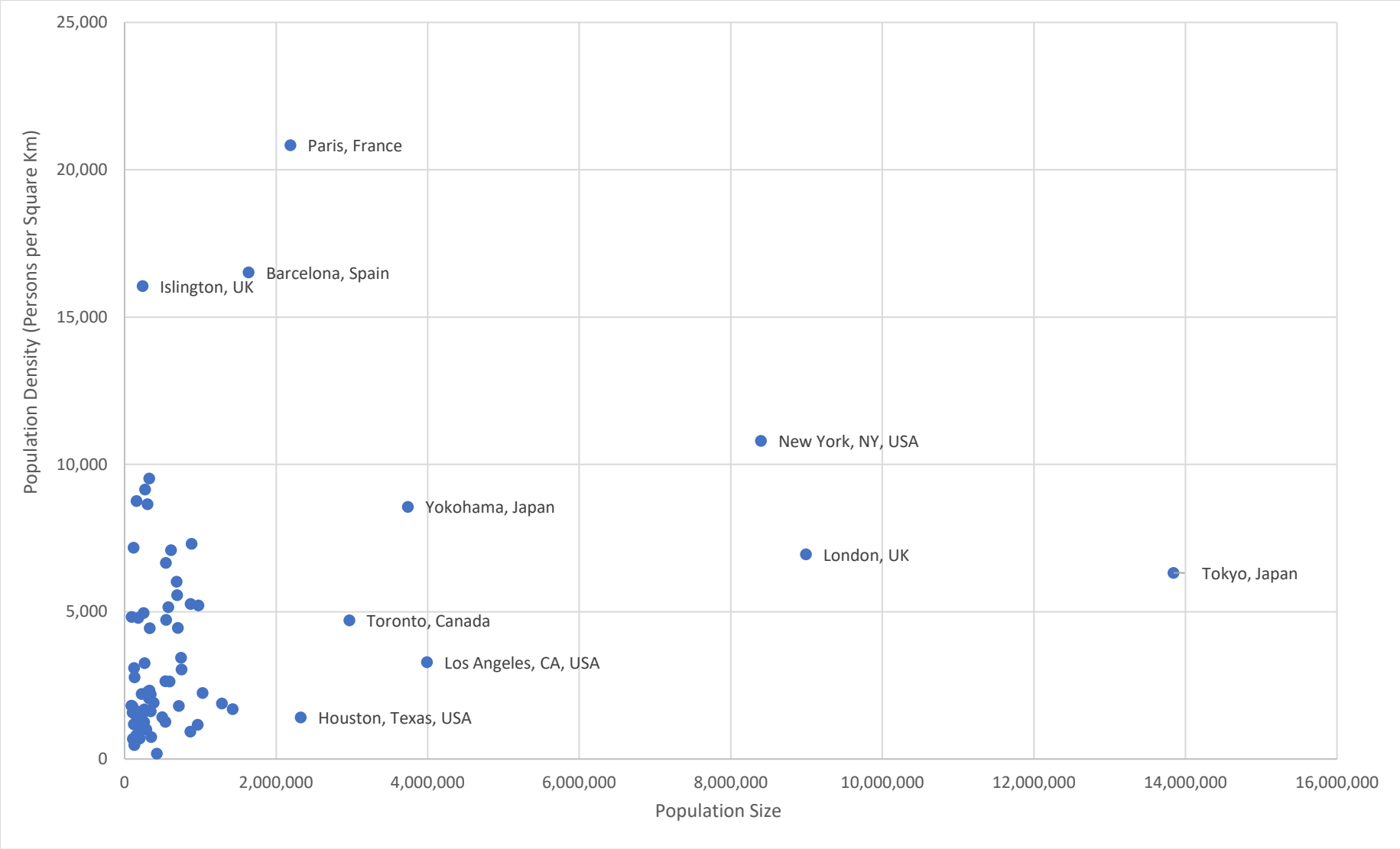
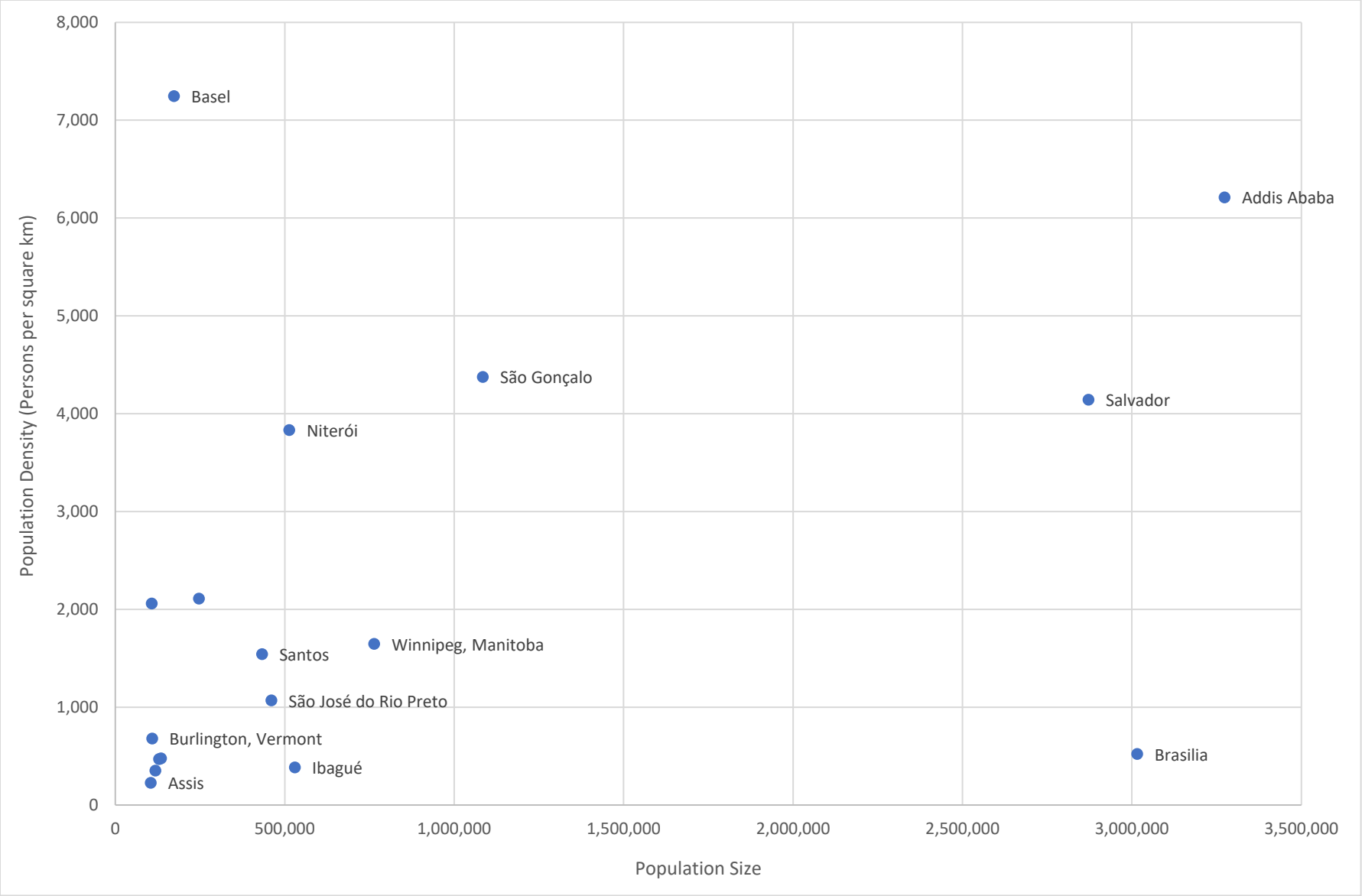


Figure 4: Population Density by Population Size for 17 City-Wide Achievements



Results of Content Analysis of the Most Ambitious Plans

Six cities have adopted plans towards the most ambitious category, *100% renewable energy* city-wide. These six cities are identified in Table 9. Of the final six urban cities, except for Paris, all populations are below 1,000,000. Victoria just meets the minimum criteria at 90,000 persons. The population densities are between 1,175 and 20,834 persons per square km. Paris is again an outlier with the largest population density, while the rest of the urban cities have population densities of between approximately 1,000 and 6,000 persons per square km. Table 10 provides a breakdown of the decision-making powers of the six urban cities studied and the regional and national context of renewable energy laws and policies for each.

Table 9: Cities and Plans Coded towards 100% Renewable Energy

Urban City	**Population Size**	**Population Density (Persons per Square Km)**	**Plan Name(s)/Documents**
Frankfurt, Germany	753,056	3,037	Masterplan 100 % Climate Protection (Summarized version in English) (Frankfurt am Main, 2015); and Generalkonzept im Rahmen des Masterplans „100% Klimaschutz“ der Stadt Frankfurt am Main (Full version translated from German) (Frankfurt am Main & Fraunhofer-IBP, 2015)
Malmö, Sweden	344,166	2,192	Environmental Programme for the City of Malmö 2009-2020 (Malmö, 2009); and Action Plan for the Environment 2019-2020 (Malmö, 2018)
Paris, France	2,187,526	20,834	Paris Climate Action Plan: Towards a Climate Neutral City and 100% Renewable Energies (Paris, 2018)
Saanich, British Columbia, Canada	122,173	1,175	2020 Climate Plan 100% renewable & Resilient Saanich (Saanich, 2020a)
Vancouver, British Columbia, Canada	685,885	6,017	Renewable City Strategy 2015-2050 (Vancouver, 2015); and Renewable City Action Plan 2017 (Vancouver, 2017)
Victoria, British Columbia, Canada	94,005	4,821	Climate Leadership Plan (CLP): Strategies and actions for a prosperous, low carbon future (2020) (Victoria, 2018)

Table 10: Decision Making Powers and Laws of 6 Urban Cities

Urban City	Decision Making Powers	Regional and National Context for Renewable Energy Laws and Policies
Frankfurt, Germany	Frankfurt is a city in the state of Hesse. Frankfurt has an Urban Planning Office. The planning process in Germany involves the primary actors of the Federal government, state governments, planning regions, and municipalities (Schmidt & Buehler, 2007, p. 5). Level of responsibility and detail increases at the lower level of government (Schmidt & Buehler, 2007, p. 7).	The country of Germany has committed to transforming its electricity supply to 100% renewable by 2050, as well as reducing its greenhouse gas emissions by 80-85 percent below 1990 levels by 2050 (United Nations, 2010).
Malmö, Sweden	Malmö is the largest city in county of Scania, Sweden. Local authorities in Sweden have planning monopoly (only the municipality can decide how land is used within municipality) (Kanters & Wall, 2018, p. 56). The municipality creates a comprehensive plan, followed by more detailed development plan, similar to a zoning plan in other countries (Kanters & Wall, 2018, p. 56). The Planning and Building Act regulates what a detailed plan can or should contain.	Sweden is targeting 100% renewable electricity by 2040, and has already reached its 2020 target of 50 percent in 2012 (Sweden, 2015).
Paris, France	The responsibility for preparation of a local plan in France lies with the commune under the mayor's direction (*Local Plans in France (Plan Local d'Urbanisme)*, n.d.). In France, the main units of local government are the regions, the departments, the communes, and overseas territories. The commune is the smallest unit of democracy in France. Communes include municipal councils responsible for the affairs of the commune ("France - Regional and Local Government," 2020). The city of Paris is one of 6 "collectives with special status" which replace departments and regions and have slightly different administrative frameworks ("France - Regional and Local Government," 2020). Paris has a mayor and councillors, who approve urban planning projects (Paris, 2020).	France does not have an 100% renewable energy or electricity goal. However, through the "Energy transition law for green growth," France has goals to reduce greenhouse gas emissions by 40% between 1990 and 2030 and divide GHG emissions by 4 between 1990 and 2050; reduce final energy consumption by 50% of 2012 levels by 2050; increase renewable energy to 23% by 2020 and 32% by 2030; and increase nuclear electricity supply to 50% by 2025 (France, 2015). However, France is falling behind on taking action (Savolainen, 2019).
Saanich, British Columbia, Canada	The Community Charter and Local Government Act in British Columbia give local governments, led by municipal council, authority to adopt bylaws, establish policies, guide development, etc. (Saanich, 2020b). While also referred to as the 'district of Saanich,' Saanich is a municipality represented by a mayor and eight councillors. Saanich has an Official Community Plan which provides the primary guidance of growth and chance within the municipality.	The cities in British Columbia (Saanich, Vancouver, and Victoria) are in a supportive environment for renewable energy because of plans and regulations that have been in place by the Province for many years. The 2007 BC Energy Plan sets out BC's commitment to 100% self-sufficient electricity supply by 2016, with 90% from renewable, clean energy sources. The BC Bioenergy Strategy commits province to provision of 50% renewable fuel requirements and 10 community energy biomass projects by 2020 The 2010 Clean Energy Act requires 93% renewable electricity (British Columbia, n.d.). BC Hydro is "mandated to produce as much power as BC needs from facilities within the province and is regulated to do so with 93% of the total generation met by clean sources" (Vancouver, 2015). CleanBC plan "includes electrification as a key GHG reduction strategy, and states there is sufficient capacity for increased electricity use with existing and planned projects to 2030" (Saanich, 2020a).
Vancouver, British Columbia, Canada	Vancouver City Council is made up of a mayor and 10 councillors. The city has development policies, guidelines, and bylaws. Its main urban planning document is called the 'Vancouver Plan,' a strategic, long-range plan guiding the city to 2050 and beyond.	
Victoria, British Columbia, Canada	The city of Victoria consists of a mayor and eight councillors who make decisions for the City. The city is responsible for guiding planning and development through permits, zoning, official plan, land division, etc.	

Adoption Dates, Target Years, and Interim Targets

The adoption dates of the plans, target years for achieving the commitments set out in the plan, and any interim targets from the urban cities' plans are describe in Table 11. Most plans were adopted in 2015 or later. All target years for reaching 100% renewable energy are 2050 except for Malmö, which has a target year of 2030. Five of the six cities have interim targets identified in the plan. The interim targets include both city operations and community-wide targets for reducing GHG emissions and increasing renewable energy consumption by a certain percentage by 2020, 2030 or 2040.

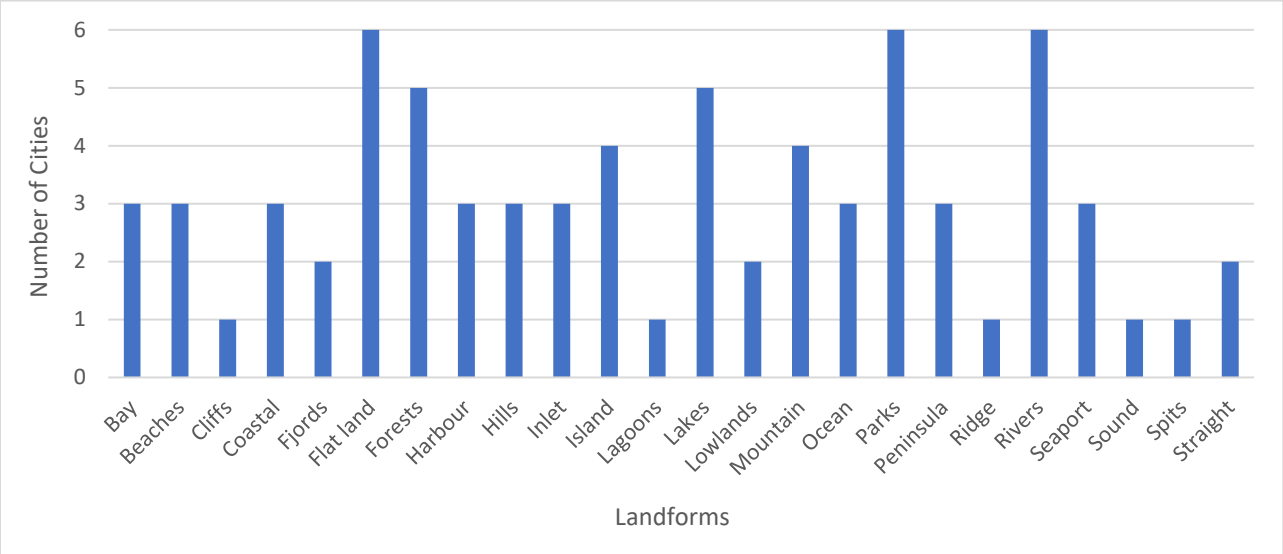
Table 11: Cities' Adoption Dates, Target Years, and Interim Targets

City	**Plan Adoption Year**	**100% Renewable Energy Target Year**	**Interim Targets**
Frankfurt	2015	2050	None identified
Malmö	2009	2030	100% renewable electricity (city operations only) by 2020
Paris	2018	2050	By 2020: 45% renewable energy consumption including 10% locally produced; zero fossil fuel and domestic heating oil; 50% GHG emission reduction; and 35% energy consumption reduction.
Saanich	2020	2050	Cut emissions in half by 2030; net zero GHG emissions city operations by 2040
Vancouver	2015 (Strategy); and 2017 (Action Plan)	2050	Derive 55% of energy in Vancouver from renewables by 2030
Victoria	2018	2050	Reduce community GHG emissions by 50 percent (by 2007 levels) by 2030, and cut the City of Victoria's corporate emissions by 60 percent by 2030

Climate and Landforms

All cities were identified to be in a temperate climate. Of the various landforms that make up the geography in and around the cities studied all cities include parks, rivers, and flat land (Figure 5). Five of six cities include forests and lakes. Half the cities include harbours, peninsulas, seaports, coasts, inlets, bays, hills, beaches, and ocean.

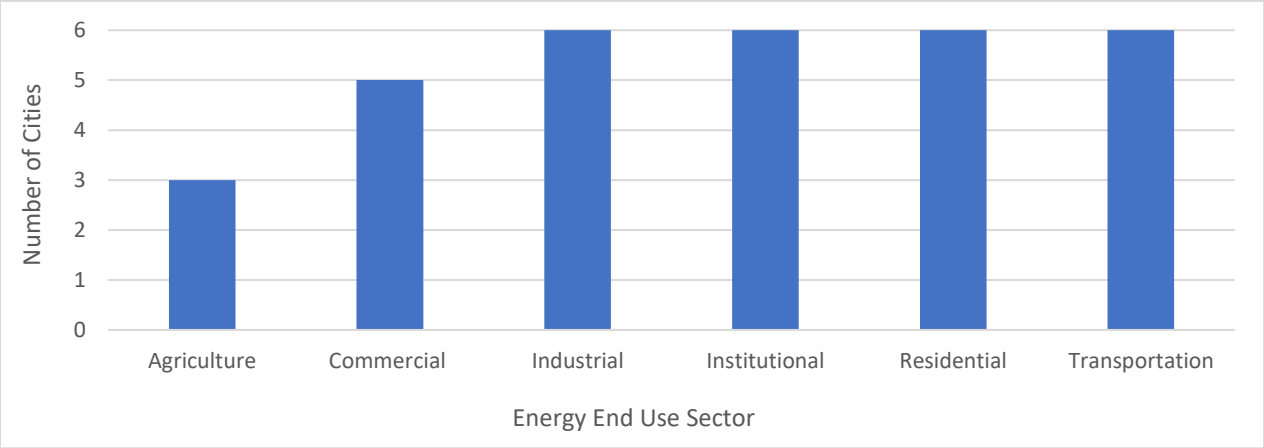
Figure 5: Landforms (Category 6B)



Technology and Innovations

Figure 6 shows the energy end use sectors identified by the plans. All cities identify residential, industrial, institutional, and transportation as energy end use sectors involved in the plan.

Figure 6: Energy End Use Sectors (Category 2B)



Agriculture is discussed by Malmö, Saanich, and Paris. Examples of plans in the agriculture sector include: using rural areas as a resource for local food (Malmö); promoting sustainable, organic, and/or local agriculture (Malmö); supporting the local food industry (Saanich); and supporting urban agriculture which reduces GHG emissions (Paris).

The commercial sector is mentioned by five of six cities. Plans include to incentivize/require retrofits of buildings (Saanich); increasing renewable power of buildings (Vancouver, Victoria); and improve efficiency by replacing fluorescent lamps with more efficient lighting in buildings (Frankfurt).

Industrial sector is discussed by all six cities. For example, Malmö discusses "industrial symbiosis," when "industries utilize each other's flows of raw materials, productions and waste to create as sustainable a whole as possible" (Malmö, 2009a). Industrial sector plans include reducing emissions from consumer choice and industry transition (e.g., refrigerants, aerosols, foams, equipment, livestock, fertilizer, etc.) by 33% by 2030 and 100% by 2050 (Saanich); using industry's "significant rooftop space and underutilized land" for creating "significant renewable energy hubs through local and on-site generation" (Vancouver, 2015); and efficiency improvements (Frankfurt, Saanich, Paris).

Institutional sector is also mentioned by all six cities. Examples include building renovations/retrofits and standards, increased renewable energy, and education, including in schools, nursing homes, theaters, and cultural institutions.

Residential sector mentions include supporting residential population densities that support low-carbon and public transit (Saanich, Malmö); and building retrofits and/or efficiency improvements like heat pumps (Saanich, Vancouver, Victoria, Frankfurt, Paris).

Examples of transportation policies include: improved cycling paths and/or accelerating active transportation (Malmö, Saanich, Paris); electric mobility strategy; increasing uptake of EVs and/or converting city's fleet (Saanich, Vancouver); smart land use to prioritize transit (Victoria) in addition to the transportation measures discussed in the results for Coding Category 2A: Energy End Uses.

Figure 7: Energy End Uses (Category 2A)

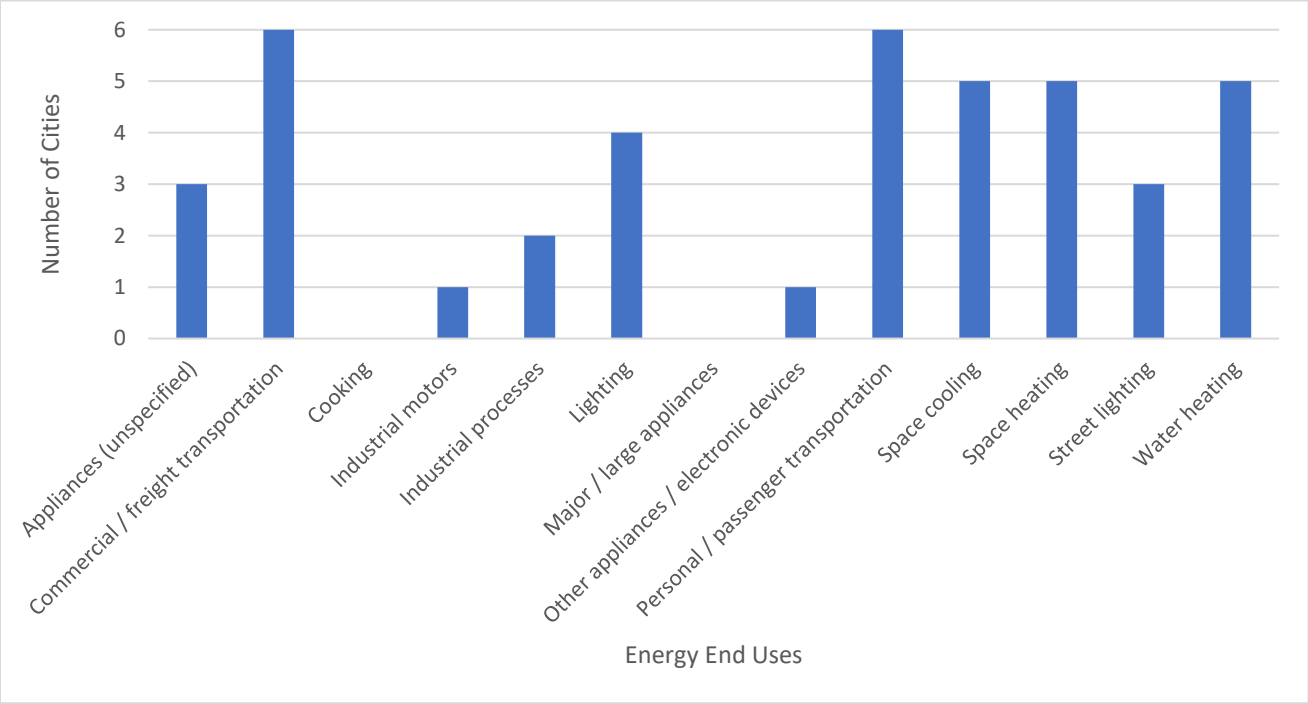


Figure 7 presents the energy end uses included in the plans.

Appliances are mentioned (Vancouver, Victoria, Frankfurt), although whether they are major/large appliances or other/electronic devices is only specified by Frankfurt. Frankfurt's plan says that "consumption [in the household]

can be almost halved with the consistent use of efficient appliances and the latest technology" and "220,000 tonnes of CO_2 could be saved just by replacing outdated appliances with new ones" although this may not always make economic sense (Frankfurt am Main, 2015). Frankfurt encourages replacement of old appliances to reduce power consumption, such as standby-switches and thin-client solutions and terminal workplaces, and desk-top computers with laptops (Frankfurt am Main, 2015).

All cities mention commercial / freight transportation. The plans include to convert their heavy duty city fleets (such as garbage trucks, etc.) to electric vehicles (Saanich); use of biofuels (hydrogen, biomethane, electricity) for large vehicles (Vancouver, Frankfurt); powering 30% of commercial vehicles operating in Victoria with renewable power by 2030 (Victoria, 2018); and challenging the aviation sector to develop sustainable fuel (Paris).

Industrial motors is only mentioned by Frankfurt, which states that "At 68 %, mechanical energy (motors for compressors, ventilators, etc.) accounts for the greatest share of the power consumed in the industrial sector" and will replace existing motors with high-efficiency motors, which would save around 20% of the energy (Frankfurt am Main, 2015, p. 16). Industrial processes are mentioned by Frankfurt, in terms of using industrial waste heat, and the process cooling requires for refrigerated warehouses.

Lighting is mentioned by four cities: Victoria, Vancouver, Frankfurt, and Paris. Street lighting is addressed by Paris, Frankfurt, and Victoria. Paris will reduce energy consumption by 30% by 2020 through energy performance for public lighting and continue investing achieving 50% in energy savings by 2030 and use public lighting facilities such as environmental and traffic sensors, shade structures, etc.) (Paris, 2018, p. 23). Victoria has completed its "Streetlight replacement program to swap-in energy- efficient LEDs, and "replaced 6,700 street lights reducing energy use by 50 percent, avoiding, an estimated $200,000 in energy costs per year" freeing up financing to support electrification across the city (Victoria, 2018, p. 52).

All cities also discuss personal / passenger transportation as an energy end use. Plans include to develop more cycling infrastructure (Malmö); add more electric vehicle infrastructure (Paris); use of complete communities (Saanich, Vancouver, Victoria); and add more cycling, walking, public transport, and/or car sharing, and reducing car dependence (Malmö, Vancouver, Victoria, Frankfurt, Paris). More specifically, Victoria envisions that "55% of trips are walking/cycling and 25% of trips are transit by 2041" (Victoria, 2018) and Paris is targeting 100% renewable energy in transport by 2050 (Paris, 2018).

Space cooling, space heating, and water heating are discussed by all but one city (Malmö). They are discussed in combination with improving energy efficiency in buildings (Victoria, Frankfurt), installing heat pumps (Victoria, Saanich, Vancouver), replacing with renewable heat and cooling systems (Saanich, Vancouver, Victoria), building retrofits (Saanich), improved affordability of heating and cooling (Vancouver, Paris, Victoria), being serviced by neighbourhood renewable energy systems (Vancouver), using waste heat from sewage for space heating and/or hot water (Vancouver, Frankfurt), increasing building comfort (Vancouver, Paris), and use of green roofs for having urban cooling outcomes (Saanich). Saanich will replace all oil heating with heat pumps by 2030; replace 40% of natural gas space and hot water systems replaced with renewable sources by 2030, and 100% by 2050; and upgrade 40% of all building envelopes by 2030, and 80% by 2050 (Saanich, 2020a).

Location of Energy Generation

Table 12: Location of Energy Generation

Code	No. of Cities	Findings
Local and/or Within City Limits (scale not specified)	3	Wind electricity (Malmö); Geothermal and solar (Paris); Solar PV, solar heat, waste to energy (Frankfurt)
On-site	5	Rooftop solar (Victoria, Frankfurt, Paris); On site biogas, solar, wind (Saanich); Geothermal heating (Victoria); Renewable natural gas (Victoria); On-site unspecified (Vancouver)
Neighbourhood or District Scale	5	Neighbourhood energy systems (Vancouver); District energy (Frankfurt, Malmö, Paris, and Victoria); Microgrids (local heating grids specifically) (Frankfurt);
Imported / Outside City Limits	6	Reliance on regional utility (Saanich, Victoria, Vancouver) Decentralized generation from neighbouring local authorities (Paris, Malmo, Frankfurt)

Table 12 presents the location of energy generation discussed in cities' plans.

Local and/or Within City Limits (Scale unspecified)

Malmö has the ambition for "as large a proportion of this energy as possible to be produced locally" (Malmö, 2009, p. 7). Malmö will work to increase the supply of renewable energy within the municipality's geographical area. Malmö will use its "good conditions" for generating electricity from wind energy (Malmö, 2018, p. 10). Malmö will also push for "both the establishment of small-scale energy production and the opportunities for Malmö residents to own renewable energy production facilities" (Malmö, 2018, p. 10).

Paris wants to be "a city that produces renewable energy on its own soil" (Paris, 2018). Paris will need to exploit its "substantial renewable energy resources – particularly geothermal and solar" and aims to achieve a target of 20% locally produced energy, although whether this is within it's geographic boundaries is not clear) by 2050 (Paris, 2018, p. 20). This target will "guarantee its energy security" and "develop a more resilient, low-carbon model" (Paris, 2018, p. 20).

Frankfurt discusses meeting as much of its renewable energy needs locally as possible and provides different scenarios to do so. Frankfurt estimates the extent to which Frankfurt can meet its requirements internally and shows that "30 % of the electrical power demand can be met, and 31 % of the heat demand if all renewable energy potentials are exploited" and "solar energy represents the greatest potential: PV power meets 23 % of the demand for electrical power, solar heat 17 % of the heat demand. Waste contributes 6 % to energy generation" (Frankfurt am Main, 2015, p. 37).

For generation within city limits, the plans discussed a blend of on-site generation, neighbourhood scale generation and distribution networks, and generation within and outside of city limits.

On-site Generation

Urban cities discuss on-site generation including solar rooftop (Victoria, Frankfurt, Paris); on-site geothermal (Victoria); on site or local biogas or wind (Saanich), renewable natural gas (Victoria), or on-site unspecified technology (Vancouver).

Saanich will "work with the Province and utilities to encourage or incentivize on-site or local renewable energy generation (e.g., biogas, solar and wind)" and will "support the development of local renewable natural gas production, such as an RNG facility at Hartland landfill, by providing Saanich compost or other CRD opportunities as they arise" (Saanich, 2020a, p. 55).

Victoria will require "Widespread adoption of renewable fuels and on-site renewable power generation in residential and commercial buildings" including from on-site geothermal heating, rooftop solar panels and/or renewable natural gas (Victoria, 2018, p. 25). To support these goals, Victoria will make all new buildings "net-zero energy ready" by 2032, meaning they will be highly-efficient and easily accommodate renewable energy add ons, such as rooftop solar panels, enabling the buildings to produce at least as much energy as they consume (Victoria, 2018, p. 29).

Paris is "seeking to exploit the opportunity associated with its high-density built environment to rethink the use of its roofs, which will be used as solar energy production sites, possibly in association with other uses such as the planting of green roofs and urban agriculture" (Paris, 2018, p. 21). Paris specifies that "Conforming to the 100% renewable energy trajectory will require nearly 20% of roofs in Paris to be equipped with solar power units by 2050" (Paris, 2018, p. 21).

Frankfurt has "great potential" through its roofs and open spaces for solar power.

Vancouver states that "low-density development must have its heating needs met by renewable electricity from the grid or from on-site renewable energy generation" (Vancouver, 2015, p. 36).

Geothermal is often a form of local generation and is mentioned by three cities (Victoria, Paris, and Vancouver). However, the cities do not specifically specify whether it is on-site geothermal (except for Victoria), which mentions on site geothermal heating.

Neighbourhood Scale

Neighbourhood scale systems, such as district energy/district heating and cooling are mentioned by five cities. In Vancouver, 20% of total building floor area in 2050 will be serviced by neighbourhood-scale renewable energy systems (Vancouver, 2015, p. 27).

District energy / district heating and cooling is mentioned by Frankfurt, Malmö, Paris, and Victoria. Paris' urban district heating system is "currently the main vector for renewable energy in Paris" (Paris, 2018, p. 22). Malmö will "encourage new solutions and technologies for the city's systems and infrastructure" such as district heating networks (Malmö, 2018, p. 14).

Microgrids are only mentioned by Frankfurt, which states that the trend is turning to local heating grids in residential areas with a low heat density (e. g. large-scale residential estates with low-energy single-family homes) (Frankfurt am Main, 2015).

Imported/Outside City Limits

All cities will rely on renewable energy generation from both inside and outside of the city's limits. How they plan to achieve that is different. The three cities in Canada, in the province of British Columbia, all plan to rely on the regional, province-wide electricity utility that relies predominantly on hydroelectric power. Paris and Frankfurt use the term 'decentralized energy' to discuss receiving power from adjacent districts.

Vancouver, Victoria, and Saanich can get most of their buildings' supply of renewable energy from utility renewable electricity, that is province-wide. The rest can be generated locally, within the city. Vancouver states that "low-density development must have its heating needs met by renewable electricity from the grid or from on-site renewable energy generation" (Vancouver, 2015, p. 36). According to Saanich's plan, the province's CleanBC plan "includes electrification as a key GHG reduction strategy, and states there is sufficient capacity for increased electricity use with existing and planned projects to 2030" (Saanich, 2020a). BC Hydro is "mandated to produce as much power as BC needs from facilities within the province and is regulated to do so with 93% of the total generation met by clean sources" (Vancouver, 2015). Victoria's plan recognizes that electricity is already "relatively clean" since "nearly all of the electricity supplied by BC's power grid comes from renewable hydropower" and 40% of Victoria's energy is already renewable" (Victoria, 2018, p. 14).

Malmö and Paris both express using rural areas outside the city as local food and energy production sources (Malmö, 2018, p. 6; Paris, 2018, p. 2), and Frankfurt discusses how the city would need PV potential from adjacent administrative districts (Frankfurt am Main, 2015).

Frankfurt discusses how it has great potential for renewable energy supply through roofs and open spaces, but it will not be sufficient to cover its own power demand completely from renewable energy. Frankfurt completed a feasibility study which found that self-generated electrical power could be 90% with 10% imported, when factoring in economic considerations (the recommended scenario). Frankfurt discusses partnering with neighbouring municipalities to achieve a sustainable and climate neutral energy supply, since densely built-up cities have limited renewable energy potential.

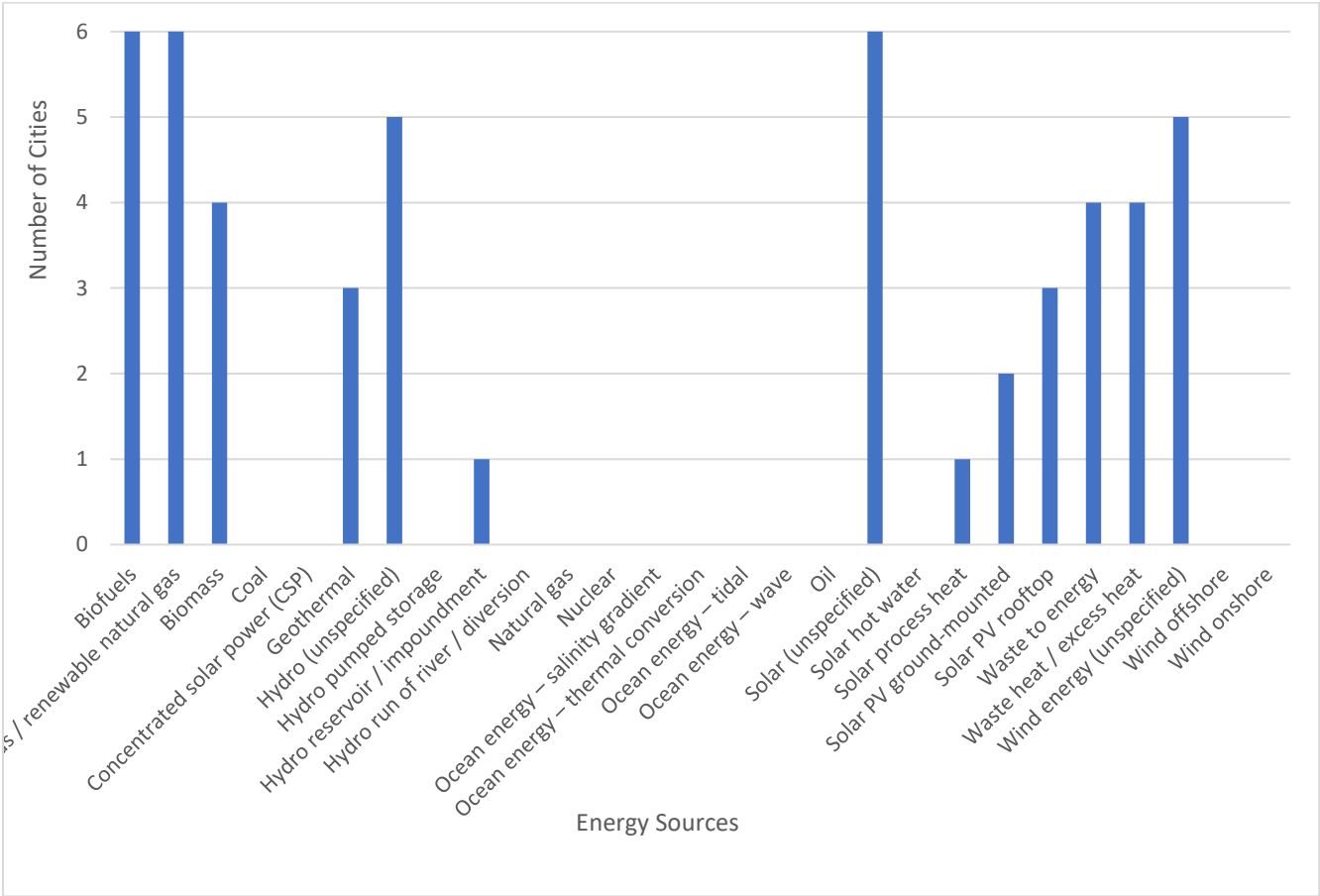
Paris understands that "To attain its 100% renewable energy target and become carbon-neutral, Paris must support and contribute to the funding of renewable energy production outside its territory. Indeed, even if it halves its needs, the French capital will need to continue "importing" over three-quarters of its required energy supplies" and will need to participate in developing supplementary production capacities including installing 50 km² of solar panels by 2050; 3,000 wind turbines by 2050; and 9 TWh of biogas by the horizon of 2030" (Paris, 2018, p. 23). Paris states that a 100% renewably powered energy system is decentralised and "will inevitably require new collaborations between territories and their stakeholders" to "share common goals and interests, take joint control of their energy-related futures, exploit these resources optimally and strengthen the principles of solidarity" (Paris, 2018, p. 20). Paris aims to forge new, "win-win territorial partnerships with local authorities" and invest in renewable energy production outside the city (Paris, 2018, p. 20). Paris is "advocating a decentralised energy model, including at the national and European levels, which will allow cities to regain direct control of networks and grids and favours the inclusion of renewable energy in the local energy mix with a policy of solidarity between territories via energy grids and networks" (Paris, 2018, p. 20). Key issues apply at the city level, such as the optimal management of different networks, grids, and energy and information exchanges between different areas (Paris, 2018, p. 20).

Malmö discusses rural areas as a food and energy source: "In dialogue with stakeholders, strategies will be developed for how Malmö's rural areas should be used, developed and protected so that the urban agricultural land becomes a resource for food and energy production as well as, for example, pedagogy and recreation, business development and tourism" (Malmö, 2018, p. 6).

The plans varied in the level of detail regarding the proportions of energy to be produced inside or outside city limits. Frankfurt is unique in that is a very specific and detailed feasibility study, which estimates electricity that is 90% inside and 10% outside (for its recommended scenario). Paris would need to import at least three quarters even if it halves its energy needs and Paris is targeting 20% locally produced energy. Paris will need to exploit its "substantial renewable energy resources – particularly geothermal and solar" and aims to achieve a target of 20% locally produced energy by 2050 (Paris, 2018, p. 20). The other plans were not specific.

The specific energy sources identified by cities to be used toward 100% renewable energy are describe (Figure 8). All cities mention using biofuels and biogas / renewable natural gas. All cities also mention using solar; however, it is not always specified if it is PV rooftop or PV ground-mounted.

Figure 8: Energy Sources (Category 3)



Biofuels and biogas/renewable natural gas are often discussed in association with transportation.

Biomass is mentioned by Saanich, Vancouver, Frankfurt, and Paris, to add to renewable energy supply, but makes up a smaller portion of energy supply. Frankfurt states that its biomass potential is already being almost completely exploited today.

Frankfurt provides detail on the potential of its various renewable energy sources: with the exception of the PV potential of which only 31.9 % is used, the potential of the various energy sources is completely exploited. 34 % of power is generated from wind energy and 21 % from PV. biomass covers 15 % and waste 9 % of energy demand.

Heat pumps supply 21 % of heat demand solar heat 21 %, boilers 11 %. In the thermal area, biomass power stations account for 13 %; waste plays a comparative large role with 31 % (Frankfurt am Main, 2015, p. 36)

Hydropower is mentioned by five of six cities. Three of these cities (Saanich, Vancouver and Victoria) are located in British Columbia, Canada, which uses mainly renewable electricity from hydropower. According to Saanich's plan, the province's CleanBC plan "includes electrification as a key GHG reduction strategy, and states there is sufficient capacity for increased electricity use with existing and planned projects to 2030" (Saanich, 2020a). BC Hydro is "mandated to produce as much power as BC needs from facilities within the province and is regulated to do so with 93% of the total generation met by clean sources" (Vancouver, 2015). Vancouver, Victoria, and Saanich can get most of their buildings' supply of renewable energy from utility renewable electricity, with the remainder can come from sources like renewable natural gas, solar (including rooftop), wind, geothermal heating, and/or biomass. Vancouver adds that "space heat can be met with biomethane, heat pumps, or resistance heating using renewable electricity or renewable waste streams such as biomethane, waste wood, and sewer heat, with geoexchange systems able to provide renewable heating and cooling" (Vancouver, 2015, p. 9).

Frankfurt discusses an Industriepark which encompasses 90 companies in the chemical industry. A small hydroelectric power station in a waste water treatment plant provides some regenerative energy to the industriepark (Frankfurt am Main, 2015). Besides this, Frankfurt hardly mentions the use of hydro power. Paris discusses the use of hydrothermal as part of its main production tools.

Solar process heat has "major potential" according to Frankfurt, and "solar energy plants can be run more economically in industrial operations than in residential buildings" (Frankfurt am Main, 2015, p. 24).

Frankfurt states that "theoretically, 80 % of the region's power consumption could be supplied by solar power" and "Frankfurt, with its roofs and open spaces, has the greatest potential" (Frankfurt am Main, 2015). Paris "will continue to invest in urban solar power plants, as at the Halle Pajol" and a large-scale solar power plant of between 5,000 and 10,000m² will be installed in the Bois de Vincennes power park (Paris, 2018).

Waste to energy is identified by four urban cities (Malmö, Vancouver, Victoria, and Paris), including through using GHG produced from organic materials for renewable energy supply (Victoria); industrial symbiosis (Malmö); using waste streams such as wood and food scraps to generate energy (Vancouver); and using biowaste as an energy and agriculture resource (Paris). Victoria plans to "Capture methane from collected organic waste to provide renewable energy by 2025" (Victoria, 2018, p. 45). Victoria's Hartland Landfill has a target "to capture 75 percent of the methane produced from its decomposing waste" (Victoria, 2018, p. 46).

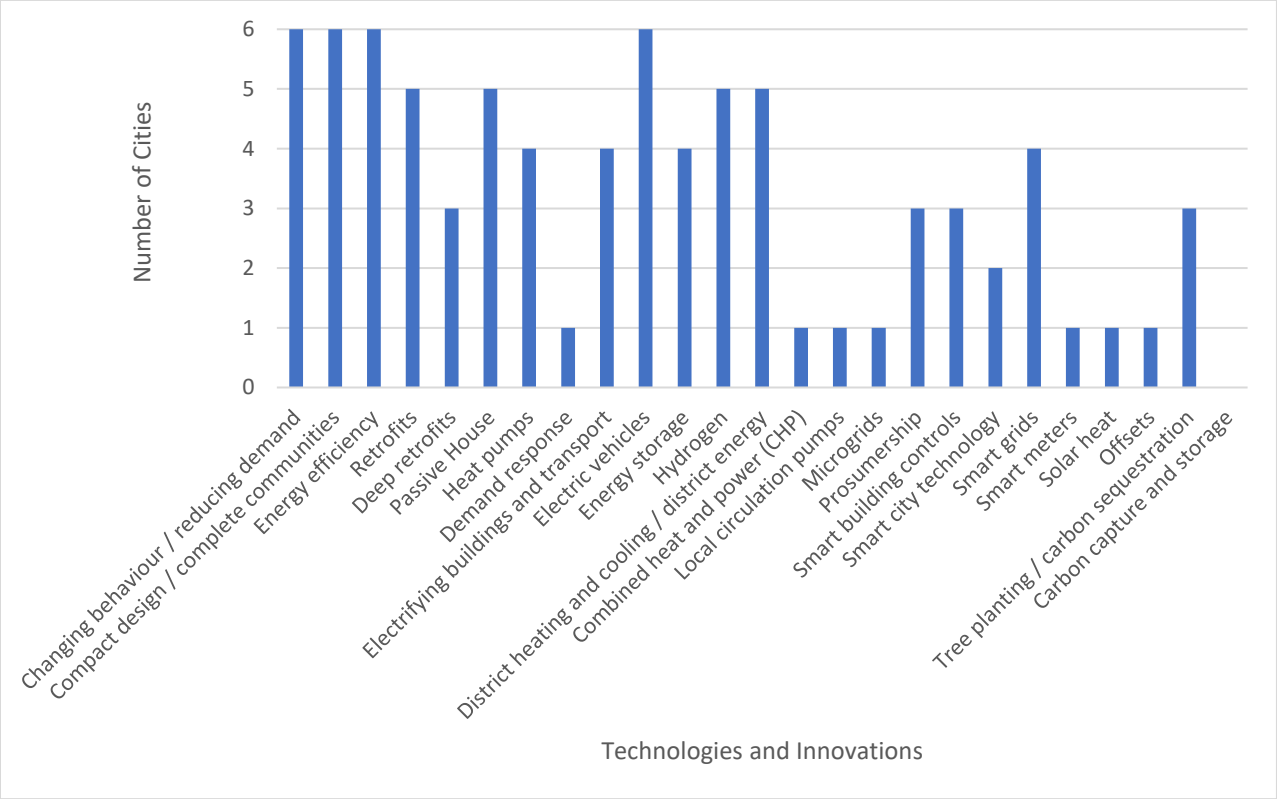
Waste heat / excess heat is mentioned by four urban cities (Frankfurt, Malmö, Vancouver, and Paris), including through industries using each other's waste flows (Malmö); sewage heat recovery providing heat and hot water to buildings (Vancouver, Frankfurt); and using process heat for heating networks or buildings, such as wastewater and data centre recovery heat (Paris, Frankfurt). Frankfurt's study finds that around 460 GWh annually could be won from the waste heat of industrial operations, data centres and waste water in Frankfurt in 2050 to provide district heating and district steam for households and enterprises in the tertiary sector, which could save 40% CO2 compared to oil heating (Frankfurt am Main, 2015, p. 23).

Wind (unspecified) is mentioned by five of six cities, through wind plants owned by the city (Malmö); on-site or local generation (Saanich); and small turbines to partially meet electricity needs of homes (Vancouver). Paris will install 3,000 turbines by 2050. Frankfurt will meet 4.3% of its overall electrical power needs through wind (Frankfurt am Main, 2015, p. 17).

The location of the energy generation (coding category five) provides more details regarding solar PV rooftop and geothermal.

Figure 9 shows the specific technologies and innovations identified by the plans.

Figure 9: Technology and Innovations (Category 4)



All cities mention changing behaviour/reducing demand; electric vehicles; energy efficiency; and compact design/complete communities.

All cities discuss the importance of reducing demand / changing behaviour. Examples of cities' plans include reducing energy in city operations (Malmö); active transportation and/or car sharing (Saanich, Vancouver); building envelope improvements (Saanich); strategic tree planting for cooling and windbreaks (Saanich); use of energy efficient equipment (Saanich); changes in consumption behaviour (Saanich, Victoria, Paris); and encouraging residents to choose lower carbon foods (Saanich, Victoria). Saanich will also reduce heating demands by 30% in at least 40% of all buildings by 2030 and at least 80% of all buildings by 2050 (Saanich, 2020a, p. 43). Vancouver says that energy conservation and efficiency programs "are the most cost-effective way to a renewable energy future" (Vancouver, 2015, p. 10). Vancouver's energy use has been decreasing by about 0.8% a year (Vancouver, 2015, p. 16). This reduction must be accelerated to reach a level that can be supplied by renewable sources. Once energy use is substantially reduced, "a zero-emission building can meet its energy needs through either on-site generation or connection to an off-site renewable energy source like a neighbourhood renewable energy system or the electrical grid" (Vancouver, 2015, p. 32).

Frankfurt's plan focuses on reducing energy demand, first, through halving final energy consumption by the year 2050 and then meeting the remaining demand entirely from regenerative energies. Paris will use positive incentives

to alter behaviour; because "changes in the habits and behaviours [are] needed to carry out this transition" (Paris, 2018, p. 73).

All cities identified compact design/creating complete communities to reduce demand and create more energy efficient behaviour. This will occur by building dense, green, and functionally mixed cities with residential, green spaces, services and other activities situated close together (Malmö). Residents will live in 'complete communities' where sustainable transportation (i.e. walking, cycling, transit, zero-emission shared and personal mobility options) is made easy and encouraged.

Saanich explains the important of compact development: "it is easier to build low-carbon buildings at higher densities due to reduced energy losses from shared walls and other economies of scale. It is easier to have a low-carbon transportation system when individuals are able to travel shorter distances to meet their needs. It is also more affordable for the District and other levels of government in the long run to provide infrastructure for low-carbon transit, pedestrian and cycling infrastructure if Saanich continues to develop more compactly with easy access to services" (Saanich, 2020a, p. 23). Vancouver also mentions that "Transportation and land use are inextricably linked" because community design affects journey and travel choices (Vancouver, 2015).

Energy efficiency is mentioned by all cities as part of their plans to reduce emissions and transition to 100% renewable energy. Cities envision that efficiency will be carried out through high efficiency requirements/standards (i.e. net-zero carbon new construction) for construction of homes and buildings; as well as retrofits and renovations (i.e. efficiency improvements, renewable energy upgrades).

Maximizing energy efficiency because it is the "largest, least expensive, most benign, most quickly deployable, least visible, least understood, and most neglected way to provide energy services" (Victoria, 2018). Malmö will decrease its consumption by at least 20% per person by 2020 and a further 20% by 2030 (Malmö, 2009b).

Frankfurt states that the region could "halve its power consumption through efficiency measures" enabling it to meet its demand completely from renewable sources (Frankfurt am Main, 2015, p. 17). Paris' building stock is aging and 70% is particularly inefficient. Therefore, "the City of Paris is setting all territorial stakeholders the aim of renovating 100% of the existing building stock to make it compatible with very low energy consumption standards between now and 2050" (Paris, 2018, p. 35). For the housing sector specifically, Paris "is aiming to reduce energy consumption by one-third between now and 2030 and to halve it between now and 2050 in relation to 2004" (Paris, 2018, p. 35). These results show that there is immense potential through efficiency alone to reduce emissions, reduce energy use, and make it easier to switch to renewable energy.

Frankfurt demonstrates the value of energy efficiency by saying that "If the power consumption remains at today's level, Frankfurt will only be able to cover 35 % of its electrical power demand from renewable energy sources, the Regional Authority, at least, 92 %. However, if all the proposed energy saving measures were implemented by 2050, the power consumption in Frankfurt would be reduced by 38 %. The Regional Authority would actually be able to halve its power consumption through efficiency measures and meet its demand completely from renewable energy sources. Frankfurt can increase the coverage to 56 % though energy savings alone" (Frankfurt am Main, 2015, p. 17).

Retrofits are mentioned by five of six cities generally (Saanich, Vancouver, Victoria, Frankfurt, and Paris), while deep retrofits specifically are mentioned by three (Saanich, Vancouver, and Victoria). Saanich states that "Approximately 70% of the residential buildings that will be in operation in 2050 are already constructed today, meaning retrofits are essential to achieving [its] climate goals" while also bringing opportunities to save costs, improve indoor health and comfort and make buildings sites of renewable energy production (Saanich, 2020a, p. 47). Vancouver states that "City-wide building energy demand could be reduced by about one-third over 2014 levels by adopting zero-emission buildings, requiring buildings that undergo retrofit to attain a similar level of performance, and connecting buildings

to neighbourhood renewable energy systems" (Vancouver, 2015, p. 27). Renovating buildings in Paris sustainably is a key issue for Paris to achieve its carbon neutrality goal because "80% of the building stock was built before the introduction of the first thermal regulations in 1974, and less than 1% of new floor area is constructed each year" (Paris, 2018, p. 34).

Passive house is mentioned by five cities (Saanich, Vancouver, Victoria, Frankfurt, and Paris). Cities will support the building industry in passive house practices (Saanich); develop an affordable rental housing project using Passive House standards (Saanich); develop a new Fire Hall and other new city buildings to the Passive House standard and support training on passive house trades (Vancouver, 2017); and apply the standard to all new constructed municipal buildings (Frankfurt, Paris). Passive houses provide comfort, low heating bills, and no furnace or air conditioner to worry about or maintain (Victoria, 2018). Passive house buildings use close to 90% less heating and cooling energy than typical buildings through optimized solar orientation, high insulation, high performance windows and doors, air tightness and balanced ventilation with heat recovery (Victoria, 2018, p. 31).

Heat pumps are discussed by four cities (Saanich, Vancouver, Victoria, and Frankfurt). Saanich plans to replace all oil heating systems with heat pumps by 2030. Saanich describes heat pumps as "a market-ready technology for space and water heating that use electricity very efficiently and also provide cooling, which will be increasingly useful with hotter summer temperatures" (Saanich, 2020a, p. 48). Vancouver also mentions using heat pumps to service 70% of total building floor area in 2050, while the other 10% might use baseboards and about 20% will be serviced by neighbourhood renewable energy systems (Vancouver, 2015, p. 27). Victoria will replace oil furnaces with heat pumps, which "could save up to 50,000 tonnes of CO2 per year" (Victoria, 2018, p. 28). Heat pump upgrades can also "save homeowners 40 to 75 percent of their annual heating bills" (Victoria, 2018, p. 28). Frankfurt's plan envisions that heat pumps will supply 21% of heat demand, solar heat 21%, boilers 11% (Frankfurt am Main, 2015, p. 36).

Frankfurt is the only city to mention demand response.

Electrifying buildings/transport is identified by four of six cities (Saanich, Malmö, Vancouver, and Frankfurt) through converting transit buses, cars, and buildings to electrical operation. Saanich mentions that all BC Transit buses will be electrified by 2030, as transit use increases (14% of trips taken by transit by 2030, and 20% by 2050) (Saanich, 2020a, p. 33).

Electric vehicles are mentioned by all cities. The cities' plans include investing in more infrastructure for electric cars, such as new charging stations in new and existing buildings, especially city-owned buildings; lowering costs and making it easier for commuters to switch to EVs; and developing comprehensive strategies. Saanich envisions that 36% of all personal vehicles are electrified by 2030, 90% by 2050, and 50% of commercial vehicles are electrified by 2050 (Saanich, 2020a, p. 24). Victoria envisions that 100 percent of passenger vehicles will be renewably powered by 2050 and 30 percent of commercial vehicles operating in Victoria will be renewably powered by 2030. Paris envisions ending diesel mobility by 2024 and petrol by 2030. (Paris, 2018).

Energy storage is mentioned by four cities (Saanich, Vancouver, Frankfurt, and Paris). Saanich will develop a guide for residents to explore renewable energy supply and storage to improve self sufficiency and emergency preparedness (Saanich, 2020a). Vancouver discusses how the smart grid is important for managing emerging technologies like energy storage, electric cars, etc. (Vancouver, 2015). Frankfurt also discusses the use of thermal and electrical storage systems in combination with smart load management, which can increase self consumption to 70% and more (Frankfurt am Main, 2015). Simulations show that by 2050, demand for thermal storage systems in Frankfurt "will have to rise to between 2.7 and 4.2 GWh if the targets are to be achieved" (Frankfurt am Main, 2015, p. 19). Frankfurt discusses use of thermal storage systems which "permit an uninterrupted power supply even

on cloudy and calm days" (Frankfurt am Main, 2015, p. 19), electrical storage for PV systems, and electrical storage for e-vehicles, which should halve in price by 2020 (Frankfurt am Main, 2015, p. 30).

Hydrogen is discussed by five cities (Malmö, Vancouver, Victoria, Frankfurt, and Paris), mainly as a renewable source for transportation, especially in commercial or industrial transportation. Frankfurt discusses using hydrogen from industry toward transportation: "In the Industriepark Höchst, 30 million cubic metres of hydrogen occur annually" as a by-product of chlorine production, which "can run 400 busses or around 10,000 cars" and save "around 15 % of the fuel" in the industry by 2050 (Frankfurt am Main, 2015, p. 24).

Combined heat and power (CHP) is only mentioned by Frankfurt, which discusses CHP in relation to synergies between energy sources and as an efficient local energy system.

Frankfurt also discusses the use of local circulation pumps. A trial conducted in a test building determined gas savings of 19 % and electricity savings of around 53 % for compared to a conventional central circulation pump" (Frankfurt am Main, 2015, p. 21).

Frankfurt is the only city to discuss microgrids, in terms of "small local heating grids" for low heat density residential areas (Frankfurt am Main, 2015, p. 22).

Prosumership is identified by three cities (Malmö, Vancouver, and Frankfurt). Malmö is promoting the establishment of small-scale energy production and opportunities for residents to own renewable energy production facilities. Vancouver discusses how the global investment in clean energy; dropping renewable energy technology prices are creating new business models where individuals and neighbourhoods "are no longer passive consumers, but are actively producing, using, and selling their products and services, including the energy they generate" (Vancouver, 2015, p. 25). Frankfurt also states that private households and operations will play a central role in the transition, as a high percentage of consumers will become 'prosumers' who generate energy themselves; store any power not consumed or pass it on to neighbours or into the energy grid (Frankfurt am Main, 2015, p. 30).

Smart building controls are mentioned by three cities (Victoria, Frankfurt, and Paris), which involves monitoring and managing building energy consumption, and coordinating with times of peak input, for example. Users can take responsibility for their energy consumption. Paris says that encouraging users to take responsibility for their energy consumption, combined with smart energy management systems is key to obtaining 100% low-carbon buildings (Paris, 2018, p. 34). Frankfurt discusses the significant increase in self-consumption that is possible through smart load management in homes (Frankfurt am Main, 2015, p. 13). Victoria discusses redesigning building construction and operations to include smart controls that monitor and manage building energy consumption (Victoria, 2018, p. 27).

Smart city technology is mentioned by two cities (Victoria and Paris). Victoria will "Work with municipal partners to implement 'smart city' technologies that improve safety, affordability and convenience for public transit, walking, cycling, car-sharing and ride-sharing" (Victoria, 2018, p. 40). Paris discusses using 'smart water' strategy and developing energy supply based on smart networks.

Smart grids are mentioned by four cities (Malmö, Vancouver, Paris, and Frankfurt). Malmö mentions connecting its city operations to smart grids but does not provide further details. Vancouver recognizes that smart grids are more reliable and resilient when things go wrong, and are "more adaptable to the future demands on the electrical system" (Vancouver, 2015, p. 36). Smart grids will help better meet customer needs, and is important for managing energy storage, electric cars, the 'home ecosystem' and on-site power generation distributed throughout the city (Vancouver, 2015, p. 36). Paris also states that smart grids "offer new opportunities for the efficient management of energy networks and grids, and enable the development of predictive, preventive and corrective solutions for faster

fault detection, fewer losses, better coordination of network maintenance and improved management of critical situations" (Paris, 2018, p. 23). Paris will transform all its energy networks and grids to smart systems by 2030 (Paris, 2018). Frankfurt discusses the construction of smart grids to deal with fluctuating generation of electricity from wind and solar energy through more flexible operation (Frankfurt am Main & Fraunhofer-IBP, 2015, p. 72).

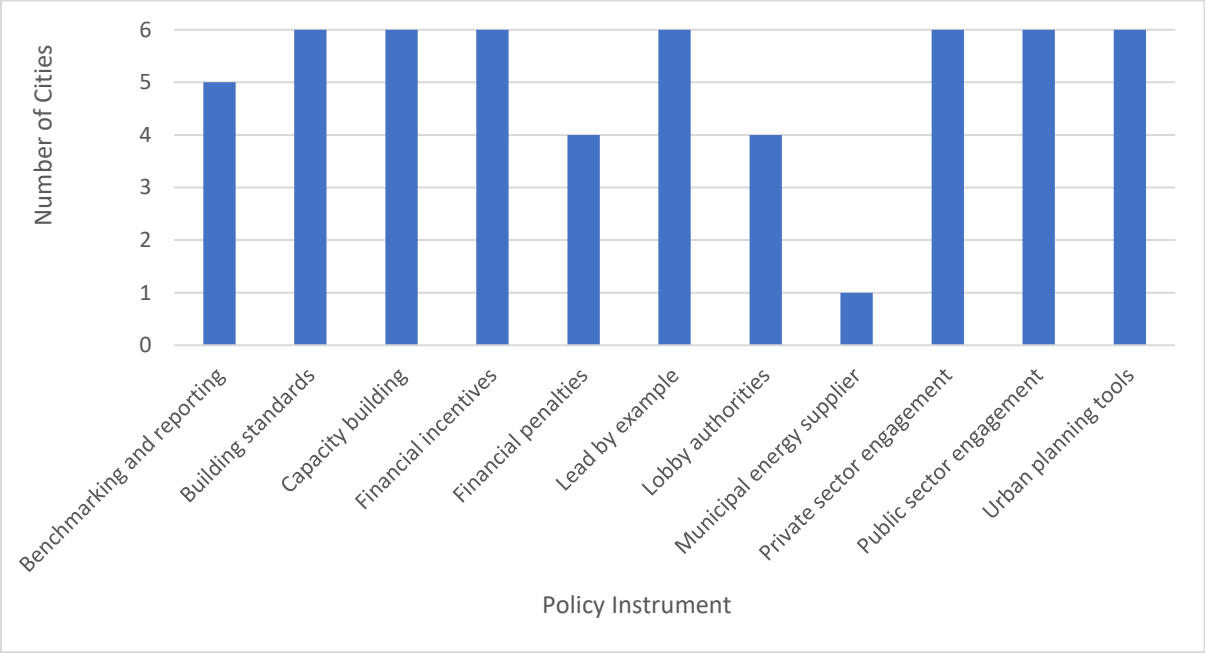
Paris is the only city to mention the use of offsets. The city mentions introducing offsets "as a last resort" for residual and irreducible emissions (Paris, 2018).

Tree planting is identified by three cities' plans (Saanich, Victoria, and Paris), including expanding, connecting, and restoring natural areas for ecosystem services, biodiversity, and carbon sequestration.

Policy Instruments

Figure 10 shows the specific policy instruments identified in their planning documents.

Figure 10: Policy Instruments (Category 7)



Benchmarking and reporting (identified by five cities) is the use of benchmarks/goals and reporting of results. Examples include: Malmö's web-based tool Environmental Barometer to follow-up its action plan annually (Malmö, 2009a) and measuring, tracking and reporting on actions annually, adjusting where required (Victoria, Paris); and requiring mandatory benchmarking for new buildings and/or voluntary benchmarking for existing buildings (Saanich, Vancouver, Victoria).

Building standards, such as building requirements to meet relating to energy or carbon, are an important policy instrument mentioned by all six cities. Examples of building standards discussed by cities' plans include ensuring that buildings meet net zero or zero-carbon emissions standards from the time they are built; strict energy efficiency requirements; climate-neutral construction; having 'net-zero ready' buildings that can easily accommodate renewable energy add-ons, such as rooftop solar panels; and passive house standards.

Capacity building**,** the provision of information, increasing skills, or providing technical analysis, is identified by all six cities. Malmö highlights the importance of "competent citizens" and states that "People's knowledge and their

actions are crucial to sustainable development. Equally important is that the city creates structures that make it easier for citizens - it should be easy to do right" (Malmö, 2018). Capacity building partly overlaps with public sector engagement. Some examples include: Supporting training programs for industry on building practices that improve climate resilience (e.g., high-quality heat pump installations, passive design techniques, incorporation of climate projections into designs, etc.) (Saanich); and developing renewable energy guide for residents / develop a guide to explore clean, renewable energy production potential and support residents in renewable energy use, supply, storage to improve self-sufficiency and emergency preparedness (i.e. information about net-metered solar photovoltaics and battery backup systems) (Saanich, 2020a).

Financial incentives (such as grants, loans, or financial rewards) are also mentioned by all cities. Examples include: "Green leases" to promote energy-optimizing measures in properties where Malmö city leases premises (Malmö); and launching a home energy retrofit municipal financial pilot project to provide financing to homeowners who convert oil to heat pumps (prioritized for lower income households) (Saanich, 2020a). To encourage local generation, Malmö is through investigating alternative financing models for the establishment and development of renewable energy production. Malmö residents "should be able to be co-owners of renewable energy production plants" (Malmö, 2018, p. 12).

Financial penalties (mentioned by four cities) include fees or taxes to discourage unsustainable behaviour or practices. Examples include carbon pricing for city projects/city operations (Saanich, Vancouver); and energy or climate tax relating to the energy efficiency quality of buildings (Frankfurt). Introducing different parking prices according to vehicle emissions and free parking for electric vehicles (the cleaner the vehicle, the cheaper the parking) (Paris, 2018).

Leading by example (mentioned by all cities) includes targeting municipal operations or assets that demonstrate behaviour or technology that should be imitated. For example, through supporting the "development of a 'Building Centre of Excellence' to showcase leading-edge design and construction practices and to foster a high-performance culture" within building industry (Victoria).

Lobbying authorities (mentioned by four cities) is about targeting change in policies at another level of government, business, or other agency outside the city's control. Examples of lobbying authorities include: advocating for stronger building codes at the provincial level to include better efficiency standards, mechanical systems/fuel types, and climate resilience (Saanich, Victoria); advocating for low and zero-emission vehicle standards, strengthened renewable and low-carbon fuel requirements, and development of financial incentives to support renewably fuelled vehicles (Vancouver); etc.

Private sector engagement (identified by all six cities) is the engagement of businesses through things like awards. Examples of private sector engagement include: An annual "Green Mobility Award", which would go to a company (Frankfurt); and providing workshops and educational programming for businesses on topics related to renewable energy and climate resilience (Saanich).A municipal energy supplier, when the city delivers carbon or energy through their own controlled utility company, was only addressed by Malmö, which mentioned increase renewable energy production in the form of wind power from plants owned by Malmö City administrations and companies (Malmö, 2009a).

Public sector engagement (mentioned by all cities) includes public displays relating to energy or carbon, and engagement with citizens/residents. For example, A competition on the city's bike paths, a Commuter Mobility Day on which as many people as possible are encouraged to make their journeys on foot or by bicycle (Frankfurt).

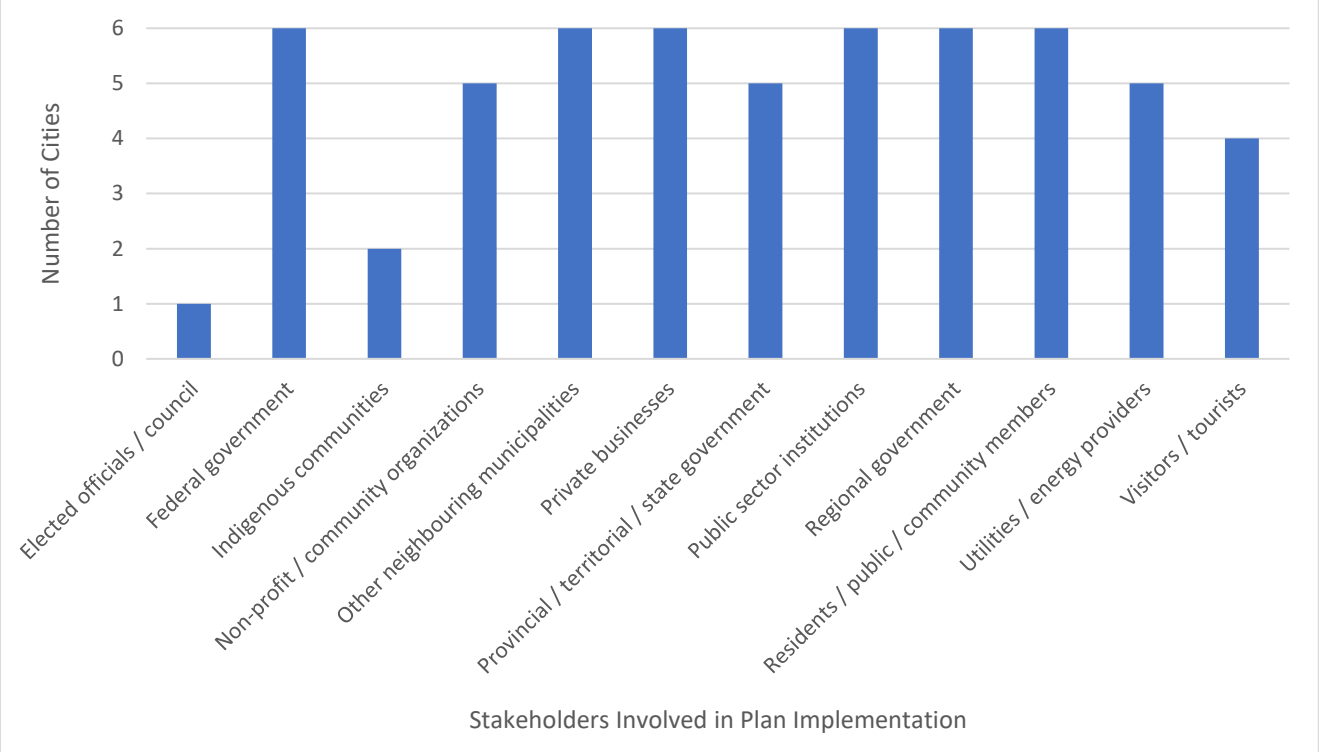
Urban planning tools include zoning and fee structures. Planning and land use tools are "essential tools for transforming the city in order to develop clean mobility, improve air quality, increase the number of natural areas

within the city and improve the living environment of Parisians" (Paris, 2018). This policy instrument also overlaps with the technology/innovation code "design compact/complete communities." Some examples of urban planning tools include: By bylaw, requiring new buildings to be EV-ready by ensuring sufficient electrical capacity and infrastructure in new developments to allow for future installation of EV chargers (Saanich); and Using land-use and zoning policies to develop complete compact communities and complete streets that encourage active transportation and transit (Vancouver, 2015).

Stakeholder Involvement and Benefits

Figure 11 shows the number of cities that identified codes relating to stakeholders involved in plan implementation.

Figure 11: Stakeholders Involved in Plan Implementation (Category 8)



Overall, plans state that they need involvement from everyone to achieve targets: "All Victorians (residents, businesses, employees, and visitors) have a role to play in improving GHG performance, and should be encouraged to take meaningful action" (Victoria, 2018). Paris states that "all stakeholders in the Paris community (residents, users, visitors, companies and institutions) need to be involved in the low-carbon transition" (Paris, 2018). From Saanich's plan, "Achieving our climate goals requires action from everybody, including residents, businesses, local farmers and food providers, community organizations, industry stakeholders, utility service providers, institutions, neighbouring municipalities, and regional, provincial and federal levels of government" (Saanich, 2020a).

Only one mentioned elected officials / council (Saanich). Saanich assigns council to work with partners to accelerate service level improvement and increase transit mode share.

The involvement of the federal government is mentioned by all six cities. This mainly relates to lobbying the federal government for higher level changes to support renewable energy adoption, and greenhouse gas emissions reductions (i.e. stronger building code requirements, efficiency standards, electric vehicle incentives, federal climate change legislation, regulatory and financial tools, etc.). Vancouver also mentions that large transportation

infrastructure like rail lines and container and shipping facilities at Port Metro Vancouver are federal jurisdiction, as well as First Nations Reserves over which the city has no direct control. Therefore, Vancouver needs to advocate for support for the use of renewable energy by the federal government. Frankfurt mentions utilizing federal government subsidy schemes such as the Market Incentive Scheme (MAP) for regenerative energies in the heat sector or the Renewable Energies Act (EEG).

Only Saanich and Vancouver mentioned working with Indigenous groups. Saanich states that it will "work towards reconciliation with local First Nations governments through collaboration on climate action" (Saanich, 2020a, p. 13) and "Seek opportunities to work with neighbouring First Nations Seek opportunities to partner with or otherwise support climate initiatives and climate-related priorities of neighbouring First Nations governments" (Saanich, 2020a, p. 90). Saanich's plan includes a land acknowledgement wherein it states Saanich will "look for opportunities to learn from and collaborate with First Nations to help us improve our community's resilience to a changing climate" (Saanich, 2020a, p. ii). Vancouver states that "To complement the actions the City is taking, we'll continue to build strong partnerships with the federal and provincial governments, First Nations, and utilities as we work towards our shared objectives" (Vancouver, 2017, p. 6).

Involvement of non-profit/community organizations is identified by five cities. This includes neighbourhood community kitchen program to provide safe, local, free groceries with minimal waste and GHG emissions (Saanich, Victoria); involving stewardship groups, residents' groups in the transition (Saanich); partnering with faith groups and other non-profit groups to ensure the success of the strategy (Vancouver); and creating the Paris Climate Agency to speed up the energy transition which supports residents with renovation projects and economic operators, etc. (Paris).

Other neighbouring municipalities is mentioned by all six cities. Neighbouring municipalities are discussed in relation to renewable energy generation; support for developing efficient and renewable transit and improving air quality for the larger area. Paris will also explore the practicality of partnering with other local authorities to create a cooperative operator for renewable energy supplies between territories which would promote a new form of partnership with rural areas (Paris, 2018).

Involvement of private businesses is also mentioned by all six cities, through having to increase their operational efficiency (Saanich, Victoria, Frankfurt); undertaking retrofits of multi-unit commercial or residential buildings (Saanich); being educated on topics like renewable energy, climate resilience, stormwater management, flood mitigation and emergency preparedness (Saanich); being involved in partnerships with the city to ensure the success of the renewable city strategy (Vancouver); businesses could be invited to share a zero-emissions business park (Frankfurt); and potentially signing a voluntary charter to join the fight against climate change and commit to reduce emissions of a certain amount in a defined timeframe (Paris).

The Provincial /territorial / state government is identified by five cities and is tied to the same involvement examples as regional government and/or federal government.

Public sector institutions (education, health, police, social housing providers, etc.) are also identified by all six cities for involvement in plan implementation. This involvement includes collaborating with academia to provide research on climate action (Malmö, Saanich); educating children in schools on sustainability, active transportation, etc. (Malmö, Saanich, Paris); carbon reduction from fleets of school districts and transit authorities (Saanich); social housing providers reducing energy consumption of 55,000 dwellings by 30% by 2020 (Paris); and improved energy management systems in theaters and cultural institutions (Frankfurt).

The involvement of regional government relates to coordinating regional transportation planning and growth strategies (Saanich, Vancouver); partnering to create an industrial treatment facility for organic waste (Victoria);

partnering with the region to obtain renewable energy for demand that cannot be met within the city (Frankfurt); and partnering with regional authorities to ensure effective action to improve air quality (Paris).

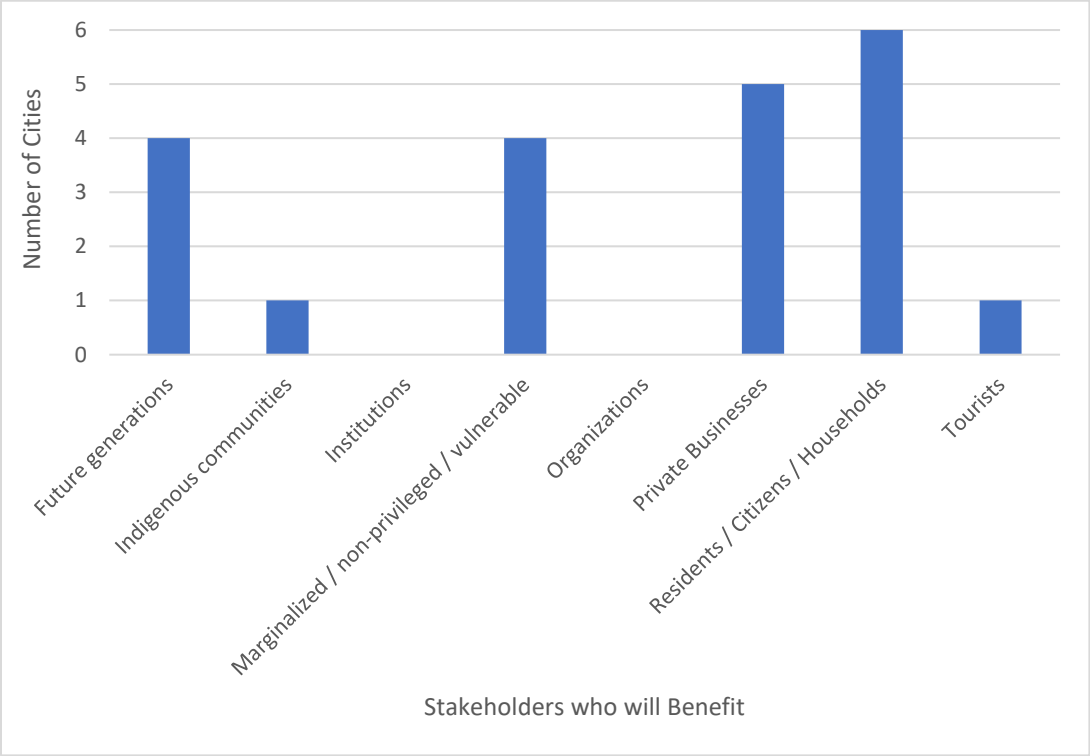
The involvement of residents / public / community members is discussed by all six cities. Examples of involvement include small-scale energy production and opportunities for residents to own renewable energy production facilities (Malmö, Saanich, Paris); promoting sustainable consumption and lifestyles among citizens (Malmö, Paris); education and workshops on renewable energy, climate resilience, home retrofits, gardening, waterwise landscaping, emergency preparedness, etc. (Saanich, Victoria); residents are supported and encouraged to take action in improving GHG performance and using energy more efficiently (Victoria, Vancouver); residents encouraged to use low-carbon transportation/change mobility habits (Victoria, Frankfurt); and residents will be encouraged to replace outdated appliances with new ones (Frankfurt). Frankfurt will also advocate for utility companies and service providers to present invoices in a more transparent way to involve consumers more actively in the energy process (Frankfurt). In Paris, citizens will be more involved in collective self-consumption – a mechanism that brings together different consumers who share the energy they produce.

Involvement of utilities / energy providers is identified by five cities. This includes partnerships toward incentivizing local renewable energy production (Saanich, Vancouver); establishing neighbourhood energy utilities (Vancouver, 2015); advocating and/or partnering with utilities to develop energy efficiency incentives and funding mechanisms (Victoria, Paris); ensuring the provincial utility's plans are aligned with city's goals (Vancouver); and advocating for more transparent utility bills for consumers to more easily save power (Frankfurt).

Involvement of visitors/tourists is also identified by four cities (Malmö, Victoria, Frankfurt, and Paris), through working towards more sustainable tourism (Malmö, Paris); encouraging tourists to improve GHG performance (Victoria, Paris); increasing bike-sharing for tourists and businesspeople (Frankfurt, Paris).

Figure 12 shows the stakeholders who will benefit identified by cities' plans.

Figure 12: Stakeholders who will Benefit (Category 9)



Future generations are mentioned as a beneficiary by four cities (Saanich, Malmö, Vancouver, and Victoria). Future generations will benefit by not being left with generational impacts resulting in unfair burdens and having their quality of life considered (Saanich); allowing space for coming generations to make their own choices (Malmö); improving quality of life, health and affordability, now and for future generations (Vancouver); and ensure that "all our kids are safer, happier and healthier than they were in 2018" (Victoria, 2018).

Indigenous communities are only mentioned at all by two cities, as discussed in the Results for Category 9: Stakeholders Involved in Plan Implementation. Of these two mentions, Indigenous communities could potentially benefit through reconciliation as mentioned by Saanich's plan.

Marginalized / non-privileged / vulnerable stakeholders were identified as beneficiaries by four cities (Malmö, Saanich, Victoria, and Paris), because these cities identified that these groups would be better off through improved resilience, emergency preparedness, comfort, and safety of transportation/walking. Saanich will develop an equity tool for municipal climate actions to improve climate resilience of vulnerable community members and fairly share the benefits of climate action such as access to rebates or incentives for renewable energy technology. Victoria envisions that "all corners of Victoria are prepared for the changes ahead, particularly our most vulnerable populations, including lower income and older residents" (Victoria, 2018, p. 55) and that no one will be left behind in the transition.

Private businesses are mentioned to benefit by five cities (Malmö, Saanich, Vancouver, Victoria, and Frankfurt). Private businesses could potentially benefit through growth in sustainable sectors, lower costs through efficiency and renewable energy, and training and skills development in the low-carbon economy. Frankfurt states that companies can save money (€ 40 million per year even today) through energy management solutions and reducing

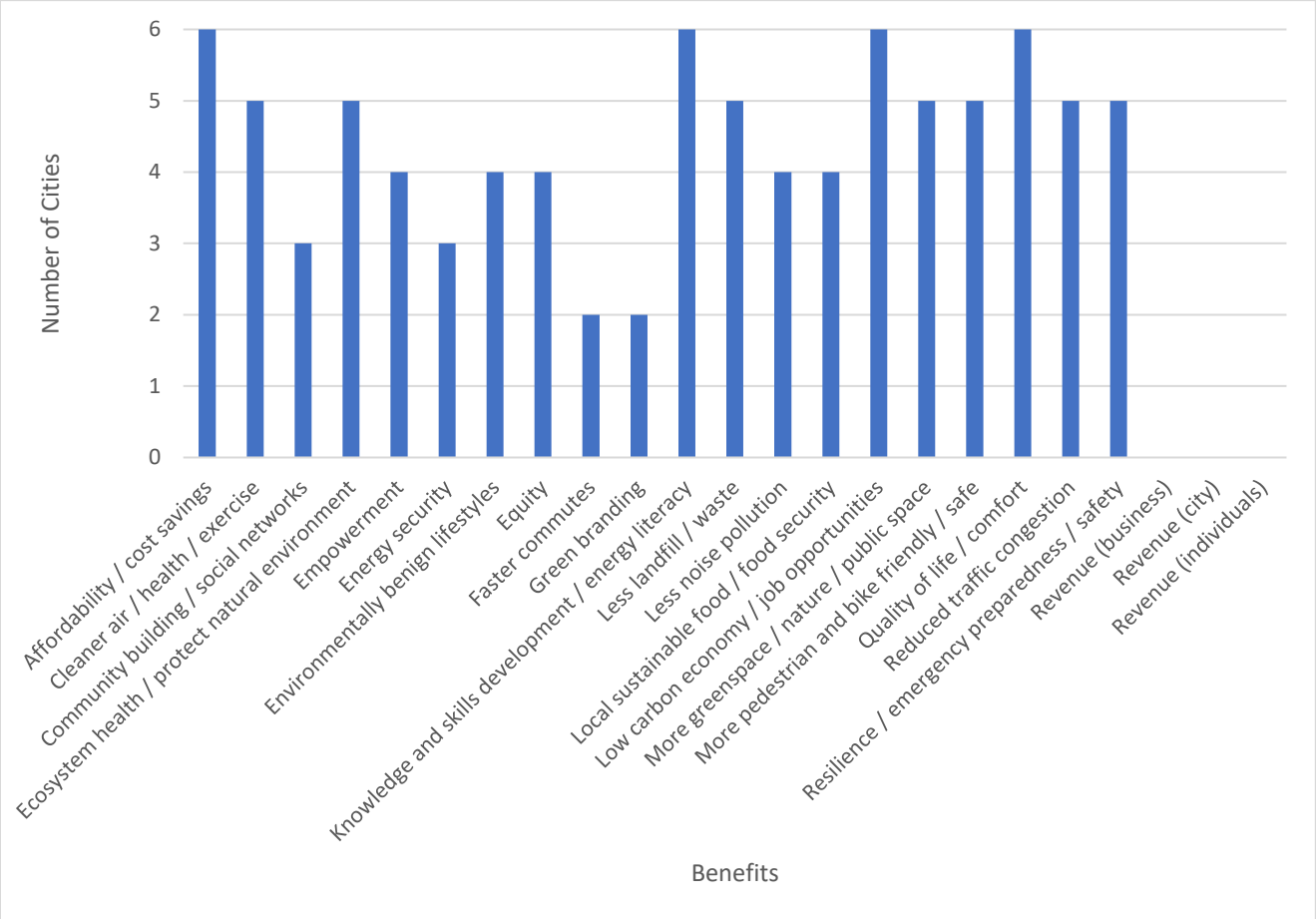
energy consumption. In the tertiary sector, the comprehensive use of LEDs reduces power consumption by 30-40 % and brings further annual savings of € 75 million" (Frankfurt am Main, 2015, p. 31).

Residents / citizens / households are expected to benefit by all cities. Ways that they will benefit include: attractive job creation and/or thriving economy (Malmö, Victoria, Paris); increased emergency preparedness and climate resilience (Saanich, Victoria); more green space and proximity to nature (Malmö, Victoria); more thermal comfort (Malmö, Vancouver, Paris); better public space (Vancouver); better safety (Malmö, Vancouver); more connection to environmentally benign lifestyles (Vancouver, Victoria); better mobility options and/or reduced congestion (Vancouver, Victoria, Frankfurt); improved health (Vancouver); cost reductions / affordability (Vancouver, Victoria, Frankfurt, Paris); and empowerment and/or knowledge and skill development (Victoria, Frankfurt, Paris). These results demonstrate that plans do identify a variety of local benefits.

Frankfurt alone mentions that tourists will benefit particularly from bike-lending schemes, as it is a fast and inexpensive alternative to the car for getting around (Frankfurt am Main, 2015).

Figure 13 demonstrates the number of cities which identified different codes for expected benefits in their plans. No cities identified revenue of any kind.

Figure 13: Expected Benefits (Category 10)



All cities discuss affordability / cost savings as a benefit of their plans. Improved affordability and cost savings mainly apply to residents through: improved energy efficiency and/or retrofits to improve energy performance which make homes less expensive to heat and cool (Malmö, Saanich, Vancouver, Frankfurt, Paris); lower transportation costs (i.e. through more compact complete development making it easier for people to travel less, affordable low-carbon mobility options) (Saanich, Victoria); better understanding and involvement in energy consumption leading to better and more affordable energy use (Frankfurt, Paris); and incentives which make EV parking cheaper than traditional cars (Frankfurt, Paris). Paris believes combating climate change and fuel poverty go hand in hand. Frankfurt states that households can save an annual € 230 million (up to 2050 by € 8.5 billion) through energy efficiency upgrading (Frankfurt am Main, 2015). Paris states average savings of €360/year per household (Paris, 2018).

Affordability and cost savings also apply to businesses through improved energy efficiency and/or retrofits to improve energy performance (Malmö, Saanich, Vancouver); future generations through the economic opportunities of renewable energy Vancouver); and the city through reduced waste which is costly to landfill and compost (Victoria, Paris). Frankfurt estimates that even today companies can make savings of € 40 million per year through energy management solutions and reducing energy consumption (Frankfurt am Main, 2015).

Cleaner air / health is mentioned by five cities as a benefit (Malmö, Saanich, Vancouver, Victoria, and Paris). Cleaner air and better health is discusses as a result of increased access to nature, its biodiversity and ecosystem services (Malmö, Saanich, Vancouver, Paris); switching to clean active transportation which have very little GHG emissions (Saanich, Malmö, Paris); building improvements which improve indoor air quality (Saanich, Vancouver, Victoria); and decreasing car dependence and/or switching to EVs which lowers emissions (Saanich, Malmö, Paris).

Community building / social networks is identified as a benefit by three cities (Saanich, Victoria, and Paris). Community building and improved social networks are discussed as a result of more human-powered forms of transportation (Saanich); neighbourhood actions which strengthen community connections (Saanich); and fostering strong civic engagement and cohesion, and helping Parisians take ownership over issues relating to the ecological transition (through energy cooperatives funded by the city for renewable energy production) (Paris, 2018, p. 73). Victoria states that "First and foremost this climate challenge is human-centred. It is about us, all of us. Yes, technology and innovation will help us get there. But to truly solve the climate challenge we need to weave a strong social fabric. We must build on the gifts and talents of our friends, neighbours, and colleagues. It means we need to shift our thinking from me to we, from now to the long term. We are all in this together." (Victoria, 2018, p. 5).

Ecosystem health and protection of the natural environment are mentioned by five cities. For example, Saanich plans to "double the rate of planting trees to enhance urban forest for increased carbon sequestration and other ecosystem services" (Saanich, 2020a, p. v). Malmö will safeguard and develop its 'green and blue amenities' which will have strong recreational and biological value (Malmö, 2009b).

Empowerment is discussed by four cities (Saanich, Paris, Victoria, and Vancouver). Residents and businesses are empowered through more knowledge and participation in the energy revolution and climate resilience.

Energy security is discussed as a benefit by three cities (Vancouver, Paris, and Victoria). Smart grids are more reliable, more resilient when things go wrong, and more adaptable to future demand on the electrical system (Vancouver, 2015, p. 36). As Paris puts it, "The renovation of one million housing units, and particularly social housing, will have a direct impact on these two contributors to fuel poverty: electricity bills and the feeling of being cold" (Paris, 2018, p. 74). More energy security is also a benefit of producing energy locally (Paris, 2018).

Environmentally benign lifestyles is mentioned by four cities (Malmö, Paris, Vancouver, and Victoria). As people are more aware and involved in their energy production, energy and environmental behaviours, more people will adopt more environmentally benign lifestyles and be more considerate of their impacts. For example, residents will be encouraged and educated on sustainable consumption, energy efficiency, decreasing waste, and better food choices.

Equity is mentioned by four cities (Saanich, Vancouver, Victoria, and Paris). For example, Saanich discusses the equity of public transit/human powered transportation. Saanich and Vancouver envision the equitable share of benefits and burdens of climate change, prioritizing helping those in highest need. Saanich will develop an equity tool for municipal climate actions to improve climate resilience of vulnerable groups. Vancouver discusses how renewable energy can increase social equity through lower energy bills; more stable energy costs; allowing residents or neighbourhoods to produce their own electricity and sell excess they don't use; more accessible and affordable transit; and increased access to jobs and economic opportunity (Vancouver, 2015).

Faster commutes are mentioned by Saanich and Frankfurt, because of improved public transit and cycling infrastructure. Frankfurt already has a high share of trips by bicycle (13%) but will work to increase this share through fast bicycle paths. (Re)development of corridors could cut one third of travelling time off of the routes, and commuters in the catchment area (130,000 to 140,000 commuters) of 5 to 15 km could reach their destination faster than by car in rush hour (Frankfurt am Main, 2015, p. 24).

Green branding is discussed by Vancouver and Malmö as a benefit. For example, Malmö's plan states that by its target date, "Malmö will have developed a strong trademark as 'the sustainable city', attracting visitors, residents and industry. The city will be an attractive place for everyone who wants to continue driving and developing sustainability" (Malmö, 2009, p. 5). Vancouver's plan states that "A healthy environment is essential to attracting and retaining the very best minds, establishing Vancouver as an innovation hub with high and inclusive employment—positioning Vancouver in the vanguard of long-term economic stability and success" (Vancouver, 2015, p. 7).

Knowledge and skills development / energy literacy was also discussed by all six cities. Examples of subjects in which residents and businesses can gain skills and knowledge include: nature, ecosystem services, and biodiversity; sustainable consumption; climate mitigation and adaptation; recycling, composting and waste reduction; renewable energy technologies and production; energy efficiency and conservation; emergency preparedness; high performance buildings; retrofits; etc.

Less landfill and waste is identified by five cities (Victoria, Vancouver, Malmö, Saanich, and Paris) through: educating and encouraging residents and businesses to recycle, compost and reduce their waste; working towards zero waste city-led events; developing and implementing waste plans or strategies; and using waste toward energy production. Paris has an ambitious target of "zero non-recovered waste" (Paris, 2018).

Less noise pollution is also a benefit mentioned by four cities (Saanich, Malmö, Victoria, and Paris). Noise is reduced, for example, as a result of reduced car dependence and switching to EVs; and switching to more cycling, walking, and public transport. Paris has already halved perceived noise as observed in 2017, a drop in noise of 2.7 decibels (Paris, 2018).

More local sustainable food and food security is identified as a benefit by four cities (Malmö, Saanich, Victoria, and Paris). Cities will aim to produce more local food on increased green spaces; use urban agricultural land for both food and energy production; increase community gardens; and encourage residents to support local food and choose more lower-carbon and plant-based meals. Like energy, cities connect more local food production and consumption with greater food security.

The low carbon economy and its job opportunities is mentioned as a benefit by all six cities. According to Vancouver's Action Plan, the global clean energy economy was worth $1.4 trillion US in 2016 (Vancouver, 2017, p. 4). Malmö will become a knowledge and innovation city, strengthen existing clean tech businesses and attract new business by continuing to develop (Malmö, 2009, p. 12). Vancouver's progress to date has been accompanied by a growing number of green jobs (8,100 new green jobs created between 2010 and 2016, or a 49% increase) (Vancouver, 2017, p. 7). Frankfurt states that there are convincing economic arguments in favour of implementing its plan's measures, such as regional value added and positive effects on employment and counteracting the outflow of financial resources. The "local character of the energy reversal" offers a "chance to retain medium-sized companies in the region, create jobs, boost spending power and increase fiscal income" (Frankfurt am Main, 2015, p. 30). Paris says it will create of over 7,500 jobs from building renovations alone (Paris, 2018, p. 7).

More greenspace / nature / public space is discussed as a benefit by five cities (Malmö, Paris, Saanich, Vancouver, and Victoria). This code overlaps with other benefits such as ecosystem health and protection of the natural environment, as well as cleaner air / health. These public greenspaces help sequester carbon; provide more pedestrian and bike friendly spaces; provide breathing spaces, cooler temperatures, shade, water absorption, slowing of floods and trapping of dust; support relaxation and even food production; beautify the city; and provide a healthy living environment for residents and ecosystems.

More pedestrian and bike friendliness and safety are mentioned by five cities (Malmö, Saanich, Vancouver, Frankfurt, and Paris), in connection with improved cycling networks and paths, more sidewalks, upgraded transit, less car dependence, and improved green spaces. Frankfurt discusses using traffic tailored to pedestrians, such as introducing 30 kilometre speed zones on main transport routes (Frankfurt am Main, 2015, p. 24).

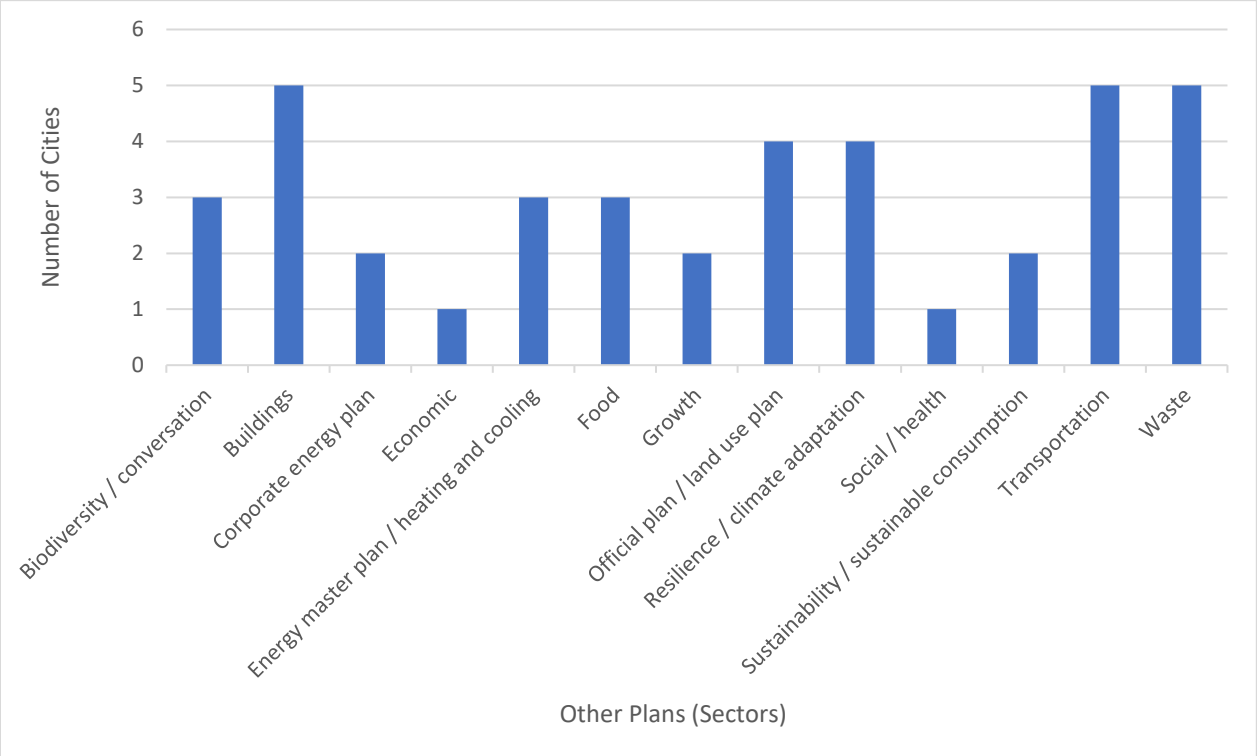
Quality of life / comfort is identified as a benefit by all six cities, which overlaps with the other benefits including cleaner air / health; compact design / complete communities; reduced traffic congestion; more pedestrian and bike friendliness; shorter commutes; empowerment; community building; more greenspace; less noise pollution; etc. In addition, quality of life and comfort relates to the improved thermal comfort of buildings once retrofitted/renovated. Quality of life with be high despite minimal use of resources (Malmö, 2009b, p. 5).

Reduced traffic congestion is also mentioned by five cities (Malmö, Vancouver, Victoria, Frankfurt, and Paris) through more complete communities resulting in less need to travel, better public transport, more use of car sharing schemes, and more active transportation.

Resilience and emergency preparedness is discussed by five cities as a benefit (Malmö, Saanich, Vancouver, Victoria, and Paris). Residents will be educated and more involved in tackling climate change mitigation and adaptation, renewable energy supply and storage, etc. and therefore more resilient and prepared in the event of emergencies from a changing climate. Resilience is also a benefit of more on-site generation, more greenspace, and upgraded buildings and infrastructure.

Figure 14 presents the different sectors for which other plans are identified within the cities' plans. All the cities' plans identified other plans that will help work towards the goals of the plan except for Frankfurt.

Figure 14: Other Plans (by Sector) Identified in Plan (Category 11)



Funding Sources

Three cities somewhat mention funding for the plan. Table 13 below shows the content relating to funding from the three cities that mention funding.

Table 13: Cities that Identified Funding (Coding categories 12A and 12B)

City	Funding
Frankfurt	Describes support from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety in creating the plan
Paris	Mentions that the City will be endowed with an Investment Fund for Energy Transition for acceleration actions towards measures such as the thermal renovation of buildings, renewable energy supplies, the development of tools for financing the energy and ecological transition of the Paris area, and the mobilisation of the available data in order to develop new solutions to address the key issues in the Climate Plan
Saanich	Mentions recent increased funding for climate action from senior levels of government.

Discussion

Limitations

One limitation is the difficulty of finding plans, that resulted in a limited sample size. For example, 20 city-wide commitments for 100% renewable energy were identified, but we could only locate six published plans. All these plans were for the same climate, with no variation, so the findings may not be widely applicable to cities with other climates. The variation in the plans is another limitation. Frankfurt's plan consisted of an in-depth feasibility study which had been conducted on the specific and technical details of various scenarios for *100% renewable energy*, the other cities were more high-level visions focusing on policy. Malmö was also unique in that the first planning document studied was a short high-level vision from 2009 and the second document studied was the specific action plan for 2019-2020. Overall, cities can be difficult to compare. As such, the details provided for the qualitative analysis was variable. A final limitation is that although our sampling technique was thorough, searching in English may have resulted in limited plans. We mostly identified plans from English speaking countries (US, UK, Canada).

Results

The results demonstrate the challenge of transitioning to *100% renewable energy* in urban cities, and the need to understand how to achieve it. As of 2010, there were 4,231 cities with 100,000 people or more (Schlomo et al., 2016b, p. 12). Our findings show only 342 commitments and achievements. There are many more city-wide commitments (209) than less ambitious city operation commitments (69), while 41 commitments are unconfirmed to be city-wide or for city operations. There are more city-wide commitments and achievements to carbon neutrality (109) and 100% renewable electricity (97) than to 100% renewable energy (20). Seventeen urban cities have achieved 100% renewable electricity, but none has achieved more ambitious goals of city-wide 100% renewable energy or carbon neutrality. Far more cities have adopted city-wide plans for carbon neutrality (48), than for 100% renewable electricity (26) or 100% renewable energy (6). In addition, because there are no urban cities that have achieved *100% renewable energy* or *carbon neutrality* city-wide, an examination of how urban cities achieve *100% renewable energy* is limited to plans that are adopted, although not implemented. More research and practice are needed on the implementation, follow-up, and monitoring stages of the energy planning process of urban cities' *100% renewable energy* plans. Given the urgency to respond to the climate crisis and protect people and the planet, these results on the status of 100% renewable energy and carbon neutral plans for cities are concerning. However, municipalities and local authorities often have limited scope to act; many may be depending on regional, state, provincial or national climate change and renewable energy transition plans.

Due to the high, and potentially growing, spatial density of energy demand in urban cities, it is unclear how urban cities can rely on renewable energy, characterized by low spatial density of supply, that can create spatial planning pressures (Hoicka & MacArthur, 2019; Ramirez Camargo & Stoeglehner, 2018; Smil, 2010, 2015). The results find that urban cities are planning demand reduction and energy conservation (including through more compact/complete land use design) and improving energy efficiency first, to greatly reduce their energy demand and more easily switch to renewable energy. Only Frankfurt offered a detailed analysis of the scale of demand reduction. All six urban cities studied are in temperate climates, indicating this type of climate is likely more favourable for increasing walking, biking, and other human-powered modes of transportation, which helps reduce transportation demand. All cities specified that renewable energy will be generated within city limits, whether through on-site generation, neighbourhood or district scale generation, or within city limits (scale not specified). The technologies and innovations within city limits were solar rooftop; on-site geothermal, on-site solar, biogas, and wind; geothermal heating; renewable natural gas; microgrids; and district energy / district heat and cooling. Three

cities (Paris, Frankfurt, and Malmö) will prioritize renewable energy production within city limits. All cities also plan to rely on importing renewable energy from outside of their geographic limits. The six analysed cities are following two different strategies. Paris, Malmö and Frankfurt plan to engage surrounding districts and authorities in a decentralized strategy. Saanich, Vancouver, and Victoria are in British Columbia, Canada, and are serviced by BC Hydro, a provincial utility. These three cities will rely on electricity provided by the public utility. These results demonstrate that the challenge of power density cannot be easily overcome without producing energy outside the city. One particular concern, then, is that the literature discusses that the shift to renewable energy in cities requires construction and maintenance of access roads to wind turbines; buffer zones between areas of human habitation; and extensive transmission rights-of-way to export electricity from sunny or windy areas (for example) to major urban and industrial areas (Smil, 2010, p. 17). However, cities do not discuss these aspects even though urban cities discuss importing energy from outside the city.

Cities demonstrate a combination of communities of place and interest, because while cities will endeavor to produce energy locally, it will be necessary for urban cities to 'import' at least some renewable energy in order to meet their urban city demand. The motivations of the cities' renewable energy plans align with the motivations discussed in the literature for communities of place and interest, as the cities' visions include both local and non-local benefits such as energy literacy and cost savings/affordability (communities of place), and efficiency, jobs/employment, and sustainable energy supply (communities of interest). Plans demonstrate a blend of local involvement in energy plan implementation by residents and community organizations and the need for involvement by many non-local actors, such as other municipalities; regional, provincial/territorial/state, and federal governments; private businesses; and utilities. Involvement of local Indigenous communities is hardly discussed. Plans discuss a variety of local benefits for residents and marginalized groups but lack real discussion of local Indigenous benefits. The cities also discuss benefits for non-local groups such as private businesses and tourists. Therefore, the results show that the cities' plans also reflect a combination of communities of interest and place in terms of their distribution of benefits. All but one city (Frankfurt) identify plans in other sectors. These results show the need to transition across multiple sectors and include specific plans and strategies for each sector.

Conclusion

Climate change requires urgent action in cities to prevent catastrophic results (Bazaz et al., 2018; IPCC, 2018). The results of this research demonstrate how challenging and ambitious it is for urban cities to achieve 100% renewable energy, and that we need to understand how urban cities can achieve this ambitious goal. Cities both impact and are impacted by climate change. Cities are increasingly becoming involved in local energy planning and 276 urban cities globally were found to have committed to or achieved various levels of 100% renewable energy. Still, the findings suggest no 'urban city' has successfully achieved 100% renewable energy or carbon neutrality city-wide yet while 17 urban cities have achieved 100% renewable electricity. While there were many commitments to renewable energy, over half of these have not developed a plan yet, so they are early on in their planning process. Only six urban cities have adopted plans towards 100% renewable energy city-wide. These results are concerning since urgent action is required to combat the climate crisis. However, pursuing 100% renewable energy is not the only action cities are taking, as many others are working on reducing their emissions and switching to increase their renewable energy supply without transitioning 100%. Political support from different levels of government is needed to achieve ambitious renewable energy commitments.

Urban cities will add more local energy generation, although none of the urban cities' high power densities of demand can be met with renewable energy production within the city. Urban cities will need to work with other neighbouring municipalities, levels of government, and stakeholders outside the city to achieve 100% renewable energy. However, they do not discuss the need for access roads, transmission right-of-way, and buffer zones in their plans despite needing to import energy.

The plans all recognize the social aspects of the renewable energy transition, including stakeholder involvement, and benefits to stakeholders, and motivations. The plans reflect a combination of communities of place and interest, meaning that while urban cities have some locally-oriented motivations, and urban cities endeavor to produce as much energy locally as possible, while involving and benefiting local people, it is not possible to switch entirely to local energy generation within dense urban cities, and therefore a variety of stakeholders will need still to be involved, including communities outside of the urban areas, and benefits and motivations will not be entirely local.

Further research can address how urban cities achieved less ambitious goals, such as including the 17 that achieved *100% renewable electricity*; that achieved *100% renewable energy (city operations only*), and one that achieved *carbon neutrality (city operations only*). Ongoing research can also be done on plans as they make their way through the planning process to plan implementation, and then monitoring. Research could be also be conducted on the content of cities' plans which have adopted other ambition categories such as *carbon neutrality*, *100% renewable electricity*, and goals toward city operations. Further research can also address stakeholder involvement in the development of plans. This further research could include in-depth research and analysis into the process of making the plans, including the stakeholders involved and their level of participation. This analysis could use the framework of community energy and/or energy democracy. The economic aspect of the renewable energy transition in cities is another potential area for further research. Cities' economies could be evaluated for their ease of transitioning to renewable energy. For example, Vancouver and Malmö identify in their plans that their *100% renewable energy* goal will further establish them as leaders in the green economy and contribute to green branding. Whereas, for other cities it might be more difficult or less desirable to transition from their established economy.

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Appendices

Appendix A: Organizations Used to Create List of Urban Cities

Source of Organizations

The organizations were compiled using combinations of keyword searches; advice from professors and colleagues and checking reference lists of academic articles relating to (renewable) energy and cities. Identifying organizations was carried out through internet searches of keywords such as "100% renewable energy", "100% renewable cities," "100% renewable energy city organizations," "smart energy cities" and "renewable energy organizations." Some organizations were discovered from the websites of other organizations (often through networks). In addition, reference lists of scholarly articles relating to climate change or energy and cities for organizations were checked.

Table 14: Organizations Used for Creating List of Urban Cities

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
1	100 percent.org	"Mapping renewable energy efforts across the globe". This website is designed to document, analyze, and disseminate current practice, projects, and plans for communities, cities and countries determined to be entirely independent from fossil fuel and nuclear power. https://www.100-percent.org/	Provides cities, towns and villages targeting 100% renewable energy.	Global	Not applicable.	https://www.100-percent.org/target-achieved/ https://www.100-percent.org/category/city-town-village/?tag=work-in-progress
2	100% RE Ontario	Encourages commitment of Ontario switching to 100% renewable energy. http://www.100reontario.org/	Provides information on switching to 100% renewable energy in Ontario, including which Canadian communities have committed to 100% RE.	Ontario / Canada	Not applicable.	http://www.100reontario.org/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
3	American Cities Climate Challenge Renewables Accelerator (City Renewables .org)	The Renewables Accelerator provides cutting-edge tools, resources, and technical assistance to help U.S. cities advance ambitious renewable energy goals. The partnership supports the Bloomberg American Cities Climate Challenge and the Urban Sustainability Directors' Network cities with renewable energy commitments. They work with cohorts of cities grouped around key renewable procurement methods to deliver knowledge, tools, assistance, and peer learning to quickly implement and scale clean energy solutions. https://cityrenewables.org/city-stories/	Has page on "city stories"	American	Cities may participate in program	https://cityrenewables.org/city-stories/
4	Bluedot	Bluedot is a national grassroots movement based on the idea that everyone in Canada deserves the right to a healthy environment, including clean air and water, and a say in decisions that affect our health and well-being. https://bluedot.ca/wp-content/uploads/2017/06/Municipal-Toolkit-Guide-8.pdf	Contains some information on municipalities relating to 100% renewable energy.	Canada	Not applicable.	https://bluedot.ca/wp-content/uploads/2017/06/Municipal-Toolkit-Guide-8.pdf

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
5	C40 Cities	C40Cities is a network of the world's megacities committed to addressing climate change. It supports cities to collaborate effectively, share knowledge and drive meaningful, measurable, and sustainable action on climate change. C40 cities connects 94 cities to take bold climate action. Mayors of C40 cities are committed to delivering the most ambitious goals of the Paris Agreement at the local level and cleaning the air we breathe. https://www.c40.org/why_cities	Provides list of cities around the world committed to climate change mitigation; also has case studies, useful articles etc.	Global	C40 cities are required to have a plan to deliver their contribution towards the goal of constraining global temperature rise to no more than 1.5 degrees Celsius above the pre-industrial average.	https://www.c40.org/press_releases/25-cities-emissions-neutral-by-2050

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
6	Carbon Disclosure Project (CDP)	CDP is a non-profit organization which focuses investors, companies and cities on taking action to build a truly sustainable economy by measuring and understanding their environmental impact. CDP helps cities disclose their environmental activities, understand their impact and take action. CDP provides a global platform for cities to measure, manage and disclose their environmental data. https://www.cdp.net/en	Includes lists of cities getting at least 70% and up to 100% of their energy from renewable energy.	Global / regional offices and local partners in 50 countries	CDP works with over 800 cities measuring and disclosing environmental data each year to manage emissions, build resilience, protect from climate impacts and create better places to live and work. These cities are disclosing over 8,000 urban sustainability actions, demonstrating their commitment to building a sustainable economy and tackling climate change.	https://www.cdp.net/en/cities/world-renewable-energy-cities https://www.cdp.net/en/cities/cities-scores https://data.cdp.net/Renewable-Energy/Cities-Renewable-Energy-Targets/hztn-by6p https://www.cdp.net/en/articles/cities/over-100-global-cities-get-majority-of-electricity-from-renewables https://www.cdp.net/en/articles/cities/london-a-zero-carbon-future https://www.cdp.net/en/articles/cities/adelaide-leading-australia-towards-renewables https://www.cdp.net/en/articles/cities/burlington-100-renewable-electricity-city

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
7	Carbon Neutral Cities Alliance (CNCA)	The Carbon Neutral Cities Alliance (CNCA) is a collaboration of leading global cities working to cut greenhouse gas emissions by 80-100% by 2050 or sooner — the most aggressive GHG reduction targets undertaken anywhere by any city. The alliance aims to address what it will take for leading international cities to achieve these deep emissions reductions and how they can work together to meet their goals more efficiently and effectively. https://carbonneutralcities.org	Includes 21 global cities committed to emission reduction of 80-100%. However, these cities are not all necessarily aiming for 100% renewable energy.	Global	To be considered for membership, cities must fulfil criteria including: city council has formally adopted community-wide carbon neutrality goal across all sectors (electricity, thermal, transportation, waste); city has developed or is currently developing community-wide carbon neutrality implementation plan; city has dedicated budget and staff allocated to implementing carbon neutrality implementation plan; and the city is committed to achieve participation in the Alliance. There is also a process to become a member including an existing member's nomination, questionnaire and call with the steering committee involving a pitch.	https://carbonneutralcities.org/cities/ (webpage for each city)

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
8	Cities100	Cities 100 report features 100 leading climate action projects from cities around the world. The report demonstrates that cities' leadership on the climate crisis provides the added benefit of creating safe, liveable and equitable cities for all citizens. Cities100 is a collaboration between C40 Cities and Nordic Sustainability, funded by the Danish Philanthropic association Realdania. https://www.cities100report.com/about	Shows how cities are tackling climate change. The annual report focuses on how cities are making the case for climate action. One section focuses specifically on clean energy.	Global	The Cities100 application process included a number of quantitative survey questions designed to provide insights into the process of the entire project development and not merely the final project outcome.	https://issuu.com/nordicsustainability/docs/cities100_2019_report https://static1.squarespace.com/static/5d11f3107356b70001d20ff9/t/5d97792a8d934a7e2189a0ad/1570208084708/Clean+Energy.pdf
9	David Suzuki Foundation	National non-profit organization working to conserve and protect the natural environment and create a sustainable Canada through evidence-based research, education and policy analysis. Collaborates with non-profit and community organizations, all levels of government, businesses and individuals. https://davidsuzuki.org/our-work/cities/	Does not provide specific list of cities or communities committed to 100% renewable energy. Provides 'how' information on renewable energy solutions.	Canada	Not applicable.	https://davidsuzuki.org/action/call-for-a-renewable-regina/ https://davidsuzuki.org/expert-article/montreals-collaborative-model-shows-how-cities-can-become-climate-leaders/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
10	Energy Cities	Energy Cities is a network of 1.000 local governments in 30 countries. They believe that the energy transition is about more than renewable energy or great technologies: it is about a wise use of resources while strengthening local participation and well-being in a democratic Europe. https://energy-cities.eu/join-us/	Has articles about 100% RE goals in cities; Renewables page; members page	Europe	Members are local authority representatives from 30 countries. The network gathers frontrunners and energy transition beginners, city officials and technical experts. Cities of all sizes, their municipal agencies or companies, or regional authorities and their subordinated organizations can join. Energy Cities welcomes all local and regional authorities willing to engage in the energy transition. There are annual fees adapted to the specific context of members and depending on number of inhabitants (635-5000 euros). Members official demonstrate their will to take the energy transition seriously	https://energy-cities.eu/seven-cities-on-a-zero-carbon-journey/ https://energy-cities.eu/wp-content/uploads/2018/11/publi_100pourcent_final-web_en.pdf https://energy-cities.eu/best-practice/frankfurt/ https://energy-cities.eu/best-practice/rethinking-urban-lifestyles-to-transform-san-sebastian-into-a-carbon-neutral-city-in-2050/ http://energy-cities.eu/Stuttgart-towards-a-carbon-neutral-city-thanks-to-a-local-energy-ownership/ https://www.citiesoftomorrow.eu/news/road-climate-neutral-cities-3-lessons-leuven https://energy-cities.eu/seven-cities-on-a-zero-carbon-journey/ https://energy-cities.eu/project/zero-carbon-cities/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
11	Global Covenant of Mayors for Climate and Energy (GCoM)	GCoM is the largest global alliance for city climate leadership, built upon the commitment of over 10,000 cities and local governments. The cities and partners of the Global Covenant of Mayors for Climate & Energy share a long-term vision of supporting voluntary action to combat climate change. https://www.globalcovenantofmayors.org/	Provides cities committed to process of climate action. Does not necessarily mean they are committed to 100% renewable energy.	Global – 10,000 cities and local govts from 6 continents and 139 countries. Regional/National covenants also established	Any city or town in the world can commit, regardless of size or location. To join GCoM, governments must communicate their commitment to their citizens and local media using the communications toolkit; develop citywide knowledge, goals and plans that aim at least as high as their county's own climate protection commitment(s) or Nationally Determined Contribution (NDC) to the Paris Climate Agreement; develop a greenhouse gas emissions inventory; assess climate risks and vulnerabilities of the city; define ambitious climate mitigation, resilience and energy targets; and create full climate action plans; and track and report progress on a regular basis.	https://www.globalcovenantofmayors.org/press/join-one-planet-charter-lets-step-climate-action-2018/ https://www.globalcovenantofmayors.org/press/scores-of-cities-commit-to-bold-climate-action-to-deliver-on-the-highest-ambition-of-paris-agreement/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
12	Go 100% RE	"Making 100% the new normal" - Goal is to initiate dialogue about 100% RE, build capacity and educate policymakers about the opportunities, case studies and stories that are happening all over the world. Explore success stories, pioneers, best practices and policies from all over the world and see how 100% renewable energy is already reality today. https://www.global100re.org/index.php/about-us/	Articles about new commitments to 100% renewable energy.	Global (based in Bonn, Germany)	Members are organizations. Could not find specific requirements.	http://www.global100re.org/index.php/2015/06/25/oxford-county-commits-to-100-renewable-energy-by-2050/ http://www.global100re.org/index.php/2016/10/06/what-does-100-re-mean-for-cities/
13	Go 100% Renewable Energy	Global community that shares the vision that supplying electricity, heating, and transportation energy needs within 100% sustainable renewable sources is urgent and achievable. http://www.go100percent.org/cms/index.php?id=3	They are building an interactive map of 100% renewable energy-related projects and goals around the world	Global	Not applicable.	http://www.go100percent.org/cms/index.php?id=4; http://www.go100re.net/wp-content/uploads/2017/05/100RE-Building-Blocks.pdf
14	ICLEI (governments for sustainability)	ICLEI is a network of local and regional governments committed to sustainable urban development. ICLEI influences sustainability policy and drives local action for low emission, nature-based, equitable, resilient and circular development. https://iclei.org/en/100RE.html	Members are governments committed to sustainability. Also has page outlining 100% RE Cities and Regions Network leaders, governments leading a renewable energy shift in their jurisdictions.	Global (active in over 100 countries, 1,750 local and regional govts)	Membership is open to all local and regional governments, as well as their global, regional, national and subnational associations. They contribute an annual membership fee that varies regionally and according to population and gross national income per capita.	https://iclei.org/en/Meet_the_cities_and_regions.html https://iclei.org/en/media/how-to-kickstart-the-circular-transition-learnings-from-circular-turku https://talkofthecities.iclei.org/new-policy-brief-released-towards-carbon-neutral-circular-economies-at-the-regional-level/ https://talkofthecities.iclei.org/how-copenhagen-aims-to-become-the-worlds-first-carbon-neutral-capital/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
15	International Renewable Energy Agency (IRENA)	Intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. https://www.irena.org/	Provides case studies on countries, states, islands committed to 100% renewable energy.	Global	Membership in the agency is open to those states that are members of the United Nations, and to regional intergovernmental economic-integration organizations. Members must be willing and able to act in accordance with the objectives and activities laid down in the statute (includes things like desire to promote the widespread and increased adoption of renewable energy with a view to sustainable development; convinced of the major role that renewable energy can play in reducing greenhouse gas concentrations in the atmosphere, contributing to the stabilization of the climate system and allowing for a sustainable, secure and gentle transit to a low-carbon economy.	https://coalition.irena.org/-/media/Files/IRENA/Coalition-for-Action/IRENA_Coalition_100percentRE_2019.pdf https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Dec/IRENA_Cities_2018f_Vancouver.pdf?la=en&hash=45A3231EC56098A505E2E0EAA3AF845312A03B7B https://irena.org/newsroom/articles/2019/May/2050--Vancouver-roadmap-to-urban-sustainability https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Dec/IRENA_Cities_2018e_Malm.pdf?la=en&hash=15AAEB18677CA4C7575A1D86F75E9BA6C941661A

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
16	National Renewable Energy Laboratory (NREL)	NREL advances the science and engineering of energy efficiency, sustainable transportation and renewable power technologies and provides the knowledge to integrate and optimize energy systems. NREL researches energy systems and technologies and the science behind them for a future powered by affordable, abundant and clean energy. https://www.nrel.gov/	Provides some articles about how particular cities are using 100% renewable energy (i.e. NREL partners with City of Aspen to develop and implement strategy to reach 100% renewable energy).	National – United States	Not applicable.	https://www.nrel.gov/docs/fy15osti/62490.pdf
17	National Resources Defence Council (NRDC)	The NRDC is an environmental organization which works to safeguard the earth, its people, its plants and animals, and the natural systems on which life depends. They combine the power of over 3 million members and online activists with the expertise of lawyers, scientists and policy advocates across the globe to ensure the rights of all people to air, water, and the wild. They have programs in areas including climate and clean energy. https://www.nrdc.org/about	Contains articles on cities becoming zero carbon, climate commitments, etc. Has map for commitments including cities across the States committed or achieving climate goals: https://www.nrdc.org/resources/race-100-clean	American	Not applicable.	https://www.nrdc.org/news/boulder-colorado-going-100-percent-renewable https://www.nrdc.org/experts/luis-martinez/atlanta-leading-southeast-get-100-renewable-energy https://www.nrdc.org/resources/race-100-clean

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
18	Partners for Climate Protection (PCP) program by Federation of Canadian Municipalities (FCM)	PCP program is part of ICLEI and Federation of Canadian Municipalities helps municipalities do their part for climate change and reducing greenhouse gas emissions. The five step Milestone Framework guides in actions against climate change by reducing emissions in municipalities. https://fcm.ca/en/programs/partners-climate-protection	Lists municipalities working towards creating climate change plan, but not necessarily 100% RE plan. Provides case studies on municipalities achieving milestones.	Canada (350+ cities, 180+ local climate change action plans prepared)	Membership is free and gives access to tools, case studies, and other informational resources and support from PCP Secretariat and regional climate advisors. Members must: move through the Milestone Framework within 10 years of joining; report on progress at least once every two years; email if contact information changes; actively participate in program activities and share experience with other network members. Members must first have council adopt 'joining resolution'; appoint one staff member and one elected official to be main PCP contacts; and email adopted council resolution along with staff member's and elected official's contact information.	https://fcm.ca/sites/default/files/documents/resources/report/partners-for-climate-protection-national-measures-report-2015-av-pcp.pdf https://fcm.ca/en/news-media/backgrounder/fcmp/communities-across-canada-receive-support-159-initiatives-07082018https://fcm.ca/en/case-study/mcip/victoria-shows-leadership-in-ghg-emissions-reductions

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
19	Ren 21: Renewables Now!	REN21 is a renewable energy community of actors from science, governments, NGOs, and industry. They provide up to date and peer-reviewed facts, figures and analysis of global developments in technology, policies, and markets. Their goal is to enable decision-makers to make the transition to renewable energy happen – now. https://www.ren21.net/	REN21 provides reports including "Renewables in Cities: 2019 Global Status Report" which includes information on cities with 100% RE targets.	Global	Not applicable. REN21 members are industry associations, governments, inter-governmental organizations, NGOs, and academic and scientific institutions.	https://www.ren21.net/wp-content/uploads/2019/05/REC-2019-GSR_Full_Report_web.pdf
20	Renewable Cities	Renewable cities is a program of Simon Fraser University's Morris J. Wosk Centre for Dialogue. Their mission is to support cities through the transition to 100% RE and increased energy efficiency. Using research-based dialogue, collaboration, and thought leadership they work towards urban energy solutions with cities, governments, the private sector, utilities, researchers, and civil society. https://www.renewablecities.ca/	Discusses countries and cities that have achieved or are targeting 100% renewable energy. They have a "Progress Update: 100% Renewable Energy and Canadian Cities" and resource list of cities.	Global / Canada	Not applicable.	https://www.renewablecities.ca/news-updates/100-per-cent-renewable-energy-and-canadian-cities https://www.renewablecities.ca/resources

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
21	Renewables Networking Platform	The European platform facilitating, advancing, fostering, and connecting the debate about renewables. This platform aims at connecting the relevant European, national, regional and local actors to facilitate the development of sound policies which ensure that the minimum 32% renewables target for 2030 is met while monitoring best practices and obstacles in policies at national and sub-national levels. This program runs until Feb 2021. https://www.renewables-networking.eu/cities	Includes European case studies on renewable energy cities, including 100% RE plan for Frankfurt, Germany.	Europe	Not applicable.	https://www.renewables-networking.eu/documents/Case-Study-Frankfurt-DE.pdf https://www.renewables-networking.eu/documents/HU-Kaposvar.pdf https://www.renewables-networking.eu/documents/FI-HINKUforum.pdf https://www.renewables-networking.eu/documents/ES-ElHierro.pdf
22	Rocky Mountain Institute (RMI)	RMI is an independent, nonpartisan non-profit. RMI's mission is to transform global energy use to create a clean, prosperous and secure low-carbon future. RMI engages businesses, communities, institutions and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI is helping cities, communities, states and regions meet their energy and climate goals, boost economic growth, and achieve the goals set out in the Paris Accord. https://rmi.org/impact/carbon_free_pathways/	Provides articles on renewable energy targets and cities.	RMI has global reach and reputation	Not applicable.	https://rmi.org/what-good-are-city-clean-energy-targets/ https://rmi.org/cities-in-red-and-blue-states-act-for-a-clean-energy-future/ https://rmi.org/four-creative-ways-cities-are-transitioning-to-a-clean-energy-future/ https://rmi.org/fulfilling-americas-pledge-cities-lead-clean-energy-procurement/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
23	Sierra Club	The Sierra Club is a grassroots environmental organization. They have a Ready for 100 Campaign. https://www.sierraclub.org/?_ga=2.209885845.103570318.1575916697-1943657938.1575916697	Provides list of cities committed to 100% renewable energy.	United States	Not applicable.	https://www.sierraclub.org/ready-for-100/commitments https://www.sierraclub.org/sites/www.sierraclub.org/files/blog/1846%20RF100-CaseStudies2018_Report_06_web.pdf
24	Smart Cities Info System (SCIS)	SCIS is a knowledge platform to exchange data, experience, and know-how and to collaborate on the creation of smart cities, providing a high quality of life for its citizens in a clean, energy efficient and climate friendly urban environment. SCIS brings together project developers, cities, research institutions, industry, experts and citizens from across Europe. Launched with support from the European Commission, SCIS encompasses data, experience and stories collected from completed, ongoing and future projects. Focusing on energy, mobility & transport and ICT, SCIS thus showcases solutions in the fields of energy-efficiency in buildings, energy system integration, sustainable energy solutions on district level, smart cities and communities and strategic sustainable urban planning. https://smartcities-infosystem.eu/	Includes knowledge base of 64 demonstration and urban planning projects and their demonstration sites (not all applicable as 100% renewable energy cities).	Europe	Not applicable.	https://smartcities-infosystem.eu/sites/default/files/concerto_files/concerto_publications/2014-01_concerto_premium_recommendations_for_policy_makers_final.pdf https://smartcities-infosystem.eu/sites/default/files/document/the_making_of_a_smart_city_-_best_practices_across_europe.pdf

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
25	The Atmospheric Fund (TAF)	TAF is a regional climate agency that invests in low-carbon solutions for the Greater Toronto and Hamilton Area and helps scale them up for broad implementation. They are experienced leaders and collaborate with stakeholders in the private, public and non-profit sectors who have ideas and opportunities for reducing carbon emissions. TAF advances the most promising concepts by investing, providing grants, influencing policies and running programs. They are particularly interested in ideas that offer benefits beyond carbon reduction such as improving people's health, creating new green jobs, boosting urban resiliency, and contributing to a fair society. https://taf.ca/about-us/	Contains some articles on cities becoming zero carbon.	Canada	Not applicable.	https://myhomepage.ca/markham-commits-becoming-canadas-largest-net-zero-emissions-city/
26	The Solutions Project	The Solutions Project accelerates the transition to 100% clean energy by championing a movement that is more inclusive, more collaborative, and more celebratory. Through storytelling, grantmaking, and capacity building, we honor clean energy leaders, invest in promising solutions and build relationships between unlikely allies. https://thesolutionsproject.org/	Contains list of US cities committed to 100% RE. Website also includes map of 100% clean energy vision for cities in US and Canada.	North American, mostly United States	Not applicable.	https://docs.google.com/document/d/12jDSqUx3OV10aWrYu2i6e9Xbcw2QKDW8zt8vzRwv9yw/edit https://thesolutionsproject.org/why-clean-energy/#/map/cities/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
27	Track0	Track0 is an independent, not-for-profit organization serving as the hub to support all of those transitioning to a clean, fair and bright future for future generations around the world compatible with the goals set out in the Paris Agreement. They convene leaders and provide strategic research, training, advice, communications and networking support to governments, businesses, investors, philanthropies, communities and campaigns run by civil society. http://track0.org/cities-regions/	Provides a chart of cities and regions commitments to long-term goals, including GHG reductions, carbon neutral, or 100% Renewables target.	Global	Not applicable.	http://track0.org/cities-regions/
28	UK100	UK100 is a network of highly ambitious local government leaders, who have pledged to secure the future for their communities by shifting to 100% clean energy by 2050. UK100 is the only network for UK local authorities, urban, suburban, and rural focused climate and clean energy policy. They connect local leaders to each other, to business and to national government, enabling them to showcase their achievements, learn from each other and speak collectively to accelerate the transition to clean energy. https://www.uk100.org/	Lists member cities and towns in Britain which are pledging 100% clean energy by 2050.	UK/Britain	Members take the UK100 pledge. Which includes the ambition of making all towns and cities across the UK 100% clean before 2050.	https://www.uk100.org/our-members/

No	Organization	About / Main Website	Useful for List?	Scale / Location	Entry Requirements	Webpages Used for List
29	We Are Still In	We Are Still In is a declaration made by mayors, governors, and business leaders as a promise to world leaders that Americans not retreat from the global pact to reduce emissions and stem the causes of climate change. It is a bottom-up network supported by many individuals and organizations. https://www.wearestillin.com/about	Lists cities and countries that "Are still in" and still support climate action. Provides articles on cities taking climate action.	America	Not applicable.	https://www.wearestillin.com/signatories https://www.wearestillin.com/organization/arlington-ma-0 https://www.wearestillin.com/organization/boulder-co-0 https://www.wearestillin.com/organization/concord-nh https://www.wearestillin.com/organization/madison-wi
30	Zero Energy Project	The Zero Energy Project is a non-profit educational organization whose goal is to help home buyers, builders, designers, and real estate professionals take meaningful steps towards radically reducing carbon emissions and energy bills by building zero energy homes and near zero energy homes. they envision positive energy homes which also power vehicles in the future. https://zeroenergyproject.org/our-mission/	Contains webpage on cities heading towards zero carbon.	American	Not applicable.	https://zeroenergyproject.org/advocate/cities-on-a-path-to-zero/ https://zeroenergyproject.org/2017/02/11/getting-zero-carbon-menlo-park/ https://zeroenergyproject.org/2017/03/20/cities-leading-way-zero-energy/ https://zeroenergyproject.org/2014/09/16/net-zero-energy-news-september-16-2014/

Table 15: Organizations Checked but not Used for Creating List of Urban Cities

No.	Organization	About / Main Website	Usefulness for List of Cities	Scale / Location	Entry Requirements
1	American Council on Renewable Energy (ACORE)	Non-partisan, national organization which works with its members to educate policymakers about effective policies that support investment and deployment of renewable energy and related grid technologies. https://acore.org/	Focused on investment, not on cities, members are organizations and not cities / communities.	United States (based in Washington , D.C.)	Annual dues, different membership levels ($999-$25,000). Member benefits include: drive policy & market trends; access market intelligence; connect across industry; highlight commitment to renewables
2	Association for Renewable Energy and Clean Technology (REA)	Not-for-profit trade association with goal to champion members and promote a future built on renewable energy and clean technology through developing informed policy and advocating on behalf of members to government. REA is the UK's largest renewable energy and clean technology body, representing over 550 member companies. https://www.r-e-a.net/	More focused on companies and not cities.	UK (based in London)	Members are generators, project developers, fuel producers and distributers, equipment manufacturers and distributers, installers and service providers, and range from major multinationals to sole traders.
3	Canadian Council on Renewable Electricity	Established in 2015 by a group of four industry associations to educate and engage Canadians about the opportunity to expand production and use of renewable electricity across the county. It is an initiative by Canada's leading, national renewable electricity associations to build public support for increased development of our abundant renewable electricity resources to further decarbonize the energy system. https://renewableelectricity.ca/	Members are renewable electricity industry associations in Canada. Could not find resources regarding cities or communities committed to 100% renewable energy.	Canada	Members must be Canadian national organizations representing renewable electricity industry sector; must be governed by an elected board of directors and bylaws; must be federally or provincially incorporated and must be active nationally.
4	City Energy Project	City Energy Project is a joint initiative of the Institute for Market Transformation and the Natural Resources Defense Council. It supports bold yet practical ways to deploy energy efficiency at the city level to boost local economies, reduce pollution, and create healthier, more prosperous communities nationwide. The project works with each participating city to develop tailored set of policies and programs to dramatically improve the energy performance of its building stock. https://www.cityenergyproject.org/	No information on webpage specifically relating to 100% renewable/carbon neutral city goals.	American	Not applicable.

No.	Organization	About / Main Website	Usefulness for List of Cities	Scale / Location	Entry Requirements
5	Clean Air Partnership (CAP)	CAP is a charitable environmental organization launched in 2000 with the mission to help municipalities become more sustainable, resilient, vibrant communities where resources are used efficiently, the air is clean to breathe, and greenhouse gas emissions are minimized. CAP achieves this mission through research, knowledge transfer, and fostering collaboration among all orders of government, academia, NGOs and additional stakeholders. https://www.cleanairpartnership.org/projects/	Includes resources on climate change and municipalities, but does not list cities committed to achieving renewable energy targets.	Ontario/ Canada	Not applicable.
6	Clean Energy Canada	Climate and clean energy program within the Morris J. Wosk Centre for Dialogue at Simon Fraser University, working to accelerate Canada's clean energy transition by sharing the story of the global shift to renewable energy sources and clean technology. CEC conducts original research, convenes influential dialogues, informs policy leadership and builds citizen engagement. https://cleanenergycanada.org/	Does not list cities or communities committed to 100% renewable energy.	Canada	Not applicable.
7	Greenpeace	Greenpeace stands up with communities and holds governments and corporations accountable for issues including transforming energy. https://www.greenpeace.org/canada/en/explore/transform-energy/	Does not list 100% renewable energy cities.	Canada / Global	Not applicable.
8	Pollution Probe	Pollution Probe is a charitable environmental organization that is a leading agent of change at the intersection of communities, health and environment. It defines environmental problems through research, promoting understanding through education and pressing for practical solutions through advocacy. https://www.pollutionprobe.org/category/sectors/energy/	Does not have list of 100% renewable energy cities or communities.	Canada	Not applicable.

No.	Organization	About / Main Website	Usefulness for List of Cities	Scale / Location	Entry Requirements
9	Quality Urban Energy Systems of Tomorrow (QUEST)	QUEST is a non-government organization that works to accelerate the adoption of efficient and integrated community-scale energy systems in Canada by informing, inspiring, and connecting decision-makers. QUEST commissions research, communicates best practices, convenes government, utility and private sector leaders, and works directly with local authorities to implement on-the-ground solutions. QUEST recognizes communities that have embraced these principles by referring to them as Smart Energy Communities. https://questcanada.org/	QUEST's Smart Energy Atlas is an online repository of smart energy projects, policies, programs, plans and resources in Canada. It is free, accessible, interactive, and searchable. It does not directly relate to 100% RE cities/communities. Did not find any municipal/city plans from this resource.	Canada	Not Applicable.
10	Renewable Energy and Energy Efficiency Partnership (REEEP)	REEP develops innovative, efficient financing mechanisms to strengthen markets for clean energy services in low- and middle- income countries, for the benefit of vulnerable populations. REEP is a quasi-international organization under Austrian law. https://www.reeep.org/	Does not focus on cities or 100% renewable energy.	Global	Not applicable.
11	Sustainable Energy for All (SEforALL)	SEforALL is an international organization working with leaders in government, the private sector and civil society to drive further, faster action toward achievement of sustainable development goal 7, which calls for universal access to sustainable energy by 2030, and the Paris Agreement, which calls for reducing GHG emissions to limit climate warming to below 2 degrees C. Drawing on data and evidence, SEforALL identifies a critical path to achieving in achieving SDG7. https://www.seforall.org/	Does not focus on cities or 100% renewable energy.	Global (based in Vienna, Austria)	Not Applicable.
12	Team Zero (Formerly Net Zero Energy Coalition)	Their vision is to make the built environment a positive asset on the carbon balance sheet of the planet. https://teamzero.org/	Focuses more at building level. The site includes an inventory which shows the single and multi-family units that are 'zero energy' as well as commercial buildings.	North America, mainly United States	Not Applicable.

No.	Organization	About / Main Website	Usefulness for List of Cities	Scale / Location	Entry Requirements
13	World Council for Renewable Energy (WCRE)	WCRE is the global voice for renewable energy. It operates independently and free of the vested interests of the present global energy system. It is a non-profit and non-governmental organization focused on developing policies and strategies for renewable energy and bring it into the mainstream of world economy and lifestyle. WCRE's main activity areas include information, agenda setting and networking. https://www.wcre.org/	Did not find any resources on cities pursuing 100% renewable energy.	Global	Not applicable. Members are not cities.
14	World Resources Institute (WRI)	WRI is a global research organization spanning over 60 countries. More than 1000 experts and staff turn big ideas into action at the nexus of environment, economic opportunity, and human well-being. They envision an equitable and prosperous planet driven by the wise management of natural resources. https://www.wri.org/	No list of cities committed to 100% renewable energy or carbon neutrality	Global	N/A

Appendix B: Detailed Coding Categories

Table 16: Detailed Coding Categories

No.	Question	Categories	Rationale/Relevant Literature
1a	Publication/ approval date	Date (Month, year)	
1b	If commitment, what is the timeframe to the target/target deadline?	Target year Interim targets (and what are they?)	Climate change requires urgent action. The IPCC has stated we have until 2030. To see how long cities are expecting to take to achieve 100% RE targets.
2a	What types of energy end uses does 100% RE implemented or target include?	Space Heating (Canada & NRCan, 2020; IEA, 2017; IRENA, 2016; Jaccard et al., 1997) Water Heating (Canada & NRCan, 2020; IRENA, 2016; Jaccard et al., 1997) Cooling (Space) (Canada & NRCan, 2020; IEA, 2017, 2019a; IRENA, 2016) Street Lighting (Canada & NRCan, 2020) Lighting (Canada & NRCan, 2020; IEA, 2019a; IRENA, 2016) Major/Large Appliances (Canada & NRCan, 2020; IEA, 2017) Other Appliances/Electronic Devices (televisions, radios, computers, toasters, etc.) (Canada & NRCan, 2020; IEA, 2017; Smil, 2006) Heat Pumps (IEA, 2017, 2019a) Personal / Passenger Transportation (cars, buses, bicycles, motorcycles, passenger rail, air, boats, ships) (Canada & NRCan, 2020) Commercia/Freight Transportation (trucks, trains, planes, boats/ships/barges) (Canada & NRCan, 2020) Cooking (IEA, 2017; IRENA, 2016) Industrial Processes (grinders, refiners, thermal reducers, etc. (Jaccard et al., 1997, p. 1066) Industrial Motors (IEA, 2017) (Canada & NRCan, 2020; IEA, 2017, 2019a; IRENA, 2016; Jaccard et al., 1997; Smil, 2006)	Canada, G. of, & NRCan. (2020, January 30). *Canada's Secondary Energy Use (Final Demand) by Sector, End Use and Subsector*. Nrcan.Gc.Ca. https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB&sector=aaa&juris=ca&rn=2&page=6 IEA. (2019). *Energy Efficiency 2019* (p. 110). https://www.iea.org/reports/energy-efficiency-2019 **(Page 64 and 67, Table 3.1 and Table 3.3)** IRENA. (2016). *Renewable Energy in Cities* (p. 64). International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf **(Especially Page 16)** Jaccard, M., Failing, L., & Berry, T. (1997). From equipment to infrastructure: Community energy management and greenhouse gas emission reduction. *Energy Policy*, *25*(13), 1065–1074. https://doi.org/10.1016/S0301-4215(97)00091-8 Smil, V. (2006). Chapter 5 Energy in everyday life: From eating to emailing. In *Energy: A Beginner's Guide* (pp. 127–155). Oneworld Publications. http://ebookcentral.proquest.com/lib/york/detail.action?docID=1792139 IEA. (2017). *World Energy Outlook 2017*. International Energy Agency (IEA). https://www.iea.org/reports/world-energy-outlook-2017 (Page 236)
2b	Which energy end-use sectors are targeted?	1. Residential (low-medium density, high density) 2. Commercial (offices, malls, stores, hotels, warehouses, restaurants, places of worship) 3. Institutional (Schools, hospitals, government, university campuses)	Canada, G. of, & NRCan. (2020, January 30). *Canada's Secondary Energy Use (Final Demand) by Sector, End Use and Subsector*. Nrcan.Gc.Ca. https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB&sector=aaa&juris=ca&rn=2&page=6

No.	Question	Categories	Rationale/Relevant Literature
		4. Industrial (mining, quarrying, oil and gas extraction, pulp and paper, iron and steel, smelting and refining, cement, chemicals, petroleum refining, other manufacturing, forestry, construction) (Canada & NRCAN, 2020) 5. Transportation (commercial/freight, personal/passenger) 6. Agriculture (Canada & NRCan, 2020; Davis et al., 2018; EIA, 2019b; IRENA, 2016)	Davis, M., Ahiduzzaman, Md., & Kumar, A. (2018). Mapping Canadian energy flow from primary fuel to end use. *Energy Conversion and Management*, *156*, 178–191. https://doi.org/10.1016/j.enconman.2017.11.012 EIA. (2019, August). *Use of energy in explained*. U.S. Energy Information Administration (EIA). https://www.eia.gov/energyexplained/use-of-energy/ IRENA. (2016). *Renewable Energy in Cities* (p. 64). International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf
3	What are the energy sources implemented or proposed?	Solar Photovoltaic (PV) rooftop Solar PV ground-mounted Solar Hot Water Concentrated Solar Power (CSP) Wind Onshore Wind Offshore Hydro Run of River/Diversion Hydro Resevoir/Impoundment Hydro Pumped Storage Biofuels Biomass Biogas Geothermal Ocean energy – wave energy Ocean energy – tidal energy Ocean energy – salinity gradient energy Ocean energy – thermal energy conversion Nuclear Waste-to-energy/Waste heat/Excess industrial heat (IRENA, 2016, p. 31) Natural Gas Coal Oil Emergent categories. (Barron et al., 2013; IRENA, n.d.-d, n.d.-c, n.d.-a, n.d.-b, n.d.-e, n.d.-f; U.S. Department of Energy, n.d.)	Barron, S., Tooke, T., Cote, S., Sheppard, S., Kellett, R., Zhang, L., Holy, L., Sherriff, M, & vanderLaan, M. (2013). *An Illustrated Guide to Community Energy: Exploring the sustainable energy potential of your neighbourhood*. The Collaborative for Advanced Landscape Planning (CALP). http://web.forestry.ubc.ca/calp/CALP_CommunityEnergyGuide_highRes.pdf Bruckner, T., Bashmakov, I. A., Mulugetta, Y., Chum, H., de la Vega Navarro, A., Edmonds, J., Faaij, A., Fungtammasan, B., Garg, A., Hertwich, E., Honnery, D., Infield, D., Kainuma, M., Khennas, S., Kim, S., Nimir, H. B., Riahi, K., Strachan, N., Wiser, R., & Zhang, X. (2014). Energy Systems. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. Hoicka, C. E., & MacArthur, J. (2019). The Infrastructure for Electricity: A Technical Overview. In K. J. Hancock & J. Allison (Eds.), *The Oxford Handbook of Energy Politics* (pp. 1–36). IRENA. (n.d.). *Bioenergy*. IRENA. Retrieved March 26, 2020, from https://www.irena.org/bioenergy IRENA. (n.d.). *Geothermal energy*. IRENA. Retrieved March 26, 2020, from https://www.irena.org/geothermal IRENA. (n.d.). *Hydropower*. IRENA. Retrieved March 26, 2020, from https://www.irena.org/hydropower IRENA. (n.d.). *Ocean energy*. IRENA. Retrieved March 26, 2020, from https://www.irena.org/ocean

No.	Question	Categories	Rationale/Relevant Literature
			IRENA. (2016). *Renewable Energy in Cities* (p. 64). International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf IRENA. (n.d.). *Solar energy*. IRENA. Retrieved March 26, 2020, from https://www.irena.org/solar IRENA. (n.d.). *Wind energy*. IRENA. Retrieved March 26, 2020, from https://www.irena.org/wind NRCan. (2017). About Renewable Energy. Retrieved December 10, 2019, from Natural Resources Canada website: https://www.nrcan.gc.ca/energy/energy-sources-distribution/renewables/about-renewable-energy/7295 Smil, V. (2015). Making Sense of Power Densities. In *Power Density: A Key to Understanding Energy Sources and Uses* (pp. 190–220). MIT Press. https://books-scholarsportal-info.ezproxy.library.yorku.ca/uri/ebooks/ebooks3/ieee/2016-01-28/1/7120891 Tozer, L., & Klenk, N. (2019). Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance. *Environment and Planning C: Politics and Space*, *37*(3), 539–557. https://doi.org/10.1177/2399654418784949 U.S. Department of Energy. (n.d.). *Types of Hydropower Plants*. Energy.Gov. Retrieved March 26, 2020, from https://www.energy.gov/eere/water/types-hydropower-plants
4	Which technological and innovative solutions are being used?	Community design Retrofits (reductions of up to 50%) Deep energy retrofits (reductions of 50-80%) Behaviour Energy efficiency Smart meters (also called advanced metering) Smart grids Demand-response Energy storage (if so, at what scale: building, neighbourhood, grid?) District heating and cooling Electric Vehicles Reduced energy demand Combined heat and power (CHP) Offsets	To understand technologies and solutions being used to achieve 100% renewable energy and why. Barron, S., Tooke, T., Cote, S., Sheppard, S., Kellett, R., Zhang, L., … vanderLaan, M. (2013, May). *An Illustrated Guide to Community Energy: Exploring the sustainable energy potential of your neighbourhood*. Retrieved from http://web.forestry.ubc.ca/calp/CALP_CommunityEnergyGuide_highRes.pdf Martinot, E. (2016). Grid Integration of Renewable Energy: Flexibility, Innovation, and Experience. *Annual Review of Environment and Resources*, *41*(1), 223–251. https://doi.org/10.1146/annurev-environ-110615-085725 Palensky, P., & Kupzog, F. (2013). Smart Grids. *Annual Review of Environment and Resources*, *38*(1), 201–226. https://doi.org/10.1146/annurev-environ-031312-102947 Rezaie, B., & Rosen, M. A. (2012). District heating and cooling: Review of technology and potential enhancements. *Applied*

No.	Question	Categories	Rationale/Relevant Literature
		Heat pumps Prosumership Prosumage (storage and prosumership) Microgrids Behind the meter generation Hydrogen Distributed Generation Carbon capture and storage Emergent categories (Barron et al., 2013; IEA, 2020; Martinot, 2016; Palensky & Kupzog, 2013; Rezaie & Rosen, 2012; Sovacool et al., 2017; Tozer & Klenk, 2019)	*Energy*, *93*, 2–10. https://doi.org/10.1016/j.apenergy.2011.04.020 Sovacool, B. K., Axsen, J., & Kempton, W. (2017). The Future Promise of Vehicle-to-Grid (V2G) Integration: A Sociotechnical Review and Research Agenda. *Annual Review of Environment and Resources*, *42*(1), 377–406. https://doi.org/10.1146/annurev-environ-030117-020220 Tozer, L., & Klenk, N. (2019). Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance. *Environment and Planning C: Politics and Space*, *37*(3), 539–557. https://doi.org/10.1177/2399654418784949 (Page 10)
5	Where is the energy generated? (if information is available)	Imported from outside city limits Distributed Generation Within city boundaries/limits Emergent categories Not Available	To see whether it is possible for urban areas to have energy generated within city limits, since renewable energy requires more space than traditional energy which is not present in cities. Distributed energy: is the production of electricity or heat near the point of use in the distribution network and other practices that can balance loads at a local scale (Hoicka & MacArthur, 2019, p. 15; Kuzemko et al., 2017, p. 59).
6a	Within which climate does the city exist?	Dry Tropical Temperate Continental Polar (NOAA SciJinks, 2020; Pidwirny, 2006)	Locally sourced renewable energy is dependent on the physical geography of the landscape within and surrounding the city. Arnfield, A. J. (2016). Climate classification. In *Encyclopedia Britannica*. https://www.britannica.com/topic/classification-1703397 NOAA SciJinks. (2020). *What Are the Different Climate Types?* https://scijinks.gov/climate-zones/ Pidwirny, M. (2006). Chapter 7 Introduction to the Atmosphere: Climate Classification and Climatic Regions of the World. In *Fundamentals of Physical Geography* (2nd ed.). http://www.physicalgeography.net/fundamentals/7v.html
6b	Landforms – which major physical features/characteristic are present within the city?	Emergent For example: Volcano Ocean Water Mountain Desert (Wikipedia, 2020; WorldLandForms, 2015)	Wikipedia. (2020). List of landforms. In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=List_of_landforms&oldid=948088732 WorldLandForms. (2015). *List of all Landforms*. WorldLandForms. http://worldlandforms.com/landforms/list-of-all-landforms/

No.	Question	Categories	Rationale/Relevant Literature
7	Which policy instruments are proposed in plans?	**Capacity Building** [Information providing; Increasing skills; Technical analysis; Feasibility studies; Media and marketing campaigns; Demonstration projects; Facilitating community/neighbourhood renewable energy projects/distributed generation] **Building Standards** [Requirements for standards regarding energy or carbon; LEED; Mandates] **Lobby Authorities** [Target change in policy of another level of government, business, or agency beyond control of municipality] **Public Sector Engagement** [Public displays related to energy and carbon; Continued engagement with citizens through committees and other groups; Education and outreach; Energy potentials mapping resources] **Private Sector Engagement** [Engage businesses through awards for top 'green' businesses, etc.] Benchmarking and Reporting [Mandatory for portion of buildings' energy use] **Urban Planning Tools** [Supportive zoning; Supportive fee structures; Streamlining/expediting permit process for renewable energy projects/installations; Building codes; Making buildings 'solar ready'; Social housing programmes requiring affordable housing be solar ready; Solar ordinances/municipal thermal ordinances; Policy coordination across sectors and levels of government; Encouraging modal switching in the transport sector; Biofuel blending mandates; Congestion zones with preferential rules for EVs and renewably powered vehicles] **Financial Incentives** [Direct investment; Feed in tariffs; Tax Exemptions; Grants; Loans; Rewards; Rebates; Clean energy financing; Mobilizing finance; Tradable Green Certificates (TGC); Renewable Energy Certificates (RECs); Feed in Premiums; Guarantees of Origin; Reduce administrative, permitting, inspection barriers to investment; Energy market liberalization/deregulation of monopolistic energy supply and distribution; Power Purchase Agreements (PPA); Property Assessed Clean Energy (PACE); Auctions; Attractive rate structures for smart charging/EV; Renewable Portfolio Standards; Net metering/Net billing] **Financial Penalties** [Fees; Taxes; Removal of fossil fuel subsidies]	To understand the policies being used to achieve 100% renewable energy. Burke, M. J., & Stephens, J. C. (2017). Energy democracy: Goals and policy instruments for sociotechnical transitions. *Energy Research & Social Science*, *33*, 35–48. https://doi.org/10.1016/j.erss.2017.09.024 Fouquet, D. (2013). Policy instruments for renewable energy – From a European perspective. *Renewable Energy*, *49*, 15–18. https://doi.org/10.1016/j.renene.2012.01.075 IRENA. (2016). *Renewable Energy in Cities* (p. 64). International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf (especially pages 38-51) IRENA, REN21, & IEA. (2018). *Renewable energy policies in a time of transition* (p. 112). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_IEA_REN21_Policies_2018.pdf REN21. (2019). *Renewables in Cities 2019 Global Status Report*. Renewables Now. https://www.ren21.net/wp-content/uploads/2019/05/REC-2019-GSR_Full_Report_web.pdf (especially pages 58-59) Sarti, B. (2018). *Policies for the Deployment of Renewable Energies: An Overview*. University of Pennsylvania. Tozer, L., & Klenk, N. (2019). Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance. *Environment and Planning C: Politics and Space*, *37*(3), 539–557. https://doi.org/10.1177/2399654418784949 **(definitions on page 11-12)**

No.	Question	Categories	Rationale/Relevant Literature
		Lead by Example [Binding targets; Activity targeting municipal operations or assets that demonstrates behaviour/technology to be imitated; Municipality integrating renewable energy, etc.; Municipal control over street lighting (renewable/LED); Direct municipal investment into RE power, district energy and transportation infrastructure] **Municipal Energy Supplier** [Deliver carbon and energy changes through municipally controlled utility company; "remunicipalisation": bringing back municipal energy utilities into local public and collective ownership; Community Choice Aggregation (CCA)] (Burke & Stephens, 2017; Fouquet, 2013; IRENA, 2016; IRENA et al., 2018; REN21, 2019; Sarti, 2018; Tozer & Klenk, 2019)	
8	Which stakeholders are involved in implementing the plan? (If mentioned) Who are the intended stakeholders?	Community Members/General Public/Residents Community Staff Elected Officials Consulting Firm/Consultant Non-profit Organization Public Sector (Education, Health, Police) Provincial/Territorial/State Government Federal government Utilities Elders (Indigenous) Local Community Organizations National Organizations Private Business Emergent categories. (Wyse, 2018)	Burke, M. J., & Stephens, J. C. (2017). Energy democracy: Goals and policy instruments for sociotechnical transitions. *Energy Research & Social Science*, *33*, 35–48. https://doi.org/10.1016/j.erss.2017.09.024 Lowitzsch, J., & Baigorrotegui, G. (2019). Institutional Aspects of Consumer (Co-) Ownership in RE Energy Communities. In J. Lowitzsch (Ed.), *Energy Transition* (pp. 663–701). Palgrave Macmillan US. http://ebookcentral.proquest.com/lib/york/detail.action?docID=5630975 Stephens, J. C. (2019). Energy Democracy: Redistributing Power to the People Through Renewable Transformation. *Environment: Science and Policy for Sustainable Development*, *61*(2), 4–13. https://doi.org/10.1080/00139157.2019.1564212 van Veelen, B., & van der Horst, D. (2018). What is energy democracy? Connecting social science energy research and political theory. *Energy Research & Social Science*, *46*(Complete), 19–28. https://doi.org/10.1016/j.erss.2018.06.010 Wyse, S. M. (2018). *'By and For Local People': Assessing How Canadian Local Energy Plans Contribute to the Ideals of Community Energy*. York University.
9	Who will benefit, according to the plan? / Who is intended to benefit from the plan?	Citizens/Individuals Civil society organizations Businesses Households Institutions (e.g., universities and hospitals) Rural communities	Berka, A. L., & Creamer, E. (2018). Taking stock of the local impacts of community owned renewable energy: A review and research agenda. *Renewable and Sustainable Energy Reviews*, *82*, 3400–3419. https://doi.org/10.1016/j.rser.2017.10.050

No.	Question	Categories	Rationale/Relevant Literature
		Indigenous communities Emergent categories (Berka & Creamer, 2018; Wyse, 2018)	Wyse, S. M. (2018). *'By and For Local People': Assessing How Canadian Local Energy Plans Contribute to the Ideals of Community Energy*. York University.
10	What are the expected benefits of the plan?	Revenue – city Revenue – businesses Revenue – individuals Cleaner air Reduced noise pollution Health Quality of Life Empowerment Democracy Social Capital Socio-economic regeneration Affordable energy Knowledge and Skill development Energy literacy Environmentally benign lifestyles Emergent (Berka & Creamer, 2018; Stephens, 2019; Wyse, 2018) Branding/eco-tourism/optics	Berka, A. L., & Creamer, E. (2018). Taking stock of the local impacts of community owned renewable energy: A review and research agenda. *Renewable and Sustainable Energy Reviews*, *82*, 3400–3419. https://doi.org/10.1016/j.rser.2017.10.050 Stephens, J. C. (2019). Energy Democracy: Redistributing Power to the People Through Renewable Transformation. *Environment: Science and Policy for Sustainable Development*, *61*(2), 4–13. https://doi.org/10.1080/00139157.2019.1564212 Wyse, S. M. (2018). *'By and For Local People': Assessing How Canadian Local Energy Plans Contribute to the Ideals of Community Energy*. York University. van Veelen, B., & van der Horst, D. (2018). What is energy democracy? Connecting social science energy research and political theory. *Energy Research & Social Science*, *46*(Complete), 19–28. https://doi.org/10.1016/j.erss.2018.06.010
11	Other Related Plans Identified in the Plan	List them – Emergent Sectors: Buildings Transportation Comprehensive land use plan (Official Plan) Municipal Strategic Plan (i.e. 'Vaughan 2020') Sustainability/Environment Climate Change Plan Economic Development Waste	To understand what specific plans and goals are needed in conjunction to achieve 100% renewable energy (For example, Vancouver has "Zero Emissions Building Plan" to help implement the 100% RE plan).
12a	Is a funding/revenue source identified?	Yes No	
12b	If yes, what is the funding source?	List it.	

Appendix C: Energy Sources

Table 17: Definitions of Energy Sources

Energy Source	Definition
Solar photovoltaics (PV)	The conversion of sunlight into electricity through electronic devices, also known as solar cells (IRENA, n.d.-e).
Concentrated solar power (CSP)	Used to generate electricity in large-scale power plants, though the use of mirrors to concentrate solar rays. The solar rays heat fluid, creating steam which drives a turbine and produces electricity (IRENA, n.d.-e).
Wind	Kinetic energy is created by air in motion, which can be converted into electricity through wind turbines or wind energy conversion systems. Wind turbines can be located both onshore and offshore.
Hydro run of river/diversion	Refers to smaller scale, usually from a facility design to operate in a river without interfering with its flow (IRENA, n.d.-c; U.S. Department of Energy, n.d.).
Hydro reservoir/impoundment	Refers to hydropower dams with a large reservoir which can store water to meet peak demand (IRENA, n.d.-c; U.S. Department of Energy, n.d.).
Hydro pumped storage	Refers to another type of hydropower that stores electricity generated by other sources like solar, wind, and nuclear for later use. Water is pumped uphill to a reservoir located at a higher elevation from a second lower reservoir, where it is stored during low peak times. When energy demand is high, water is released from the upper to lower reservoir to turn a turbine and generate electricity (U.S. Department of Energy, n.d.).
Bioenergy	Obtained from different materials called biomass (biological material in solid, liquid or gas form that has stored sunlight in the form of chemical energy) (NRCan, 2017).
Biofuels (such as ethanol or biodiesel)	Fuels from renewable resources. Biofuels are a convenient renewable substitute for gasoline mostly used in the transport sector (IRENA, n.d.-a; NRCan, 2017). Biofuels also include biogas or renewable natural gas (DeMates, 2013)
Geothermal energy	Geothermal energy is “heat derived from the sub-surface of the earth” (IRENA, n.d.-b).
Wave energy	Involves converters capturing the energy contained in ocean waves to generate electricity (IRENA, n.d.-d).
Tidal energy	Harvests power between high and low tide through either a dam or barrier, tidal-current or tidal-stream technologies (IRENA, n.d.-d).
Salinity gradient energy	Occurs from different salt concentrations where a river empties into an ocean (IRENA, n.d.-d).
Thermal energy conversion	Generates power from temperature different between cold seawater 800 to 1,000 metres deep and warm surface water (IRENA, n.d.-d).
Waste to energy/waste heat/excess industrial heat	Industrial energy recovery involves the capture and reuse of energy generated during industrial processes (Barron et al., 2013).

Appendix D: Technologies and Innovations

This section describes the main technologies considered important in the transition towards renewable energy. These technologies and innovations are included in the coding categories.

Buildings

Buildings and transport are the two biggest energy consumers in cities and therefore are two priority areas for renewable energy use (IRENA, 2016). Energy use in buildings focuses on heating, cooling, cooking and appliances (IRENA, 2016, p.17).

Ways that heating can be transitioned to renewable energy include district heating and cooling (a network of underground, insulated pipes that pump hot or cold water to buildings in a district, neighbourhood or city), biofuel-fired boilers, solar thermal systems (often used for water heating and sometimes space heating), and co-generation (the reuse of heat lost from power generation and industrial processes) (IRENA, 2016, pp. 17-19).

Distributed and decentralized energy generation are important for transitioning to renewables in cities because there is less land area for energy generation within cities. Decentralized renewable energy production is energy supply within the direct vicinity of buildings (such as rooftop solar photovoltaic panels or solar hot water heating) while centralized renewable energy production is when energy generated elsewhere is distributed to buildings through networks (such as district energy networks) (IRENA, 2016, p. 17). Distributed energy is the production of electricity or heat near the point of use in the distribution network (Hoicka & MacArthur, 2019).

District energy (DE) involves "multi-building heating and cooling, in which heat and/or cold is distributed by circulating either hot water or low-pressure steam through underground piping" (Rezaie & Rosen, 2012, p. 3). A district energy system generates heat and sometimes electricity that is distributed to local homes and businesses (Barron et al., 2013). District networks "incorporate an underground system of piping from one or more central sources to industrial, commercial and residential users" (Rezaie & Rosen, 2012, p. 3). DE reduces GHG emissions through: 1) facilitating the use of non-carbon (i.e. renewable) energy; and 2) replacing less efficient equipment with a more efficient central heating system (Rezaie & Rosen, 2012, p. 6). Combined heat and power (CHP) systems are highly efficient energy production systems that supply both electricity and heat (Barton et al., 2010, p. 180).

Air conditioning should come from renewable powered electricity. Cooling can also be supplied by solar cooling systems (such as absorption chillers, adsorption chillers, and desiccant cooling systems (IRENA, 2016, p. 20). Renewably sourced district cooling can use cold water from rivers, lakes or the ocean, waste heat for absorption, and solar energy (IRENA, 2016, p. 20).

Practices involving cooking on open fires are popular especially in rural areas in developing countries, but are harmful to human health. Modern cookstoves using bioenergy or renewably-powered electricity are an important solution (IRENA, 2016, p. 21).

Retrofits can reduce energy use and greenhouse gases by bringing existing buildings up to new, more efficient standards (Barron et al., 2013). Energy efficiency is the "ratio of useful energy output/energy input, usually defined as a percentage" (Hoicka & MacArthur, 2019, p. 4). Energy efficiency allows for minimal energy loss, and less energy used to produce an energy service such as lighting, heating, cooling, or mechanical work (Hoicka & MacArthur, 2019, p. 4). Examples of retrofit strategies include better insulation, energy efficient appliances, LED lighting, window upgrades, upgraded furnace, etc. (Barron et al., 2013).

Heat pumps transfer heat from one location to another. 'Low grade' dissipated energy is extracted from the ground, air or water and released as usable heat within buildings (Barton et al., 2010, p. 178).

Passive house is a building standard that is energy efficient, comfortable, and affordable. Passive houses make the most efficient use of the sun, internal heat sources and heat recovery, and can eliminate the need for conventional heating systems. They use special windows and building envelopes which are well insulated. Passive houses can create energy savings from space heating and cooling of up to 90% compared to typical building stock (Passive House Institute, 2015).

Transport

Solutions for renewable energy in the transport sector include electrification of transport; electric-powered trains, light rail, and metro systems; electric vehicles; biofuels and biogas; and hydrogen. (IRENA, 2016, p. 23). Hydrogen can be used to power vehicles renewably, such as in buses (IRENA, 2016, p. 23).

Smart Integrated Urban Energy Systems

IRENA's third priority area for a transition to renewable energy in cities is creating smart integrated urban energy systems (IRENA, 2016). This means the increase in grid flexibility and smart technology are important for integrating more variable renewables (IRENA, 2016, p. 28). Examples toward smart integrated urban energy systems include demand side management (such as vehicle-to-grid, and demand management for buildings), energy storage (such as battery or thermal storage), smart grids and networks, and integrated urban planning (including street lighting, building design, waste-to-energy, urban agriculture, and landscape planning) (IRENA, 2016).

Demand reduction is the reduction of demand, especially at peak times through reducing energy use or increasing efficiency (Hoicka & MacArthur, 2019, p. 24). What people do has an impact on energy conservation. For example, using public transit, conserving space heating and water heating in homes, cycling and walking, growing gardens, shopping locally and buying efficient appliances are ways that citizens and neighbourhoods can reduce their energy consumption (Barron et al., 2013).

Demand Response is the ability for grid operators or utilities to reduce end-user loads, sometimes on short-notice (Hoicka & MacArthur, 2019, p. 24).

Storage is a useful way of managing the variability of renewables. The five types of electrical storage include mechanical (i.e. pumped hydroelectricity, compressed air, flywheel); electrochemical (i.e. batteries); chemical (i.e. hydrogen, compressed natural gas); electrical (i.e. double-layer capacitors and superconducting magnetic energy storage); and thermal (Hoicka & MacArthur, 2019, p. 23).

The electrification of vehicles also provides opportunities for vehicle-to-grid integration (VGI), energy storage and decarbonization of the electricity and transportation sectors at the same time (Sovacool et al., 2017). Vehicle to grid integration (VGI) is the connection of the electric power system to the transportation system in mutually beneficial ways. Plug-in electric or hybrid vehicles can be switched to supply energy for other energy-uses when not being driven, which is especially valuable during peak energy-use hours. Vehicle batteries are then charged during off-peak hours (Sovacool et al., 2017, p. 379). VGI could help solve the inconsistency and unreliability issue of renewable energy.

Smart grids are one way of enhancing energy control, management and resilience to allow more flexibility (Palensky & Kupzog, 2013). The most widely discussed element of smart grids is smart metering, which provides access to automated meter readings which can be used for time-varying energy tariffs and should save energy through improved feedback about energy consumption to the consumer (Palensky & Kupzog, 2013, p. 208). Microgrids are a

small grid with generation, consumption, and sometimes storage that can operate in grid-connected or isolated mode (Hoicka & MacArthur, 2019, p. 16; Palensky & Kupzog, 2013).

In addition, community design or urban design is important because "a way a community is designed has a major impact on the amount of energy it uses and its carbon footprint" (Barron et al., 2013). Energy use is determined in large part by land use planning practice and the relationships between built form, land use, renewable energy, energy efficiency and energy use are established (Owen 1985, 1992). The objective of *energy-conscious planning* is to "plan for a physical environment which permits people to carry out their daily activities using energy as efficiently as possibly, subject to other reasonable constraints" (Owens, 1992, p. 89).

Carbon offsets are credits for greenhouse gas reductions achieved by one party that can be purchased to compensate (offset) emissions of another party. Carbon offsets are usually measures in tonnes of CO2 equivalents (CO2e) (David Suzuki Foundation, 2017).

Carbon capture and storage is an emissions reduction technology involving the capture of carbon dioxide from fuel combustion or industrial processes. This carbon dioxide is transported and can be used as a resource toward creating products or services, or it can be permanently stored deep underground (IEA, 2020).