DNV·GL

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ENERGY TRANSITION FRAMEWORK FOR CITIES: MID-SIZE CITIES LEADING THE WAY

Best practices for sustainability, climate action and resilience

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ABSTRACT

The world of energy is transforming rapidly, with cities adopting decentralized, zero carbon strategies at the local level. This publication by DNV GL examines ten of the world's pioneering cities through the lens of the seven dimensions of the DNV GL Energy Transition Framework for Cities.

Our findings show that while significant attention has been given to the world's mega-cities, smaller cities are proving to be nimble centres for energy innovation. This report highlights best practices related to sustainability, climate action and resilience as cities move from a fossil fuel-based energy economy towards a safer, smarter, greener future.

FOREWORD – THE DNV GL VIEW

The ascent of cities in the energy transition

Over the past ten years, municipalities have emerged as significant players in global energy markets. Driven by a lack of consistent international leadership on climate change, and empowered by changes in technology, energy markets and regulatory policy, cities are seeking to accelerate the shift to cleaner, more efficient and decarbonized energy supply and use.

In response, traditional utilities and energy providers are exploring new opportunities to work with cities to achieve mutual goals for environmental sustainability, energy security and resilience and economic development. Through this report, DNV GL provides an opportunity for utilities, energy providers, policymakers, financiers and investors, and cities alike to gain insight into the actions of cities and local government in the transition away from fossil-fuel based energy resources to cleaner, renewable forms of energy.

For example, our research shows that cities are acting decisively to:

- Increase their own staff capacity and resources to address climate change and lead new energy programmes
- Explore the use of decentralized energy markets and community choice aggregation to procure energy on behalf of their communities both at the distributed and wholesale market levels
- Exert leadership in programmes and policies to decarbonize energy products and use

> "To run their activities, cities require an uninterrupted supply of energy. They consume about 75 percent of global primary energy and emit between 50 and 60 percent of the world's total greenhouse gases.
>
> This figure rises to approximately 80 percent when the indirect emissions generated by urban inhabitants are included."
>
> *UN-Habitat*

Based on an international survey of the energy-related activities of municipalities, we present the DNV GL Energy Transition Framework for Cities that describes seven dimensions or ways in which cities are using their established powers to accelerate the energy transition at the local level. To illustrate each dimension, we provide case studies of best practices in city actions related to the energy transition.

While in other reports much attention has been paid to the world's mega-cities, this report highlights the efforts of the next tier of cities globally across DNV GL's Energy Transition Framework for Cities. These cities are more numerous, comprise a greater portion of the population in aggregate, and are typically obliged to be nimble and efficient in their use of more limited resources. We draw on the experience of 10 leading cities from the Americas, Europe, the Middle East, Asia, and Australia to illustrate our Energy Transition Framework and its practical application.

The world of energy is changing – over the next 35 years, electricity consumption is expected to increase by 140%[1]. Furthermore, society expects energy to be greener, more reliable and more affordable. At DNV GL, our vision is to have global impact for a safe and sustainable future, which requires a broader view across multiple dimensions of the energy transition. Together, we can help society to use technology, markets and policy to enhance the lives of people and constantly re-create a city of the future by investing and acting on the bold visions shared in this report.

Ditlev Engel, CEO
DNV GL - Energy

[1] DNV GL's Energy Transition Outlook 2017

EXECUTIVE SUMMARY

DNV GL recently released its Energy Transition Outlook, our view on a "most likely future" for energy through 2050. We predict that global energy demand will plateau around 2030 and that renewables will account for 85% of global electricity production in 2050. However, our outlook doesn't see the world on track to meet the Paris Agreement climate goal to limit global warming.

In this report, we examine the role of cities worldwide as a key player in the energy transition and meeting the goals set forth in the Paris Agreement. We chose the ten cities in this report because we recognized that they were much further along in the energy transition and that the approaches they were taking were notable both in and of themselves, and as an example that other cities can learn from and emulate on their journey along the energy transition. In addition, this publication focuses on the significant innovation happening with cities that are perhaps lesser known than the world's mega-cities.

Identifying best practices for cities on the energy transition

DNV GL's Energy Transition Framework for Cities comprises the key activity areas that cities need to focus on to accelerate the shift to cleaner, more efficient, and decarbonized energy supply and use. The Energy Transition Framework for Cities provides best practices that other cities can use to develop their own energy transition. Each of the cities we looked at chose the best practices that suited their own goals and created their own path; however, there is no one right way to approach the energy transition.

Our research on these ten leading cities is primarily based on publicly available data. We assessed whether case study cities were acting in accordance with best practice indicators associated with each dimension of the Energy Transition for Cities Framework. Figure 1 lists the seven dimensions of the DNV GL Energy Transition Framework for Cities and how active the ten case study cities are in each dimension.

Figure 1 - Overview of DNV GL Energy Transition Framework for Cities

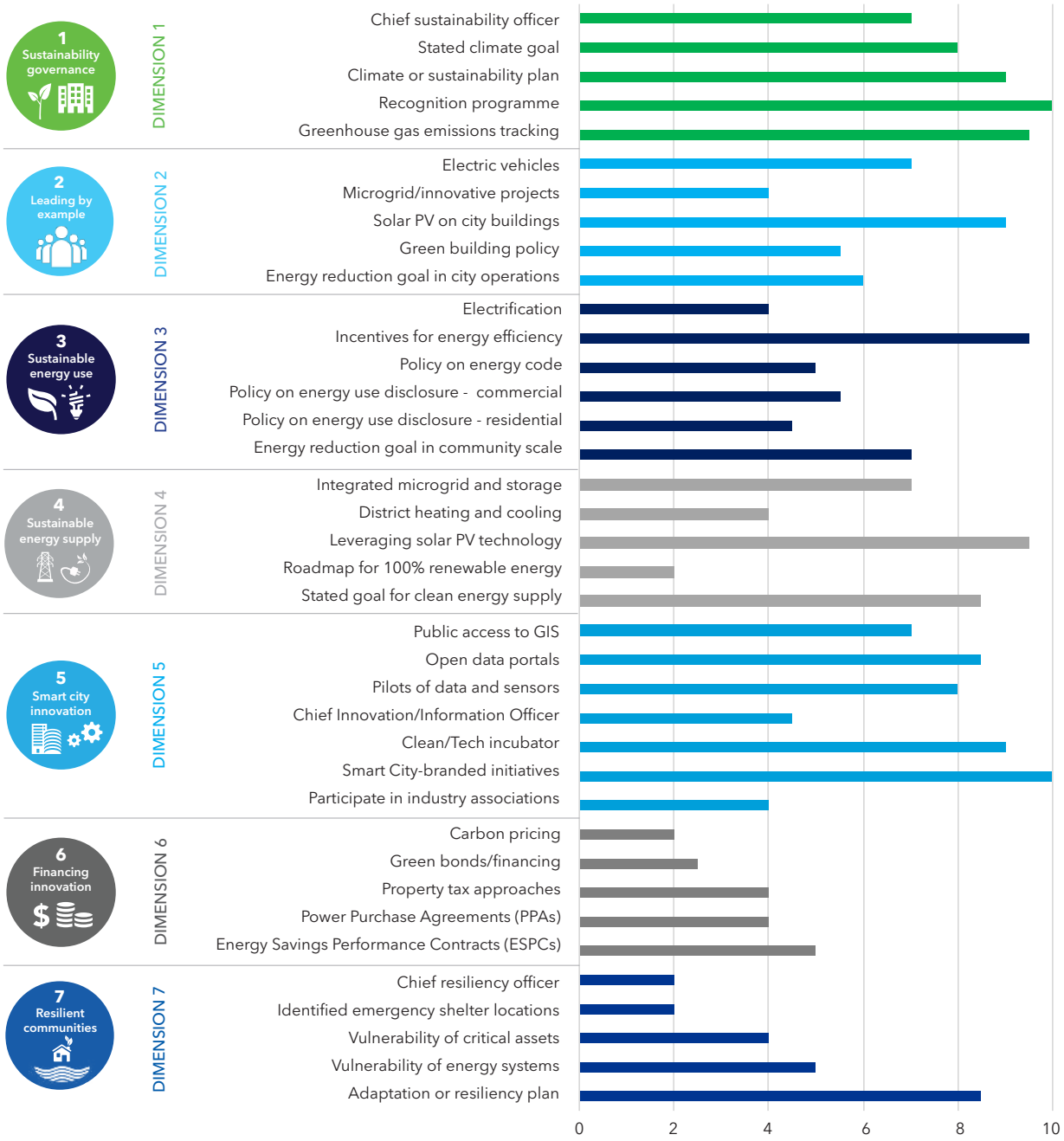


Figure 2 - Case study city actions across seven dimensions of DNV GL Energy Transition for Cities

Prioritizing initiatives for implementation

Cities have many priorities to balance, of which sustainability and energy supply is just one. In applying DNV GL's Energy Transition Framework for Cities, we find that leading cities are prioritizing action related to:

- **Cost-savings and return on investment**
  The ten case study cities were very strong in the areas of solar PV, energy efficiency and energy reduction goals in city operations (Dimension 2 - Leading by Example) which result in cost savings. This approach also frees up funds for other initiatives. By focusing on return on investments, other cities can also gain quick wins as a path to moving on to other important initiatives.

- **Positive impacts with stakeholders**
  Other strong areas related to climate goal-setting (Dimension 1 – Sustainability Governance) and smart city-branded initiatives (Dimension 5 – Smart City Innovation) are reputation-building for cities as an attractive place to be and invest in. These are also relatively low-cost opportunities for cities to engage with citizens, local business and regional stakeholders around common goals.

- **Near-term results in three to five years**
  City governments, by their nature, are focused on responding to short term needs of their citizens and infrastructure, rather than things a long way down the road. This is likely a key reason why adaptation and resilience have previously been a lower area of activity for cities. However, with more frequent severe weather events, the near-term urgency for climate resilience is increasing.

City goals are driven by many factors: budget, citizen desires, need to deliver other services, cost savings, and desire for recognition. Each city has developed unique and innovative approaches to the energy transition. For instance, the City of Cambridge's zero net energy initiative was driven by citizens, but the City of Bristol's drive to become "the first solar panel city" was spurred by the mayor at the time and continues to be pushed by the city's government.

Recommendations for the future

In our research, we found many exciting success stories including Groningen's PowerMatching City project and Bristol's achievements to have twice as many solar PV panels on houses than the UK average.

It is well known that cities often lack funding and technical resources. However, what cities accomplish represents a priority choice of how they rank specific issues. The climate imperative and rapidly changing economics related to renewable energy are causing cities to become active players in energy markets worldwide.

In this report, we invite you to learn more about what pioneering cities are doing to accelerate the energy transition and why. Most importantly, what can other cities learn and what are the key opportunities for partnerships to go further together?

INTRODUCTION

Energy industry projections recognize that the world population is expected to grow to nine billion by 2050, and up to eleven billion by 2100[2]. Meanwhile, despite forecasted decoupling of emissions from gross domestic product and population, the world is not on track to achieve the reductions needed to meet the Paris Agreement climate goal of limiting global warming to 'well below 2°C'. Given the urgency of climate action, cities are not waiting on state and national actors and are forging new paths to address the climate imperative.

> "Local governments are truly on the forefront of climate action and sustainability to create a higher living standard for their residents and help their communities grow and thrive."
>
> *Betty Seto,*
> *Head of Department, Sustainable Buildings and Communities, DNV GL*

What do we mean by the energy transition for cities?

In the past, most city governments have not taken it upon themselves to ensure reliable and environmentally sound delivery of energy to their constituents, or to encourage efficient energy use. An increasing number of cities worldwide are beginning to do so now, using their established statutory powers to respond to political expectations regarding environmental quality and economic development.

The rise of cities as key players in the energy transition is based on recent trends across three areas:

- **Technology:** Energy technology is changing quickly, presenting new opportunities for cities to affect energy delivery and consumption and citizen engagement in sustainability. New distributed energy technologies include integrated solutions such as microgrid applications and energy storage for community resiliency. New smart building controls support the aggregation of multiple sites to provide meaningful grid services and new revenue streams for residents and businesses.
- **Markets:** The falling cost of renewable energy systems combined with liberalization of energy markets that allow cities to procure energy on behalf of their citizens is changing our communities. DNV GL found that many cities are developing 100% renewable energy plans and roadmaps to identify how local jurisdictions can take advantage of new technology and market opportunities.
- **Policy:** Cities are using their established powers to enact new city policies to accelerate adoption of energy efficiency and incentivize cleaner, more local renewable sources of energy. Local policies include energy disclosure, procurement practices, land use and zoning, in addition to voluntary programme and education/outreach programmes.

Recognizing the importance of these efforts, a range of stakeholders including utilities, energy providers, renewable and distributed energy resource project developers, and regulators are seeking to better understand the opportunities to engage with cities in a productive manner. Our research suggests that the time is right for cities and utilities to explore new paradigms for partnerships that help support the energy transition for safer, smarter, greener communities.

[2] Source: United Nations

The DNV GL Energy Transition Framework for Cities

Energy infrastructure is the foundation of modern life in cities worldwide. Utilities and cities have a mutual interest in becoming "smarter" and "greener," but bring different resources to the table. Each group has its own set of unique tools and resources for integrating new energy technologies and strategies into the built environment.

The DNV GL Energy Transition Framework for Cities is based on seven dimensions of city opportunities for action and leadership, and where the involvement of utility and energy industry players is a critical component.

Based on our research of leading cities worldwide, the seven dimensions of the Energy Transition Framework for Cities are:

1 – SUSTAINABILITY GOVERNANCE
Governance refers to the establishment of structures and processes designed to ensure a set of guiding principles related to decarbonization and each city's vision for a prosperous and healthy future are in place to plan, implement, measure and track progress against city goals.

2 – LEADING BY EXAMPLE
City government recognizes it must reflect the values of the community they serve in decisions regarding infrastructure, programme and services and how public funds are invested and allocated, including values associated with sustainability and clean energy. Municipal governments can also lead by example by using city facilities as important incubators for piloting new sustainable energy technologies and programmes.

3 – SUSTAINABLE ENERGY USE
Energy efficiency is the most cost-effective emissions reduction strategy. Cities are enacting new programme and policies to provide the right incentives for the necessary upfront investments that lead to cost-saving and greenhouse gas reductions for years to come.

4 – SUSTAINABLE ENERGY SUPPLY
With the falling cost of renewable energy, cities are implementing new programmes and policies to support their local building owners and developers to incorporate locally sourced clean renewable energy systems. Furthermore, cities are taking a larger role in clean power procurement on behalf of their citizens and local businesses through strategies like green power aggregations and community solar installations.

5 – SMART CITY INNOVATION
The Internet of Things (IoT), sensors and new data platforms present opportunities for cities to better manage energy use for things like streetlighting, but also offer opportunities for improving public safety and efficiency of city services.

6 – FINANCING INNOVATION
Cities are looking at innovative ways of securing the necessary funding for the energy transition.
Green bonds, private capital, and new financing models related to tax revenues or purchase agreements will revolutionize how cities procure and use energy.

7 – RESILIENT COMMUNITIES
A critical aspect of minimizing climate hazard risks is to ensure a reliable energy supply. As part of the energy transition, cities are acting to protect their community social and economic assets through strategies that improve the resilience of building energy systems and structures.

For cities, the energy transition is about protecting limited natural resources while enhancing municipal services, ensuring energy security, supporting local businesses, and fostering new avenues for economic growth.
Each of the seven dimensions are also relevant to utility and energy providers seeking to meet customer expectations, while addressing market pressures on their traditional business model created by distributed energy resources (DERs), lower demand, and an aging infrastructure.

The DNV GL Energy Transition Framework for Cities offers utilities and cities a pathway for maintaining revenue streams (and profitability for investor-owned utilities) while rethinking the ways they interact with their constituents and customers in a rapidly evolving marketplace.

Cities in the vanguard

In this publication, we feature ten leading cities from across the globe that represent the best in innovation, action, heart and commitment for leading their communities in the Energy Transition and creating a foundation for achieving bold new sustainability goals.

CASE STUDY CITIES

1. Palo Alto, USA
2. Santa Monica, USA
3. Cambridge, USA
4. Curitiba, Brazil
5. Bristol, UK
6. Groningen, the Netherlands
7. Antwerp, Belgium
8. Abu Dhabi, UAE
9. Melaka, Malaysia
10. Adelaide, Australia

DIMENSIONS OF ENERGY TRANSITION

DIMENSION 1
Sustainability governance

City interest in the energy transition has emerged from broader sustainability efforts related to decarbonization of energy supply and demand. Over the past decade, an increasing number of cities have inventoried their carbon footprints and developed roadmaps for meeting science-based GHG emissions reduction targets. Utility and energy providers have been important partners in providing energy consumption data by customer or building sector, emissions factors, and even funding to assist cities in addressing their energy footprints.

Sustainability governance is fundamentally about establishing structures and processes to ensure accountability, transparency, responsiveness, and broad-based participation to move cities towards a more sustainable energy future. The best practice indicators identify the necessary actions for cities to set clear policy objectives, measurement and tracking systems, and establish accountability within city government to achieve citywide goals.

Best practice indicators

STATED CLIMATE GOAL

Leading cities are now exploring pathways to "carbon neutrality" and net zero carbon emissions. Of the ten case study cities, Adelaide has the most aggressive target of becoming carbon neutral by 2025. Most cities have adopted targets consistent with the recommendations of the Intergovernmental Panel on Climate Change (IPCC) to reduce greenhouse gas (GHG) emissions by at least 80% by 2050 to reduce the probability of catastrophic climate change.

GREENHOUSE GAS EMISSIONS TRACKING

Conducting a citywide GHG emissions inventory is the foundation for low carbon development planning by exposing the relative carbon intensity of different city sectors, including energy, water, and solid waste. Nine out of the ten case study cities have completed city-specific GHG inventories, except Abu Dhabi for which an emirate-level (state-level) inventory was completed. A key challenge for cities worldwide is timely and consistent access to aggregated consumption data in the community, the availability of which varies significantly across different utility and energy providers. Cities also face the challenge of data privacy rules, where utilities are often not allowed to share energy consumption data, even when it is aggregated.

CLIMATE OR SUSTAINABILITY ROADMAP

In tandem with adopting ambitious climate targets, nine out of the ten case study cities have developed climate action plans, sustainability roadmaps or low-emission urban development plans that outline priority strategies and near-term actions. As electricity supply moves to higher percentages of clean, renewable energy, cities are utilizing these planning documents to focus on addressing the remaining sources of fossil fuel – primarily related to heating buildings/water and transportation sectors.

LEVERAGING NETWORKS OF CITIES

As an organizational entity, cities are unique in their collaborative nature with their peers and sister cities. Numerous city networks and coalitions have emerged to support cities, foster peer-to-peer knowledge-sharing and pool resources to further the advancement of city sustainability targets, including a focus on the energy transition. All ten of the cities featured are participating in numerous initiatives, including the Global Covenant of Mayors for Climate & Energy, a newly merged initiative the Compact of Mayors and the Covenant of Mayors.

SUSTAINABILITY OFFICERS

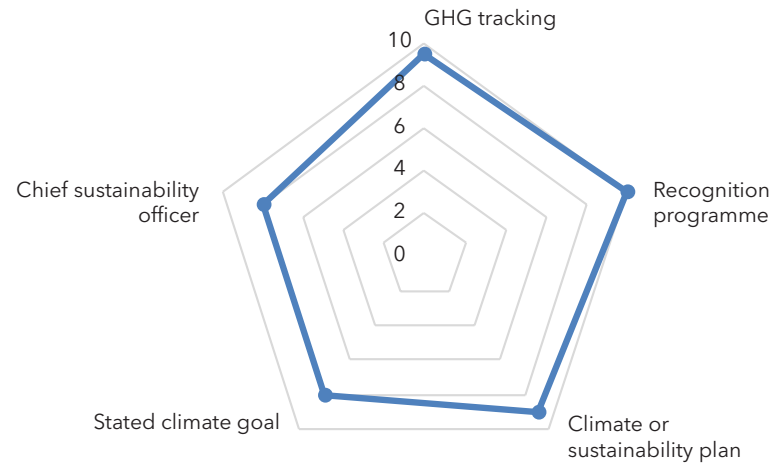
Finally, successful implementation of climate and sustainability roadmaps to achieve climate targets requires clear allocation of staff resources to manage city efforts. Eight of the case study cities have a position that is similar to/the equivalent of a chief sustainability officer or sustainability manager, but there are many different titles for this role. The positions range from Managing Director of the Environment Agency in Abu Dhabi to Team Leader of Carbon Neutral Adelaide to Chief Sustainability Officer. Regardless of the specific structure and title, responsibility for ensuring the implementation of decarbonization and sustainability initiatives must be clearly assigned.

In assessing our case study cities, we find that the Sustainability Governance dimension is generally an area where our case study cities perform strongly, with all cities having made significant progress across all indicators. Partial credit was provided to Groningen and Abu Dhabi because of the adoption of climate targets at national levels. Furthermore, a greenhouse gas inventory was completed for the Abu Dhabi Emirate in 2012.

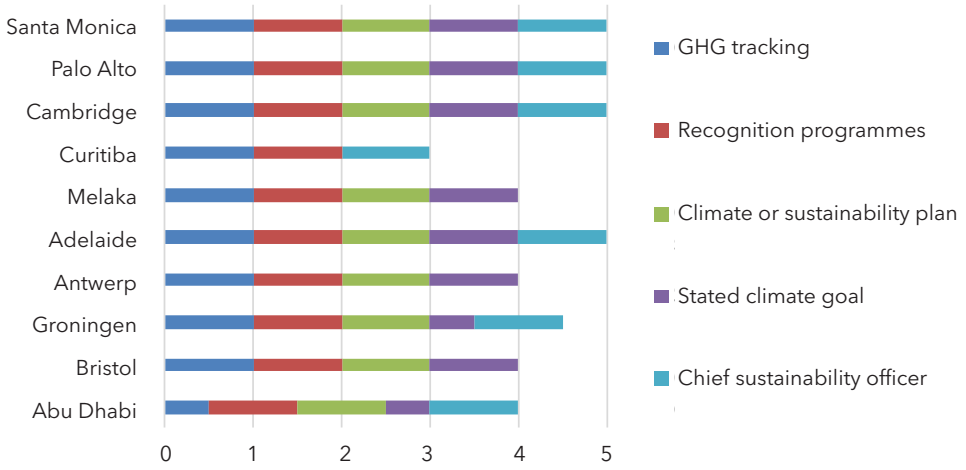
PARTICIPATION IN LEADING CITIES ORGANIZATIONS

- Global Covenant of Mayors for Climate & Energy
- Carbon Disclosure Project (CDP)
- Carbonne
- Urban Sustainability Directors Network (USA)
- Carbon Neutral Cities Alliance
- Climate Alliance of European Cities

DIMENSION 1 - Sustainability governance



DIMENSION 1 - Sustainability governance best practice indicators



What we found

Leadership areas: where cities are most active

In our examination of a sample of cities who are leaders in the energy transition, we find two dimensions in which all ten of our case study cities show significant action.

DIMENSION 1 - SUSTAINABILITY GOVERNANCE

Not surprisingly, the cities we examined for this publication have clearly articulated targets for climate action that drive much of their other actions related to the energy transition. The case study cities have all completed baseline greenhouse gas and carbon inventories and set clear climate commitments through organizations such as the Global Covenant of Mayors for Climate & Energy, Carbon Disclosure Project, ICLEI – Local Governments for Sustainability, and the Carbon Neutral Cities Alliance. Throughout, utility and energy providers have been important partners in providing energy consumption data by customer or building sector, emission factors, and even funding to assist cities in addressing their energy footprints. While many leading cities have set ambitious targets, closer examination of the other dimensions of the energy transition show that enforcing and achieving the desired climate goals remain a huge challenge.

DIMENSION 5 - SMART CITY INNOVATION

Perhaps more surprisingly, given the novelty of smart city technologies and buzzwords, the ten case study cities were found to have made significant strides in embracing opportunities presented by digital networks, sensors, and open data. Smart LED street lights and embedded sensors are allowing cities to collect and transmit information ranging from traffic and parking to air quality to crowds and noise. New opportunities related to distributed energy trading, such as blockchain technology for peer-to-peer energy transactions, are also emerging and present exciting possibilities for the energy transition in cities. To implement new energy-related technologies and uses of data, municipalities are finding they need to engage with their utility and energy providers to ensure grid harmonization, and leverage complementary initiatives and potential co-funding opportunities.

Emerging priorities: where cities are headed

A few dimensions of the Energy Transition for Cities Framework are clearly works in progress for cities and their utility/energy partners.

DIMENSION 6 - FINANCING INNOVATION

This is perhaps the most challenging task ahead for cities – i.e., how to pay for it all. Several best practice indicators for this dimension include well-established financing strategies – for instance, power-purchase agreements (PPAs) and energy savings performance contracts (ESPCs) - which were not commonly utilized by the case study cities examined. While we found some instances of innovation related to crowd-funding, green bonds and city programme for ESPCs, financing remains a tough nut to crack for cities despite significant interest in "green" and "sustainability" investing. The energy transition for cities seeks to deliver services, data and infrastructure to lower costs to society related to energy supply and use. Across the best practice indicators, it is clear that cities are still struggling to find appropriate financing vehicles for their energy initiatives. Thus, we see this dimension as an emerging priority for innovation, rather than one that is well established.

DIMENSION 7 - RESILIENCE

Adaptation and resilience is very much a topic of conversation for cities these days. While most of the case study cities have publicly available adaptation and resilience plans, they fall short on assessing risks to energy systems and infrastructure related to building operations, particularly critical assets and emergency shelters. As cities expand their role in protecting citizens and infrastructure from climate change related events, the scope of adaptation and resilience must extend to energy infrastructure as the foundation for all municipal services. While much attention has been paid to sea level rise and flood risks, we find that more work is needed to protect our energy systems at the neighbourhood and building scale, including assessing the characteristics of building systems themselves for critical assets and emergency shelters. In addition, cities need to take into account the stresses that integrating more and more sustainable energy generation can have on the grid overall. Finally, more research is needed on how to ensure that electrifications initiatives increase resilience, rather than exacerbate climate hazards.

Climate targets by year

SANTA MONICA, USA Carbon neutral by **2050** or sooner	**CAMBRIDGE, USA** Carbon neutral by **2050**	**PALO ALTO, USA** **80%** reduction by **2030**
ANTWERP, BELGIUM **20%** reduction from 2005 levels by **2020** and a **50%** reduction by municipal activities	**GRONINGEN, NETHERLANDS** **50%** reduction by **2025**, energy neutral by **2035** (Dutch national target)	**BRISTOL, UK** **80%** reduction by **2050**
ADELAIDE, AUSTRALIA Carbon neutral by **2025**	**MELAKA, MALAYSIA** **40%** reduction in carbon intensity by **2050**	**ABU DHABI, UAE** **70%** reduction by **2050** (UAE national target)

Setting the vision for a carbon neutral city: Palo Alto, USA

The City of Palo Alto began setting greenhouse gas reduction goals in 2005, and formalized these goals in 2007 in a Climate Protection Plan, with a set of ambitious targets to reduce mission by 15 percent below 2005 levels by 2020.

Since that time, the City of Palo Alto has undertaken a variety of measures, including the provision of 100 percent carbon neutral electricity by their municipally owned utility company. Starting in 2013, the City of Palo Alto Utilities utilized renewable energy certificates (RECs) as a transition strategy to long-term power purchase agreements for zero carbon electricity sources by 2017. Driven by their Climate Protection Plan, the City of Palo Alto was able to achieve its initial GHG reduction goal by 2012, eight years ahead of schedule.

To set a new bar of leadership, the City embarked on an updated Sustainability and Climate Action Plan (S/CAP) to explore how quickly the City could achieve carbon neutrality across all sectors. Through a multi-year planning process, with significant stakeholder engagement, the City engaged with constituents to ask:

- How can the City step from carbon neutral electricity to carbon neutral utility (electricity and natural gas) to carbon neutral city?
- What would it take – in technology, investment, innovation and personal change – to get there?
- In view of these requirements, are we willing to do it – to make the necessary commitments, and act to deliver the world we want?

In 2016, the City Council responded with a resounding "yes" to implementing the necessary policy direction and a framework for emissions reductions, setting a new target of 80 percent reduction in emissions by 2030. However, the City recognized that the hard work begins now, and each department is developing more specific implementation plans to set near-term priorities and actions.

DIMENSION 2
Leading by example

While the energy consumption related to city government operations, including city-owned infrastructure and fleet vehicles, is generally small compared to the city as a whole, municipalities recognize that they play an important role by leading by example. City actions in their own facilities and operations has a powerful impact by inspiring citizens and local businesses throughout the community and demonstrating the feasibility of the energy transition to cleaner, more resilient sources of energy.

To date, municipal energy projects related to energy efficiency, smart grid, and distributed energy resources (DERs) have offered an opportunity for both city governments and their utility/energy partners to implement highly visible, flagship energy projects to build community goodwill. Leading cities see their own facilities and operations as test-beds for demonstration pilots of new emerging technologies, which requires close collaboration with utility partners. While cities can identify potential municipal projects and sites, they typically have limited funding for infrastructure demonstration projects and not as much necessary technical know-how, which are both opportunities for engaging with utility and energy providers.

City of Antwerp, Belgium

Antwerp's city administration buildings are supplied with 100% green electricity. It has ambitious targets to reduce greenhouse gas emissions in its municipal buildings by 50 percent, compared to 2005 by 2020.

Best practice indicators

ENERGY GOALS FOR CITY BUILDINGS AND OPERATIONS

Six of the case study cities have adopted energy reduction targets related to their own city operations. Energy goals vary in scope, ranging from building energy use only to encompassing fleet vehicles. Furthermore, some cities (e.g., Palo Alto, Cambridge, Antwerp, and Santa Monica) include a renewable energy generation target in addition to the energy reduction goal.

GREEN BUILDING AND ZERO ENERGY BUILDING GOALS FOR MUNICIPAL BUILDINGS

Many cities throughout the world have adopted green building policies for their own municipal buildings, utilizing standards such as LEED®, ENERGY STAR®, BREEAM, Green Mark, DGNB or setting net zero building targets. The Abu Dhabi Urban Planning Council has developed its own green building rating system called the Pearl Rating System, as part of their sustainable development initiative Estidama. The U.S. cities surveyed (Palo Alto, Cambridge, Santa Monica) are leading the way amongst all of the case study cities with ordinances that require a LEED silver rating for all new City buildings, which are typically over 10,000 square feet. Furthermore, the City of Cambridge developed a net zero energy building roadmap to identify appropriate near-term strategies and actions to ensure that all new construction in the city is zero net energy by 2050.

SOLAR PHOTOVOLTAIC (PV) ON CITY FACILITIES

By far, the most prevalent renewable energy technology being adopted is the installation of solar photovoltaic on City facilities. For the eight case study cities with municipal solar PV installations, the number of facilities with installations ranges from four to eight. In addition to distributed solar systems (e.g., rooftop), in Bristol, Groningen, and Melaka city governments are directly involved in the development/ownership of utility-scale solar PV power plants.

MICROGRID AND DISTRIBUTED ENERGY RESOURCES (DER) PILOTS AT CITY FACILITIES

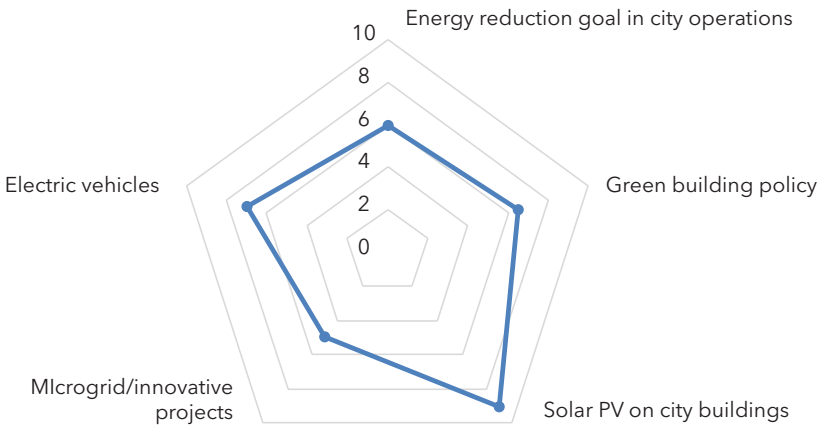
Cities are increasingly pursuing clean energy microgrids, with four of the case study cities incorporating energy storage and dynamic load control. The projects are seen as a multi-benefit solution that increases energy reliability for critical facilities and reduces reliance on fossil fuel-sourced back-up power. The cities range from having one to four buildings/sites involved in the microgrid projects to achieve net zero energy buildings and protect critical city assets. While utility and energy providers are typically involved with local microgrid projects, the scalability of such projects offers opportunities for new revenue models to facility owners and grid operators, which are still being explored.

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

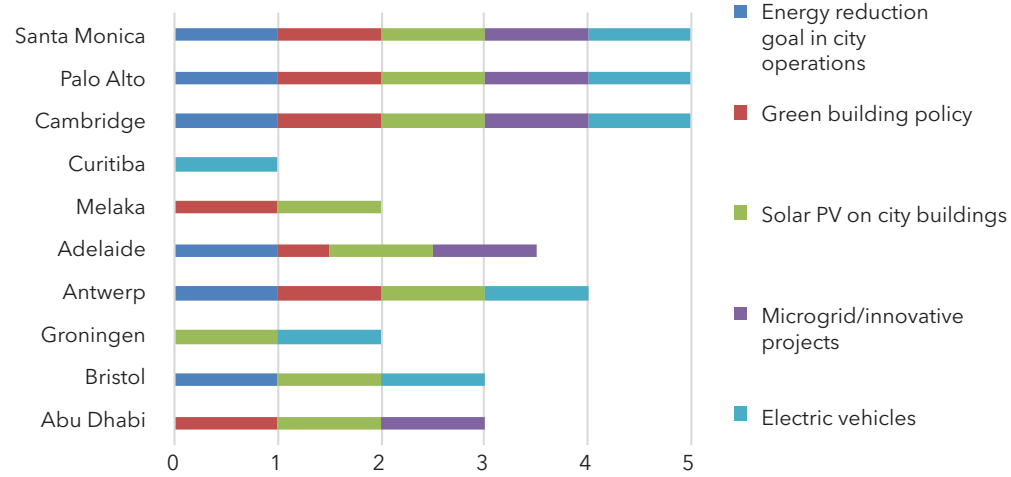
Cities are seeking to increase the uptake of electric vehicles in their community as a near-term opportunity for addressing both climate change and local air quality. Electric vehicles are compelling because existing electrical infrastructure is readily available and rapid deployment doesn't require cultural or behavioural shifts. Of the case study cities, Bristol has emerged as a leader in EV infrastructure development. In 2015, Bristol announced that it had installed its 100th electric car charging point, and now has more than 200 charging locations. Cities are tapping into local and national sources of funding for the installation of EV charging infrastructure at municipal parking facilities, libraries, convention centres, and City Hall. Many utility providers are also providing incentives and support for EV charging infrastructure, and this is a key opportunity for collaboration with city partners.

While cities are ultimately concerned about broader community-wide decarbonization and economic objectives, city governments recognize they ultimately have the most control of their own facilities and a moral responsibility to model desired behavior. In assessing our case study cities, we find that leading cities are embracing technology opportunities from the inside-out, and are furthest ahead in the deployment of solar PV in city operations, followed by EV charging infrastructures.

DIMENSION 2 - Leading by example



DIMENSION 2 - Leading by example best practice indicators



Lighting the way to a greener city: Curitiba, Brazil

Lighting and transportation are two significant contributors to energy use in all cities. For Curitiba, managing energy use for both goes hand in hand. Like many South American cities, Curitiba underwent explosive growth, and is best known for its leadership in proving the concept of bus rapid transit (BRT), which is now used by 85 percent of the population—about 2 million people a day—as a response to this growth. As the BRT system grew, city officials have continued to improve it, and are moving to electrify the bus fleet, including a test model that is completely silent, has a range of 250 km, and consumes 75 percent less energy than its diesel counterpart. The BRT model, originally developed in Curitiba, has now been adopted by more than 300 cities.

At the same time city leaders were transforming the transportation system, they launched other efforts to make the city greener and cleaner, such as a programme that allows citizens to exchange recyclable trash for vegetables and cooking oil, which solved two problems: food insecurity and the growth of landfills. The city now recycles 70 percent of its trash. Curitiba also aggressively expanded its green spaces to more than 50 square meters per person, with numerous parks and city gardens.

Curitiba's complex transportation system also requires a lot of lighting to help passengers navigate through the stations and allow the buses to operate safely. Curitiba has more than 160,000 illumination points across the city, including bus stops, lighting in parks, and along bike paths. They are undertaking a massive replacement project, changing out old systems with LEDs for 6,500 bus stops, 2,300 street lights, and all of the lighting in six municipal parks and more than 120 km of bike paths.

What is unique about all of Curitiba's actions is that the city's leaders recognized that they needed to take decisive—and sometimes controversial—actions to ensure that their city did not fall into the environmental pitfalls of other cities when it came to transportation, green spaces, and energy use.

Antwerp, Belgium Creating its own ESCO to reduce CO_2 emissions

The city of Antwerp has set very aggressive CO_2 reduction goals, aiming for a 20% reduction from 2005 levels by 2020 overall, and recognized that using energy more efficiently in municipal buildings was one of the ways to achieve this goal. To that end, the city developed its own ESCO to manage projects and avoid economic lock-in.

The approach was both systematic and pragmatic. First, the yearly consumption of electricity, natural gas, and fuel oil, divided by floor area of each building was calculated. The consumption was then ranked according to building type from high to low, and benchmarked against the performance of similar buildings in the region. This allowed the city to identify the buildings that most urgently needed attention, which were selected for an extensive energy audit.
The energy audit identified savings measures that ranged from "low hanging fruit" to major investments, as well as estimates of energy savings, required investment, and ROI. Smaller projects—the low hanging fruit—are handled by the city's maintenance teams. The big investments are entered into the "matrix of energy savings measures," where investments are distributed over six years. This allows a basket of energy savings measures to be compiled and financed over 20 tears. The intention is to prevent investments from being "cherry picked," and to create a financial buffer to tackle larger projects that will be profitable in the longer term. This way, the city isn't locked in economically to projects that are not beneficial. To ensure that the projected energy savings are realized, one year after a measure is implemented, large or small, the energy savings is calculated with data from the city's energy management system.

The matrix of energy savings is reviewed biannually, as a part of master planning, and in response to technology innovations, energy price fluctuations, and interest rate changes. This allows the investments to be integrated into building maintenance plans, to ensure the projects are completed. The project portfolio is managed by the Antwerp's engineering department, and executed through contractors and other professionals.

DIMENSION 3
Sustainable energy use

Cities can influence energy use in their communities in many ways: through permitting requirements, programmes for energy use disclosure, land use and zoning, building codes, public finance, and incentives. However, government regulatory mechanisms to increase end-use energy efficiency varies significantly worldwide, ranging from nationally-based systems In Europe to utility-led programmes in the United States.

In this dimension of the energy transition, we explore how cities are using their established powers to help residents and local businesses to reduce energy consumption and save money. As electricity is increasingly sourced from carbon-free, renewable energy sources, cities are also exploring policy opportunities to shift preferences to electrify everything, even things not traditionally electrified such as transportation and heating. Cities are emerging as important market players in the "harmonization" of consumer benefits and "system" (grid and societal) benefits. However, as cities seek to shift significant energy loads previously served by direct combustion of fossil fuels, the grid impacts have not been fully explored.

Best practice indicators

ENERGY USE REDUCTION GOAL-SETTING AT THE COMMUNITY-SCALE

As part of broader decarbonization efforts, six of the case study cities have adopted energy reduction and energy efficiency targets for different building sectors (e.g., domestic and commercial buildings). Based on DNV GL's research, cities need better access to data on the energy use in their community and associated greenhouse gas emissions. Some utilities have established and opened avenues for sharing data that does not violate privacy issues. Key challenges related to community-level data include how to provide data at sufficient detail and granularity to support action, while protecting the privacy of utility customers.

ENERGY USE DISCLOSURE AND BENCHMARKING

The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive require all European Union countries to establish national building rating policies. Cities in other parts of the world are seeking to catch up, particularly those in North America. In 2014, the City of Cambridge passed a Building Energy Use Disclosure Ordinance requiring owners of larger commercial buildings to report energy use to the City and to publicly disclose the data.

BUILDING ENERGY CODES

Leading cities in North America have had a unique opportunity to enact stricter building energy codes than state/regional and federal requirements. Novel approaches include requiring new buildings to achieve zero net energy targets through energy efficiency combined with on-site renewable energy generation such as solar PV. The regulatory context in the U.S. allows for many utility and energy providers to participate actively in the development of updated building energy codes and receive credit against efficiency targets for their participation. In Europe, the Energy Performance of Buildings Directive requires that all new buildings to be nearly zero-energy by the end of 2020; new public buildings must be nearly zero-energy by 2018.

INCENTIVES FOR ENERGY EFFICIENCY

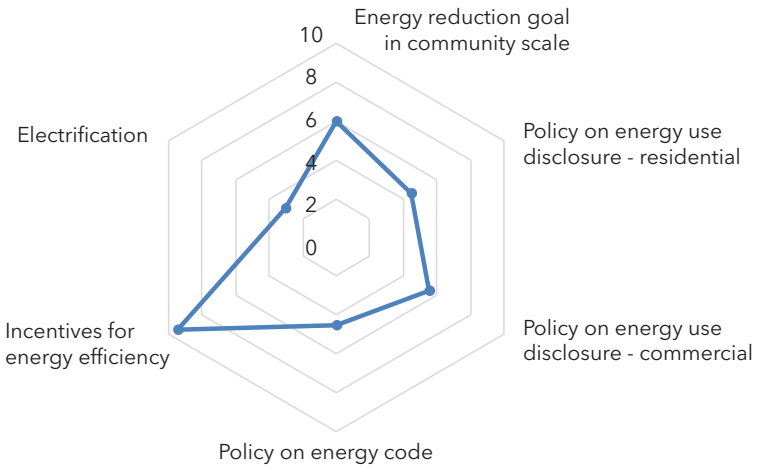
All of the case study cities have implemented local incentives energy efficiency actions in buildings, ranging from financial incentives to technical assistance to friendly competition and recognition programmes. Each city operates in a unique ecosystem of energy players and programmes. While some cities have directly designed and implemented energy efficiency programmes, most are leveraging the resources of regional, national or utility programmes. Cities should be seen as key partners for utility, state, and national programmes for energy efficiency.

ELECTRIFICATION AND FUEL-SWITCHING

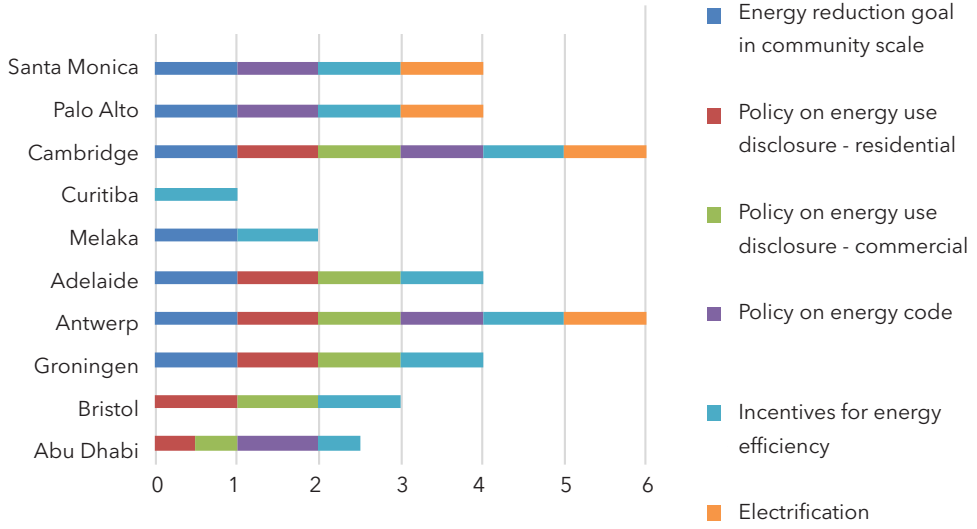
As cities are monitoring and tracking GHG emissions, it has become increasingly clear that cities can only achieve zero or near-zero carbon targets by moving away from fossil fuel-based combustion. While electrification is emerging as a hot topic for many leading cities pursuing zero carbon targets, most are in the early stages of understanding costs and opportunities. In some regions, cities are constrained from promoting electrification by regulatory cost-effectiveness methodologies that are biased towards fossil fuel combustion.

While all case study cities recognize the importance of reducing energy consumption as the least-cost pathway to emissions reductions and low-carbon urban development, the pattern of implementation is inconsistent. For the most part, cities are still relying heavily on utility and energy provider, state, and national programmes and initiatives for energy efficiency programmes. However, there are significant opportunities for cities to leverage their unique jurisdictional powers and local initiatives related to permitting, land use and zoning, economic and workforce development, water conservation, and solid waste services, to better integrate energy efficiency initiatives into broader sustainability efforts.

DIMENSION 3 - Sustainable energy use



DIMENSION 3 - Sustainable energy use best practice indicators



Efficient energy use targets

CAMBRIDGE, USA

All new buildings zero net emissions by **2030** and all buildings by **2050**

GRONINGEN, NETHERLANDS

37% of GHG emissions target to be achieved through energy efficiency

MELAKA, MALAYSIA

Reduce total electricity use per capita by **20%** by **2020**

SANTA MONICA, USA

Reduce energy use citywide in existing buildings by **1 million kWh** annually

City-led energy efficiency programmes: Adelaide, Australia

Energy efficiency is often the first and easiest step in reaching sustainability goals and mitigating climate change risks; after all, the best way to reduce greenhouse gas emissions is to use less of the electricity that generates them. As part of its Carbon Neutral Adelaide Action Plan (CNAAP), Adelaide developed a Sustainability Incentives Scheme, which is co-funded by the Adelaide City Council and the Australian government's Department of Environment, Water and Natural Resources to help reduce the amount of greenhouse gas emissions produced by buildings.

Launched in 2015, residents and building owners can apply for rebates for typical energy efficiency measures such as LED lighting upgrades, smart appliances, and efficient hot water heating systems. Incentives are also offered for solar PV panels, solar or heat-pump assisted hot water systems, energy storage systems, energy monitoring systems, electric vehicle charging points (cars and bicycles), and rainwater tanks. It also offers incentives for Energy Smart apartment blocks for commercial buildings achieving at least a four-star NABERS (National Australian Built Environment Rating System) rating. It paid $180,000 (Australian) in rebates in the first year, which supported more than $2.5 (Australian) million worth of sustainability investments.

In addition to the city-led programme, the State government is leading the Retailer Energy Efficiency Scheme (REES), an energy efficiency programme that provides incentives for South Australian households and businesses to save energy through their retail energy providers. This scheme establishes energy efficiency and audit targets for electricity and gas retailers, much like utility programmes in the U.S.

By combining energy efficiency, renewable energy, and new technologies like energy storage, Adelaide's incentive programme will help the city and its residents achieve the goal of reducing emissions from buildings by 15 percent by 2025, as well as increase the amount of renewable energy generated in the city.

The Ecohouse: a meeting place in the heart of Antwerp, Belgium

To help its citizens understand how they use energy, Antwerp built the Ecohouse, a very open house that residents can visit to get inspiration, information, and advice and financial support for renewable energy and energy efficiency projects. The Ecohouse is located in Borgerhout, an economically diverse neighbourhood. While open to all residents of Antwerp, Ecohouse focuses on citizens who are not economically able to make investments in energy projects. For example, in the Ecohouse's permanent instalment, "Do more with less," visitors can gain tips and tricks to make their homes, gardens, and kitchens greener and more efficient without making major investments. It also offers expert advice on how to lower and 'green' energy bills, rebates for energy efficiency measures, and low-interest loans of up to 15,000 Euro for energy improvements.

The Ecohouse also provides information on and subsidies for conservation projects that are not energy-related, like rainwater collection, water re-use, green roofs and facades, and other advice and information on eco-friendly construction and living. In 2016 the Ecohouse launched the "zoom into your roof" campaign, where residents of Antwerp could visit a dedicated website, enter their address, and find out how well their roof is insulated, and whether their roof is suited for solar PV or a green roof.

The Ecohouse is a resource for all of the residents of Antwerp to learn how to integrate energy efficiency, clean energy, and other strategies to make their lives greener.

DIMENSION 4
Sustainable energy supply

In addition to energy use, cities are increasingly using their authority, influence and budgetary powers to influence the design and delivery of locally appropriate, renewable energy solutions for energy systems. Improvements in distributed energy technologies such as solar PV and storage have created new applications and opportunities for cities that previously were not viable. These technology improvements and ongoing cost reductions, combined with heightened consumer awareness and national and state incentives, continue to bolster the growth of distributed energy resources. Of these technologies, cities are primarily exploring how systems such as solar photovoltaic (PV), microgrids, and battery storage can benefit them.

Cities are ultimately interested in the provision of zero emission, clean energy sources, recognizing that both distributed energy resources as well as centrally grid-sourced renewable energy are necessary. Based on research conducted by DNV GL, cities view their utility and energy providers as key partners but do not know how to or who to approach. Furthermore, they recognize concerns from utilities about shifting away from the current centralized model. At the end of the day, much of the city action has been driven by the desire to procure higher percentages of zero carbon energy sources than typically available through traditional utility and energy providers, and is indicative of changing expectations of utility customers.

Best practice indicators

STATED GOAL FOR CLEAN ENERGY SUPPLY

Leading cities have explicit goals to shift electricity supply to renewable energy resources. Most goals are related to percent of electricity obtained from renewables, with some cities adopting installed capacity or generation goals. Of the case study cities, the City of Bristol has adopted the most aggressive goal of being entirely solar powered by 2020.

ROADMAP FOR CLEANER, MORE RENEWABLE ENERGY SUPPLY

In addition to goal-setting, many cities are recognizing that roadmaps are an important tool to ensure the achievement of renewable energy targets. Many of the climate action plans and low-carbon development plans include specific strategies for achieving renewable energy targets, such as 100% renewable energy targets. Where the plans typically fall short is in the evaluation of the full range of renewable energy supply options, from both a technology and procurement standpoint, and associated costs of different levels of implementation.

LEVERAGING SOLAR PV AND DISTRIBUTED RENEWABLES

Eight of the case study cities have implemented local programme to promote solar and distributed renewables in their communities. In Bristol, the government is focused on funding utility-scale solar PV projects. In Groningen, in partnership with the Grunneger Power Energy Cooperative, residents who do not own any land or a roof, have the opportunity to invest in and profit from the development of a local solar energy park, which also promotes local economic development. Other cities, such as Curitiba and Melaka, are also exploring new solar incentive programme.

OPPORTUNITIES WITH DISTRICT HEATING AND COOLING

In the Middle East and Europe, district energy systems that provide highly efficient centralized sources of steam, hot water, and chilled water are popular, but they are far less common in other parts of the world. In North America, the most common applications for district heating and cooling are for serving college and university campuses, major airports, and other campus facilities. Of the case study cities, only Abu Dhabi and Groningen were found to be active participants in district heating and cooling. Abu Dhabi has been involved with the development of several district cooling projects and is working on establishing a regulatory framework for district cooling across the city. Groningen is also undertaking a major geothermal project to supply space heating to 10,000 households.

INTEGRATED MICROGRID AND STORAGE

An untapped "community" microgrid market opportunity lies in interconnected commercial and domestic buildings. Cities are at the early stages of understanding how microgrid systems can support city goals for resilient and sustainable communities.

Innovation in the technologies that supply energy has delivered impressive advances over the last decade, many taking place behind the scenes. Cities are seeking to leverage the rapid improvements in cost and performance of solar and wind power, batteries, and power electronics to improve their communities. While most cities have adopted specific renewable energy targets, they need technical and financial support to identify the pathways to achieve their objectives. While solar PV is a well-understood technology and opportunity, cities are ready to be active, engaged and motivated partners for utilities and other energy market actors to explore new business and financial models for clean energy technologies.

Sustainable energy supply targets

ABU DHABI, UAE

7% of generation to be renewable by **2020**

CAMBRIDGE, USA

20% renewable by **2020**; with **100%** municipal renewable electricity by **2025**

GRONINGEN, NETHERLANDS

Energy neutral by **2035**

MELAKA, MALAYSIA

20% of electricity to be renewable by **2020**

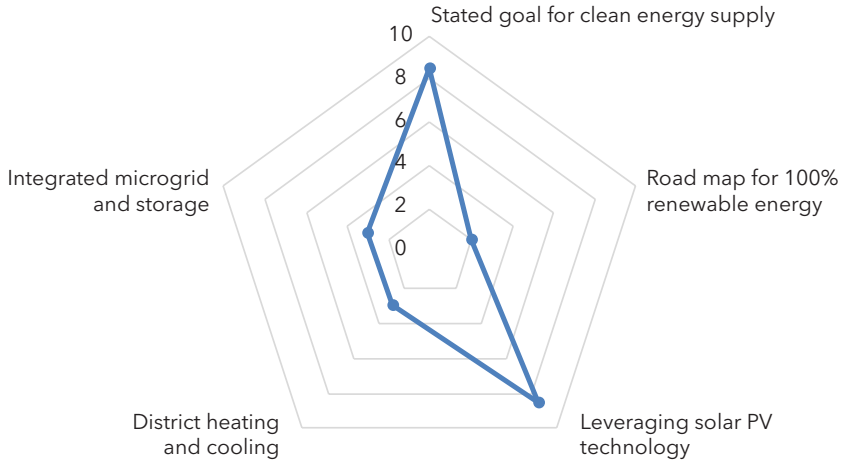
PALO ALTO, USA

100% carbon neutral electricity

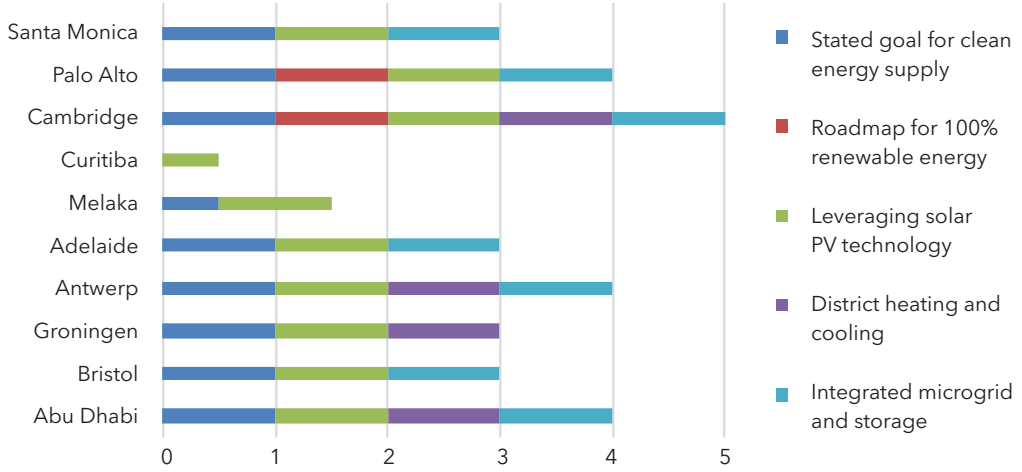
BRISTOL, UK

100% solar powered by **2020**

DIMENSION 4 - Sustainable energy supply



DIMENSION 4 - Sustainable energy supply best practice indicators



Sun City: Bristol becomes the UK's first solar panel city

Sun and the United Kingdom are not always synonymous. But in 2013, Bristol's now-former mayor, George Ferguson, announced that he wanted to make Bristol the UK's "first solar panel city." He wanted to see 1 GW of solar capacity installed in Bristol by 2020, which could provide all the electricity for domestic properties in the city. Although Bristol has a new mayor, this goal is still in place, and the initiative is being led by the Bristol Energy Collective (BEC).
The organization, started with seed money from the Bristol City Council from its Community Energy Catalyst fund, develops renewable energy and energy efficiency projects in Bristol. It also offers grants for projects that help raise awareness of climate change, reduce fossil fuel consumption, and develop activities that encourage sustainability, via the Megawatt Community Energy Fund.

Bristol has taken an innovative approach to funding their commitment to community-scale renewable energy through the BEC. It uses a combination of private-public partnerships, traditional financing through banks, crowdfunding, and bond offers to fund projects, large and small, throughout the city. The bonds and crowdfunds allow the community to directly invest in clean energy, and is one of the UK's first ISA-eligible community energy bonds. The latest round of crowdfunding, via green bonds, will be used to invest in a 100kW Tesla battery to be installed at a new housing site.

Currently, Bristol's renewable energy portfolio includes two solar farms and solar panels on eleven community buildings. It provides 9,105 MWh of electricity per year—enough to power about 2,220 homes. The profits from its solar farms are used to fund projects in the local community, like the Megawatt Community Energy Fund. What started as a desire to become the leader in solar PV installations has turned into a community-based funding initiative that benefits the entire city.

Integrating sustainable energy use, sustainable energy supply, and a smart city vision: Groningen, the Netherlands

While the DNV GL Energy Transition for Cities Framework includes separate dimensions for sustainable energy use and supply, the reality is that all dimensions can combine to achieve more holistic, integrated and optimized solutions. One example of this is PowerMatching City in Groningen, the Netherlands, where 40 households have been part of a laboratory for sustainable living from 2007 until 2017. The participating households have found a balance between energy conservation, sustainable energy supply, and home comfort. PowerMatching City combines smart city innovation and sustainable energy supply to enable its residents to use energy effectively, efficiently, and sustainably.

Creating a smarter and greener way of living

Community members use various smart technologies for managing energy use that offer sufficient flexibility to enable them to retain their freedom of choice without sacrificing comfort or reliability. The interconnected households of PowerMatching City are equipped with micro co-generation units, hybrid heat pumps, PV-solar panels, smart appliances, home energy storage, and electric vehicles. The residents receive detailed insight into their energy consumption, which informs their decisions about energy consumption, but does not restrict their behaviour.

The Smart Grid Solution

The smart grid is the key to PowerMatching City—it provides the needed flexibility and creates systems efficiency by storing heat in a buffer tank or electricity in the battery of an electric car. The energy is traded in the local market on a fully automated system – the PowerMatcher – that optimises, independently and objectively, the interests of all participants. This enables energy use—such as charging an electric vehicle's battery—when it is cheapest.

Securing quality and robustness

As part of this project, DNV GL developed an energy monitor which offers the participants online insight about their energy consumption and production, including electricity, gas, and heat storage processes. PowerMatching City reveals how smart grids have the ability to inter-connect different types and scales of energy flows, as well as implement new services and technologies – something which again will create opportunities for new business models. This is unique in the world, and sets the standard for the future development of sustainable living.

DIMENSION 5
Smart city innovation

The rapid advancement of technology over several decades has provided opportunities for better service delivery to city residents and businesses through improvements in efficiency, speed, and functionality. For instance, electricity meter-reading equipment that once relied on a person checking individual buildings can now be managed remotely and provide more granular energy use data.

Smart technology innovations cut across all city departments and include smart grid and smart utility technologies for load balancing and demand response, mobility apps and sustainable transportation sensors, electric vehicles and electric vehicle charging networks, smart appliances, building energy monitoring devices, distributed energy resources, data platforms and big data with machine learning, and a million other things offered through the Internet of Things (IoT). This new generation of digital technologies offers a range of previously unforeseen capabilities for cities to serve their citizens in more innovative and sustainable ways by improving resource efficiency and operations performance.

While the inclusion of new energy-related technologies and uses of data are beginning to support sustainable cities, municipalities need to engage with their communities, the utility, and energy providers to ensure grid harmonization, as well as identify complementary initiatives and potential co-funding opportunities.

The concept of "smart cities" – using big data and information communications technology (ICT) to improve critical urban infrastructure and services – promises profound changes to the urban experience. Yet growth in big data and the IoT alone does not improve quality of life or advance critical climate and sustainability goals.

A set of haphazard, short term pilot projects is also not the answer to substantively moving a community toward more sustainability and equity. While the smart city concept began with a top down, autocratic approach to technology procurement and management, the evolved version of smart cities puts citizens and societal goals at the centre of the strategy.

The next version of smart cities still includes city-led planning and decision making while also incorporating a significant role for the community and other stakeholders, in addition to planning and decision making. Piloting new technologies, putting innovation at the forefront, and involving the private sector in data analytics will all contribute to effective scaling of smart technologies that improve life for all.

Best practice indicators

PILOT OF SMART CITY PROJECTS

All ten case study cities are implementing "smart city" projects. These projects range from monitoring traffic flows and pedestrian movements to predictive analytics for building energy use and monitoring. Smart public lighting pilots are the most common smart city projects implemented by the case study cities, utilizing the dimming and mesh networking capabilities of new LED technologies.

CHIEF INNOVATION OR INFORMATION OR TECHNOLOGY OFFICER

Given the amount of smart city activity and interest, only four of the ten case study cities have a chief innovation or information officer. Notably, all three U.S. cities have a designated CIO who is primarily responsible for managing either information flows or the process of innovation and change management within city government. The City of Bristol also has a designated "City Innovation Manager" position.

PARTICIPATION IN SMART CITY ASSOCIATIONS

Over the past five years, numerous smart city industry associations have been formed, primarily by technology vendors who are interested in partnering with cities. These organizations offer an opportunity for cities and industry partners, including utilities and energy providers, to interact and explore new opportunities offered by various smart city offerings. Cambridge, for example, is participating in the Envision America Smart Cities Acceleration Initiative to work across a wide range of vendors to receive technical assistance.

CLEAN TECHNOLOGY/INCUBATOR ORGANIZATIONS

Partnerships come in many forms to transfer knowledge and research and implement innovative practices. The ten cities are involved in the following partnerships, labs or hubs: Energy and environment cluster, Smart Economic Zone, Emerging Technology program, Tech incubators, Living Laboratories, Smart City Studio, PowerMatching City, Energy Transition Center, and Launch Café.

PILOT PROJECTS LEVERAGING DIGITAL NETWORKS AND SENSORS

Numerous cities are now exploring digital networks and embedded sensors to collect and transmit information ranging from traffic and parking to air quality to crowds and noise. For instance, as part of the Adelaide Smart City project, a network of sensors is being installed around the Central Business District (CBD) to support the Smart Environmental Monitor, Smart Parking, and Smart Lighting pilots. The information will be made public via open data.

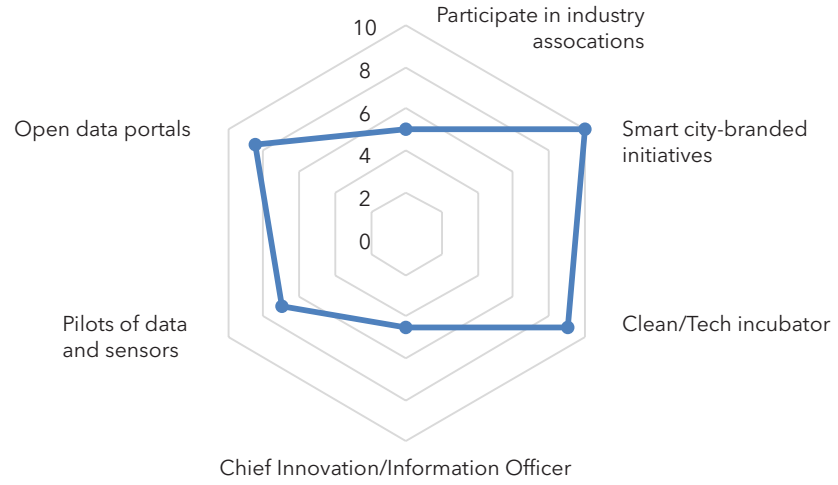
MAKE DATA AVAILABLE THROUGH OPEN DATA PORTALS

Open data policies, processes, and standards are the foundation for leveraging the creativity and intelligence of society as a whole. Fundamentally, the open data component of smart cities is a backbone for the Internet of Things – for technologies to plug in and communicate with each other. Eight of the case study cities have open data portals, utilizing a range of platforms to allow for the public and private sectors to meaningfully analyse and learn from the data being captured.

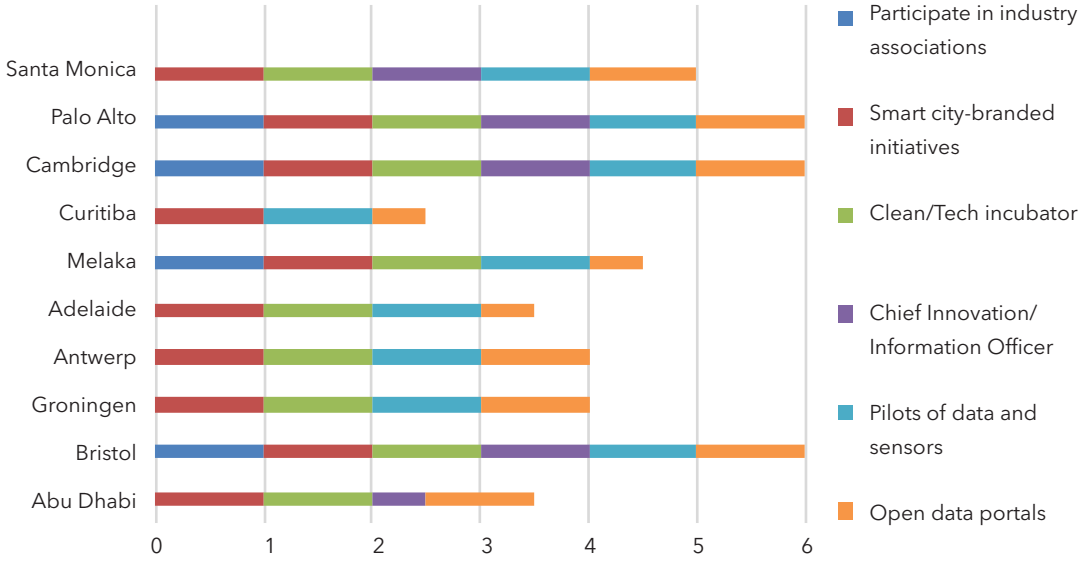
The case study cities have made tremendous inroads to testing and deploying energy-related smart city technologies to provide improved services to residents and community members. However, the provision and access to energy data remains a key challenge and opportunity for cities to work with utility partners.

CITY	SMART CITY INITIATIVE
Bristol	UK Smart Cities Index
Cambridge	Envision America
Antwerp	City of Things
Melaka	Indonesia-Malaysia-Thailand Green City Initiative
Palo Alto	Council of Global CIOs

DIMENSION 5 - Smart city innovation



DIMENSION 5 - Smart city innovation best practice indicators



Antwerp: Building a network to connect buildings, streets, and citizens

A connected city, with buildings, streets, lighting, trash cans, and other objects all linked together to provide citizens, businesses, and city government the data to make decisions and take action to create a better place for everyone sounds like a dream. But the City of Antwerp, in conjunction with imec, a research centre, are turning Antwerp and the Flanders region, into a living lab and building the City of Things. Focused on four strategic priorities—mobility, security, sustainability, and digital interaction—the aim is to create a lab that will both help its citizens and businesses grow and develop solutions for better cities as they become more densely populated.

Launched in 2017, the City of Things brings together the city government, research institutions, entrepreneurs and citizens in a test environment where innovative smart applications can be tested on a large scale—in real time. While this level of innovation could lead to an explosion of new apps and gadgets, the purpose is to find the most useful applications, as determined by the people who will use them: the citizens. In this way, the City of Things is truly a Living Lab, where citizens can decide how much they want to participate, and in which projects.

One area of Antwerp has been designated the "Smart Zone," a network of smart sensors and wireless gateways to enable real-time monitoring of a range of things, including air quality, bike and pedestrian traffic, and energy consumption is being installed. The area was selected because it has a mix of schools, offices, industry, and shops, so a variety of applications can be developed and tested. Citizens will be able to interact with the city through apps and their smartphones in ways they never dreamed of. By creating a living lab, the smart city innovations that are created will be developed, tested, and validated by the end users themselves, ensuring that these technologies are useful to and used by the citizens and businesses they were meant for.

To gauge how much citizens knew about and wanted to be involved, imec administers the Smart City Meter. The survey assesses citizen's experiences and views on smart cities and the services that smart cities provide. It found that the citizens of Antwerp are open to the idea of a smart city, and were eager to contribute. However, it also found that most people recognized the term, but did not understand what a smart city really means. While this project just started, the possibilities are endless.

Sustainable urban growth for a world heritage city: Melaka, Malaysia

In 2014, Melaka introduced its Green City Action Plan which outlines a strategy to become a Green Technology City by 2020. Melaka city is a UNESCO World Heritage Site and an increasingly popular destination for tourists, but two-thirds of the city is categorized as environmentally sensitive areas, and costal development continues without considering the risks from changes due to climate change. While Melaka had been making various efforts to address issues due to climate change and reduce greenhouse gas emissions, the Green City Action Plan coalesces those activities to ensure it achieves its goal of sustainable urban growth. The plan is guided by Malaysia's National Physical Plan-2, which, in addition to economic goals, has strong provisions for the sustainable use of land and natural resources, as well as environmental protections.

Action 3 of the Green City Action Plan calls for a feasibility study for a Smart City Demonstration project. The city was selected by the government of Malaysia for an Energy Smart Grid project, with public-private investment partnerships that will transform Melaka into a smart grid city. Melaka ICT Holdings (MICTH), a private ICT company and MIMOS, Malaysia's national technology R&D centre, have partnered to develop Smart City Services in the city. MICTH will adopt MIMOS's Smart City technology solutions, and will conduct a study exploring ways to set up a user-centric, open innovation ecosystem for Smart City implementation.

As a compliment to Melaka's smart city strategy, Tenaga Nasional Bhd (TNB), Malaysia's electric utility, is using the city as the pilot for its smart meter deployment. During the initial pilot programme, the utility installed smart meters in 1,000 houses, which allowed customers to access real-time information on their power usage, as well as keep track of their energy usage habits over time. TNB completed the first phase of the smart meter roll out in 2017, with the installation of 400,000 smart meters across the city and Melaka state. The plan is to complete a country-wide smart meter deployment in 2021. To put that in perspective, the utility has 9.2 million customers throughout Malaysia.

Melaka is combining a number of strategies that cross many of the seven dimensions in their Green City Action Plan, such as energy efficient street lights, a 5 MW solar farm, and electric vehicle charging stations, in addition to their smart city technologies. Melaka is leading the way with AMI infrastructure in southeast Asia, and this innovation will help it achieve its goal to become a Green Technology City.

DIMENSION 6
Financing innovation

New financial and business models for energy projects are empowering cities in new ways. Financing of sustainable cities projects and energy transition initiatives is a rapidly evolving field, presenting new opportunities to the investors in sustainability and to the municipalities. The Brookings Institution estimates that the world needs to build approximately $89 trillion in new infrastructure over the next 15 years alone to transition to a low-carbon economy[3].

DNV GL's interviews with investors indicated that mature projects in bigger cities may be more easily financed (the most frequent sustainability investments are in renewable energy, followed by clean technology and efficiency), while some of the smaller yet impactful projects are simply not being marketed/communicated to the right investors or de-risked properly. Often projects with higher ecological benefits require that public finance and private capital work together to create sustainable urban environments. It is critical to prioritize and communicate the pipeline of investable opportunities to better integrate clean energy and sustainability project finance into overall city planning and financing efforts.

Cities are mobilizing both public and private sector capital through green finance mechanisms such as energy-as-a-service contracts or energy performance contracts, various permit fees or tax revenues, bonds, explicit debt or equity investments, leases, financing, grants or loans. While some utility providers are exploring "on-bill financing" for energy efficiency projects through utility financing programmes, there is an opportunity in the market to leverage the investor interest in sustainability and "green investing" with the real-world city projects around the energy transition to cleaner, more renewable energy sources.

> "Climate action in states and cities is an important global investment opportunity but beyond being attractive returns, clean energy technologies that move us towards a decarbonized society are in our collective best interest. Why? The cost of externalities (health, weather, etc.) from global warming will be extremely high so investment in technologies and applications to mitigate this potential outcome, simply from a prudent risk reduction perspective, makes sense."
>
> *Stuart Bernstein, Advisory Director*
> *Goldman, Sachs & Co*

Governments can use some of their funding to incentivize clean energy markets, seek matching incentives/funds from private markets, and begin to create capital expenditures in markets not currently scaling fast enough.

[3] https://www.brookings.edu/wp-content/uploads/2016/08/global_20160818_financing_sustainable_infrastructure.pdf

Best practice indicators

ENERGY PERFORMANCE CONTRACTING

Energy Savings Performance Contracts (ESPCs) help to develop, design, build, and fund projects that save energy, reduce costs and decrease operations and maintenance. Typically, ESPCs partner with a lending institution that can provide financing such as loans or leases. Only a few case study cities were found to have utilized this approach, with some cities expressing concern about third-party ownership of equipment within city property. However, both Abu Dhabi and Groningen are formalizing ESPC programmes for local building owners as both an economic development and sustainability initiative to achieve city targets for energy reductions.

POWER-PURCHASE AGREEMENTS

While most case study cities have installed solar PV on municipal buildings, only a few are utilizing power-purchase agreements (PPAs) to finance such projects. PPAs are financial agreements where the building owner purchases the renewable energy from the project developer at a negotiated rate. While this financing strategy allows cities to overcome the first cost hurdle of outright ownership, the PPAs lock building owners into an energy rate for 10 to 20 years. In a potentially volatile energy market, this can be viewed as either an opportunity or a risk.

PROPERTY TAX APPROACHES

An innovative programme developed in the United States known as the property-assessed clean energy (PACE) programme helps domestic and commercial property owners to finance energy efficiency measures through property tax repayments. PACE ties debt to the property rather than the property owner and hence supports changes in ownerships structures for those properties. All three U.S. cities in this study are leveraging new statutory powers to make PACE programmes available to their constituents. The City of Groningen also explored a strategy to reduce property taxes for buildings with renewable energy systems, but was not able to get an exemption to implement the programme.

GREEN BONDS AND FINANCING

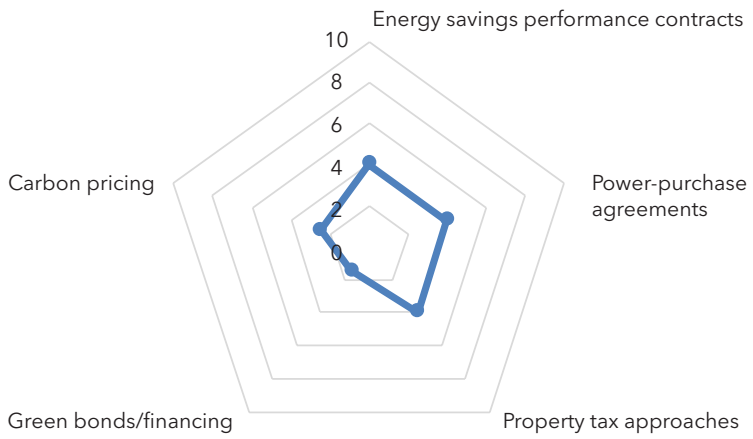
"Green bond" issuance is growing fast, part of the overall trend of do-good investments becoming more popular. A few cities such as Abu Dhabi and Bristol are looking to tap into investor demand for these bonds. In 2016, the Bristol Energy Cooperative announced a solar bond offer to support installation of a portfolio of 20 large rooftop installations, one of the UK's first Individual Savings Accounts (ISA)-eligible community energy bonds. Bristol Energy Cooperative has also launched a new crowdfund to support new micro-renewable generation and battery storage schemes.

CARBON POLLUTION PRICING

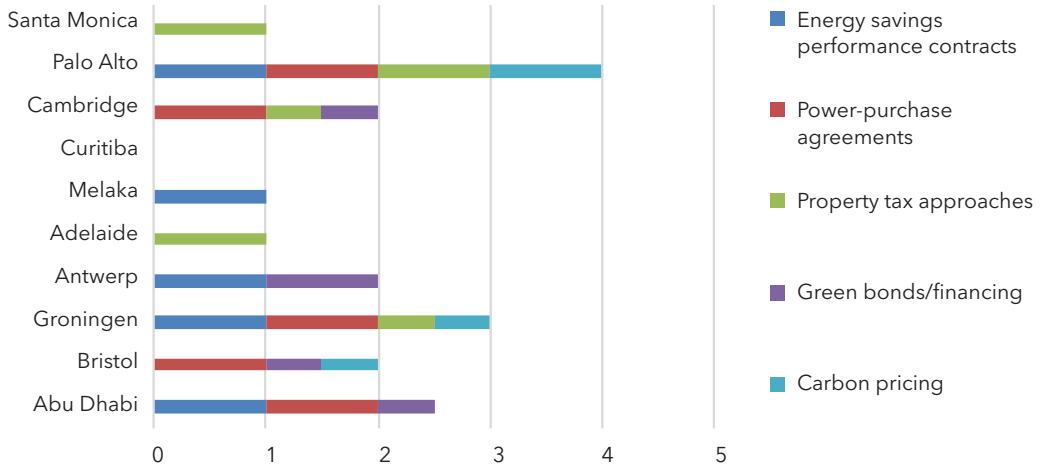
The majority of the case study cities rely on state or national schemes related to carbon pricing to evaluate costs and benefits of new city projects. Therefore, the costs of carbon are embedded in energy pricing through both the European Union's Emissions Trading Scheme (EU ETS) and the California Cap-and-Trade programme. The City of Palo Alto, through its municipal utility, is also explicitly including carbon pricing in its cost-effectiveness calculations for new energy programmes and reports to City Council.

For cities with strong financial positions, traditional municipal general obligation bonds continue to be a primary financing source for capital improvements rather than third-party financing such as ESPCs and PPAs. However, municipal bonds are typically only appropriate for large-scale projects. Therefore, we find significant opportunities for innovation in other financing strategies and partnership contracts.

DIMENSION 6 - Financing innovation



DIMENSION 6 - Financing innovation best practice indicators



Leading the way to a sustainable energy use with creative financing: Abu Dhabi

Abu Dhabi set itself a goal to reduce electricity and water consumption per capita by 20% by 2030. Considering the climate and the level of energy needed to provide cooling and water, this reduction is an ambitious target, but one that Abu Dhabi has recognized as necessary.

To achieve this ambitious plan, Abu Dhabi launched the Tarsheed initiative in 2017, with the Abu Dhabi Water and Electricity Authority and affiliated distribution companies. Alongside initiatives such as PowerWise and WaterWise, Tarsheed runs programmes to raise awareness and promote efficient technologies. Tarsheed also includes a programme for the accreditation of Energy Services Companies (ESCOs).

In addition, the distribution companies have developed energy and water conservation strategies that are now moving into the implementation phase.

To finance these retrofit projects, the emirate is also exploring the ESCO model where the building owners will not need to pay for the engineering and construction costs for the upgrades. Instead, the ESCOs will be responsible for financing the project, including the implementation of water and electricity conservation measures such as efficient cooling, lighting, and water pump technologies. The ESCO will then recoup its investment through the energy savings and reduced utility costs over a period of four to seven years depending on the project.

By placing the cost of the project on the ESCO rather than the building owner or facility manager, the ESCO is incentivized to ensure the success–and the financial return–on the project, while mitigating the risks and burdens of such a massive undertaking.

Public-private partnerships for the energy transition: Cambridge, USA

The City of Cambridge has unique partnership opportunities to accelerate the energy transition locally, such as the Kendall Square EcoDistrict Pilot. Over the past 30 years, Kendall Square has evolved from a barren commercial district filled with empty parking lots and austere buildings to a vibrant mixed-use urban neighbourhood, with development rapidly accelerating over the last ten years. EcoDistricts are a strategy to increase sustainability and resiliency at a neighbourhood scale that takes into account the specific needs, conditions, and priorities of the area.

Kendall Square is home to MIT, companies that range from biopharmaceutical, life sciences and major technology players to brewpubs and pizza shops, but also has a thriving and eclectic residential population. The Kendall Square EcoDistrict Pilot has identified several opportunities for sustainability in the neighbourhood, including increasing transit options while reducing car traffic, improved energy use in the neighbourhood, and the creation of more useable public spaces.

The City of Cambridge has also mapped out a path to achieving net zero emission buildings. This was spurred by a petition residents brought to the Cambridge City Council requesting an amendment to zoning laws that required all new construction to achieve net zero emissions by 2030. The City Council convened the Getting to Net Zero Task Force in 2014, which developed a pathway to zero emissions in new construction, identify strategies to reduce emissions in existing buildings and increase renewable energy supply.

The Getting to Net Zero Action Plan includes several strategies to achieve a net zero community: highly energy efficient buildings, onsite and offsite renewable energy generation, and, if needed, the use of offsets and renewable energy credits. For existing buildings, the plan proposes custom retrofit programmes specific to the City of Cambridge, building energy use disclosure requirements, and energy efficiency upgrades when a building is renovated or sold. For new construction, the city set tiers of target dates for different types of buildings, taking into consideration the complexity of each building type. Municipal buildings have a target year of 2020, but labs, of which there are many as the biotech and life sciences industries expand, have a target year of 2030.

Energy supply is also a key aspect of a zero net energy community, as well as a means to improve the community's resilience overall, and the city plans to explore several strategies for a low carbon energy supply. That includes increasing the amount of energy produced through solar (PV and thermal), taking advantage of waste heat from the many large commercial and industrial facilities in Cambridge through district energy networks, and expanding or "greening" the city's energy supply.

Cambridge is taking advantage of its unique resources – world class educational institutions, a large population of innovative firms and industries, and engaged and enthusiastic citizens to make strides in the energy transition.

DIMENSION 7
Resilient communities

Adaptation and resilience is very much a concern for cities these days. However, the provision of emergency management and services is not new for cities, who have historically played a key role coordinating the planning, preparedness, communication, response, and recovery during man-made or natural disasters. Cities must now incorporate projected climate risks and hazards into short-term and long-term planning processes.

The term "Resilience" can be broadly applied, but generally encompasses three aspects: preparedness – how well a city is prepared for an event; response – how a city responds during an event; and recovery – the restorative process that begins immediately following an event to get back to normal conditions. Community resilience is about the ability of a city to respond to and withstand chronic stresses (e.g., droughts) and acute negative events (e.g., flooding).

As cities strive to protect their residents and business from climate change-related events and play a larger role in the energy landscape, the scope of emergency preparedness, management, and recovery will extend beyond traditional practices to encompass energy assurance. The expansion of city-owned energy assets and distributed energy resources will require that city staff responsible for emergency services and public works coordinate more closely with utility companies and other energy providers. This provision of being a resilient community and managing energy networks during an event in a way that provides energy to businesses and citizens of all income levels in times of need is an emerging area of focus, and one where greater utility and city collaboration is needed. Climate change-related events tend to disproportionately affect low-income communities as well as small businesses.

Best practice indicators

ADOPT AN ADAPTATION OR RESILIENCE PLAN FOR THE COMMUNITY

Most case study cities have completed a vulnerability assessment and/or adaptation plan to understand projected climate impacts, risks, and hazards. In some cases, the plans are incorporated into other sustainability reports, such as climate action plans or environmental reports. For example, the City of Melaka Green City Action Plan addresses climate hazards such as flooding and air pollution.

ASSESS VULNERABILITY OF ENERGY SYSTEMS

There are vast amounts of resources available now to help cities perform vulnerability assessments and calculate the risk to city assets from climate change events. However, most city adaptation planning efforts fall short on looking at local energy systems and risks to municipal services. Furthermore, while a few cities with their own energy utilities, such as Bristol and Palo Alto, have analysed potential climate stresses on energy generation and infrastructure, not all cities with municipal utilities have done so. Resilient energy infrastructure is an emerging area for all energy players, not just cities.

ASSESS VULNERABILITY OF CRITICAL ASSETS, INCLUDING EMERGENCY SHELTERS

Critical city assets include water infrastructure (potable and wastewater), emergency operations centres, police and fire operations centres, and community emergency shelters, but cities should also consider including transportation systems and community resources such as food stores, gas stations, or cooling facilities. Only a few cities have systematically assessed a priority list of critical assets and potential vulnerability to projected climate risks and hazards.

CONDUCT BUILDING-LEVEL RESILIENCE ASSESSMENTS

Many city efforts to date have centred on vulnerability assessments and climate impacts at a neighbourhood or city-scale level. Most cities have not assessed the resilience of specific buildings or building types. While most emergency operations, hospital, fire, and police facilities have back-up power generation, cities are only beginning to look at how vulnerable populations will be affected during an event. Cities should consider assessing the resilience of low-income multifamily housing, small businesses, shelters and other community resources as well.

DESIGNATE A CHIEF RESILIENCE OFFICER

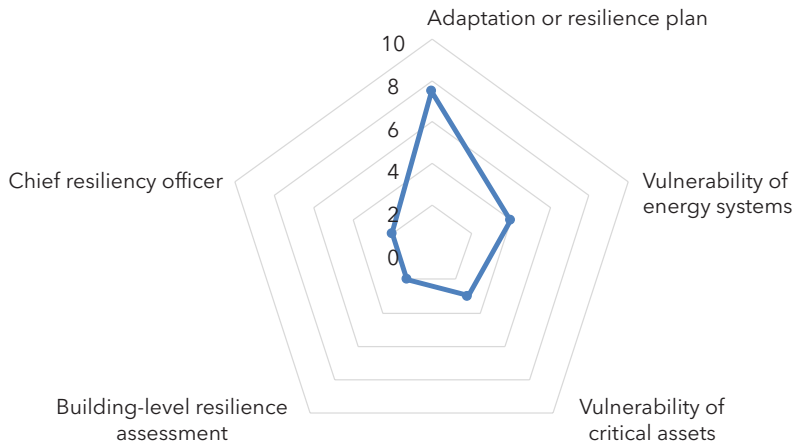
With the support of the Rockefeller Foundation's 100 Resilient Cities, cities worldwide, including Bristol, have hired Chief Resilience Officers to lead citywide resilience efforts. The City of Santa Monica, while not a 100 Resilient City member, has also recently brought on a Chief Resilience Officer with a public health background to protect the city against potential disasters and head the Office of Emergency Management.

While much attention has been paid to protecting communities against sea level rise and flood risks, more work is needed to understand and manage our energy systems during a climate-related event at the neighbourhood and building scale as distributed energy resources expand. This includes further assessments of building systems and operations, the people who occupy those buildings, and the community assets that provide the basic and essential resources to the community following an event.

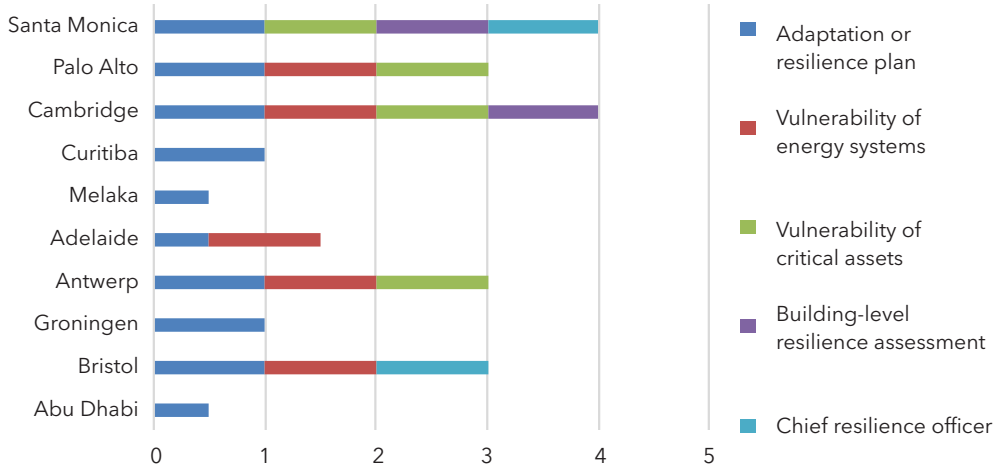
GLOBAL COVENANT OF MAYORS FOR CLIMATE AND ENERGY

The cities that have signed on to the Global Covenant of Mayors need to assess and report the hazards they are exposed to within one year of becoming a signatory. Within two years they will have had to complete a vulnerability assessment, and within three years an adaptation plan. The Global Covenant of Mayors provides a good vehicle for moving climate change adaptation services forward. Currently there is an abundance of planning resources, but relatively few tools to support implementation, monitoring and measuring progress, as well as a lack of financing resources.

DIMENSION 7 - Resilient communities



DIMENSION 7 - Financing innovation best practice indicators



CONCLUSION

The Energy Transition in Cities is already occurring. Our case study cities are using their unique role in society and presence in the energy markets make the energy systems that serve their communities more affordable, resilient, and environmentally sound.

The case study cities are taking a leadership position in setting local policy objectives related to aggressive decarbonization that drive much of their other actions related to the energy transition. Related to Dimension 1 – Sustainability Governance, the featured cities are leveraging industry standards for emissions accounting and working with their energy providers to measure progress.

Cities are unique in their collaborative spirit and desire for peer-to-peer learning exchanges with other cities around the world. Regionally, we find that European cities in aggregate are leading the way on building energy standards and disclosures due to strong mandates from the European Commission. In other parts of the world, including the United States, individual cities are leading the way by forging their own paths forward on energy efficiency and sustainable energy initiatives, resulting in more patchwork achievements across cities of all sizes.

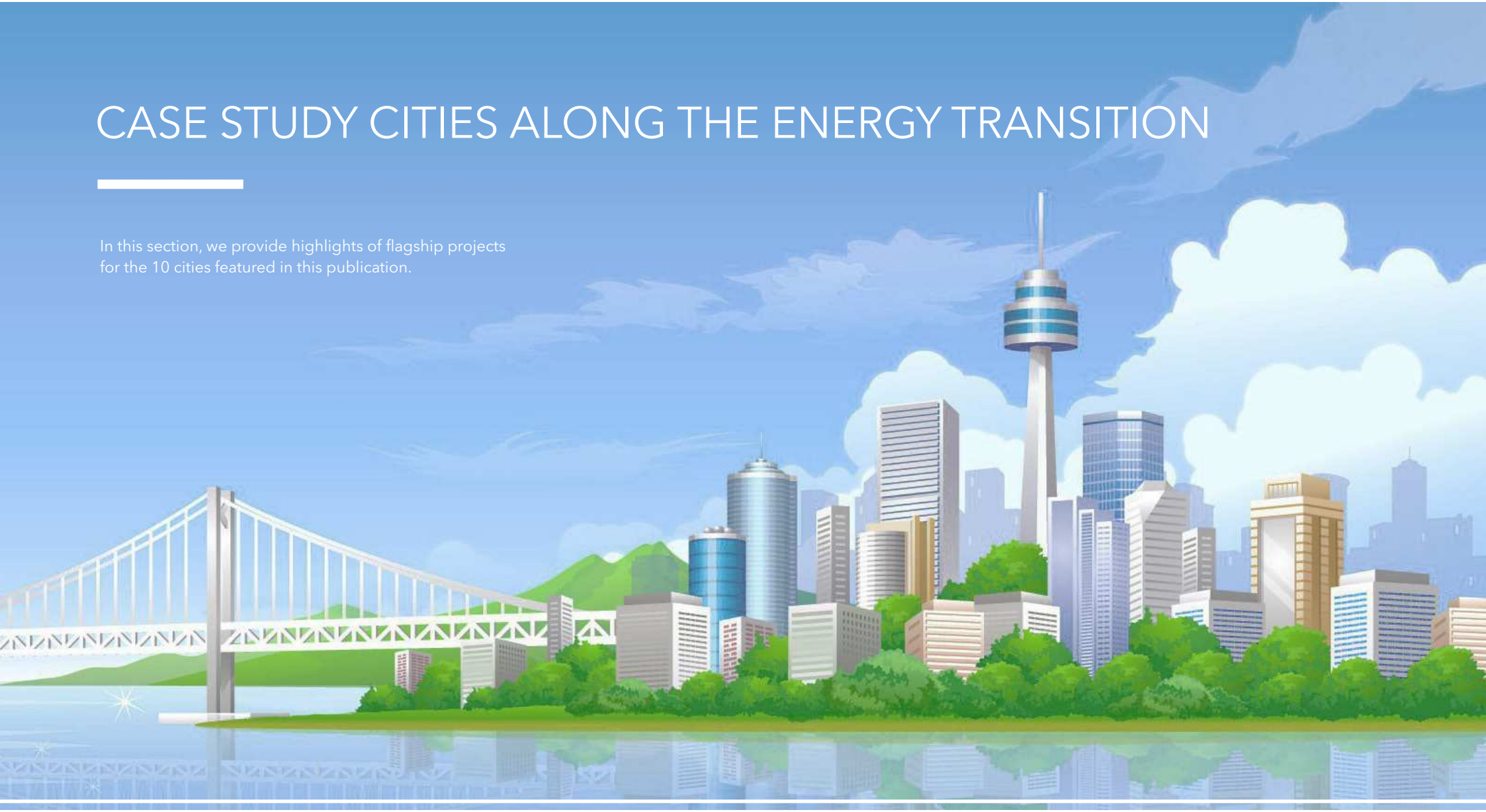
One of the most compelling findings is that cities are still struggling to find appropriate financing vehicles for their energy initiatives. It is critical for cities and their energy project partners to prioritize and communicate the pipeline of investable opportunities to better integrate clean energy and sustainability project finance into overall city planning and financing efforts.

In particular, this need for public-private partnerships extends to resilience of energy infrastructure and critical facilities that may not be entirely owned or operated by city government. A significant opportunity exists for industry partners, such as utilities, product vendors, and other energy providers, to engage more deeply with cities who clearly desire and need to accelerate the energy transition to meet global decarbonization targets.

Please look out for next year's DNV GL Energy Transition for Cities publication that will utilize new sources of data to assess advances and new emerging issues in moving towards a sustainable future for not only us, but for future generations to come.

CASE STUDY CITIES ALONG THE ENERGY TRANSITION

In this section, we provide highlights of flagship projects for the 10 cities featured in this publication.



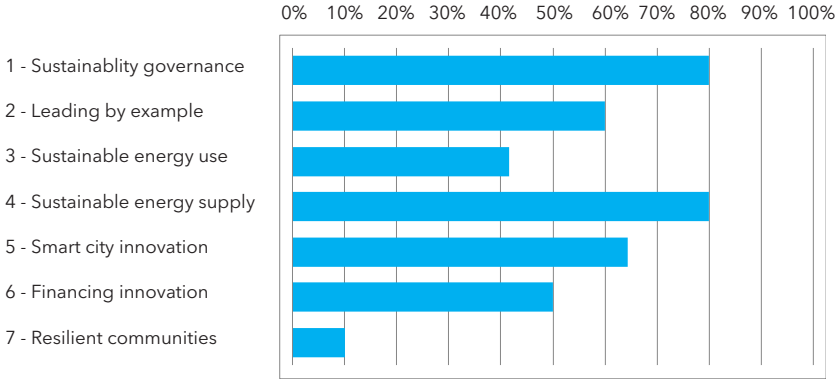
Abu Dhabi, UAE

POPULATION
1,807,000

UTILITY PROVIDER

Abu Dhabi Distribution Company (ADDC) is the sole provider of electricity and water to customers in the Abu Dhabi City region (but not to the whole Emirate of Abu Dhabi).

Abu Dhabi: Cumulative score per dimension



Abu Dhabi city is the capital of the UAE, and, along with Dubai, constitutes the two largest cities in the country. Abu Dhabi is also the name of the Emirate, which is the largest of the seven Emirates in the country. Much of the greenhouse gas and other analysis so far has been completed at the Emirate level, but as the city constitutes the large majority of population and industry, consumption and sustainable initiatives have been focussed on the city. In 2012, the Environment Agency of Abu Dhabi completed a greenhouse gas inventory for the Emirate of Abu Dhabi.

Since then, Abu Dhabi has launched the Economic Vision 2030, which is a long-term roadmap for economic progress for the Emirate through the establishment of a common framework aligning all policies and plans and fully engaging the private sector in their implementation.

The UAE has announced aggressive targets for decarbonisation across the seven Emirates, aiming to reduce CO_2 emissions by 70% by 2050. Abu Dhabi, with its large population and large hydrocarbon and aluminium industries will contribute significantly to this 70% target. However, the city or Emirate has not announced individual reduction targets.

In 2017, ADWEA, which is responsible for electricity and water across the Emirate, announced plans to reduce consumption by 20% by 2030. While the Emirate has not previously undertaken large programs on efficiency, it is now accelerating the rollout of a number of initiatives, such as rooftop solar PV, the development of an ESCO market, and electric vehicle charging stations are being installed around the city.

Due to the high temperatures, air conditioning contributes significantly to the electricity demand. District cooling can efficiently provide air conditioning to multiple buildings in city environments and has already been installed in a number of locations. This market is set to grow significantly in the following years.
With abundant year-round sunshine, Abu Dhabi is looking get more of its electricity from solar PV. Regulations have been established to encourage the rooftop solar PV market, and construction has started on a 1.17GW solar PV farm in the desert.
Large scale battery storage is also being implemented across the city.

Abu Dhabi has been leading the world with the innovation of Masdar City, which is a sustainable city that is both a university and research centre that is focussed on sustainability and the environment. It has buildings that are equivalent to LEED Gold certification, and provides a beacon on what the future can hold for Abu Dhabi.

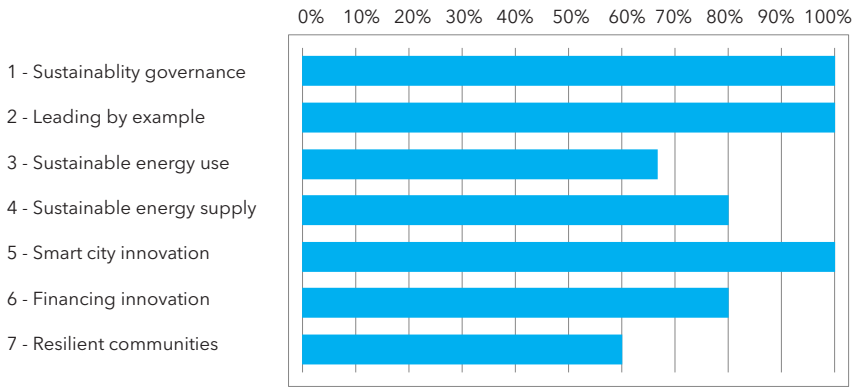
Palo Alto, USA

POPULATION
66,600

UTILITY PROVIDER

City of Palo Alto Utility (CPAU) is a full-service municipal utility including electric, water, natural gas, and waste water.

Palo Alto: Cumulative score per dimension



Located 35 miles south of San Francisco and 14 miles north of San Jose, Palo Alto is known as the "Birthplace of the Silicon Valley." Unique among U.S. cities, Palo Alto is a full-service municipality that owns and operates its gas, electric, water, sewer, refuse, and storm drainage services.

Palo Alto has long been a leader in sustainability, making great progress toward reducing its carbon impacts, greenhouse gas emissions, and resource consumption since establishing its first Climate Protection Plan in 2007.

The city has undertaken a wide range of initiatives to improve the sustainability performance of both government operations and the community at large - including approving a Sustainability and Climate Action Plan in 2016, coupled with a goal of 80% greenhouse gas reduction by 2030.

To date, the city has achieved their goal of 100% carbon neutral electricity supply and plans to offset all emissions from natural gas use in the city in 2017. City ordinances includes a city-specific policy (LEED) related to green building standards for municipal buildings. Additionally, the city has implemented a reach code of 20% beyond base code (10% with solar PV) for new buildings. This ordinance includes an updated energy "reach code" requiring building design to exceed the minimum California energy code requirements by a certain percentage based on project type and scope. It also continues solar-ready infrastructure requirements for new residential buildings and promotes all-electric building design by providing an exemption. Renewables are a big focus with at least five solar PV projects on municipal facilities, funded from grants and incentives from the Federal government and the City of Palo Alto Utilities. The total rated power capacity of the solar photovoltaic (PV) systems is 264 kilowatts (kW). Of note, the innovative solar storage project installed at Pearson Arastradero Preserve Gateway Building uses solar energy to power the lights and electric equipment and heat the water in the buildings made from straw-bales. The solar power system uses batteries because this site is not connected to the electric grid.

Local utilities offer an array of rebates on energy efficient appliances and equipment for residential and commercial users. Another asset to the community, the city has developed a Smart City Palo Alto initiative that includes smart traffic signals, open data, and applications to promote communication with and to city services like libraries, 311 (a telephone-based system providing services to residents and local businesses), police, and disaster reporting. Speaking of such, city has assessed vulnerability of critical assets and has developed a local adaptation and resiliency plan.

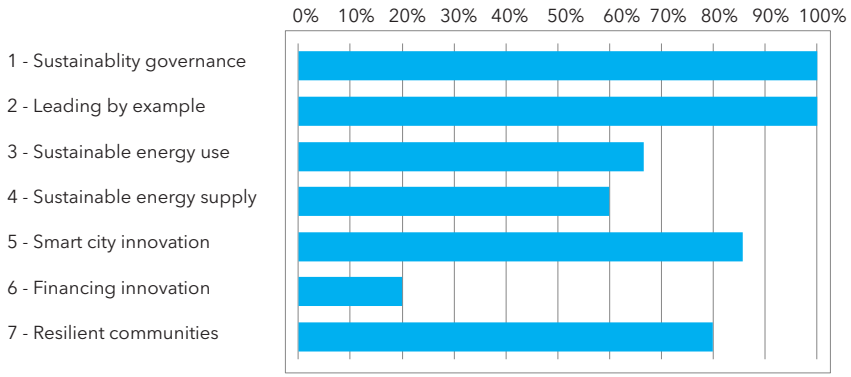
Santa Monica, USA

POPULATION
92,500

UTILITY PROVIDER

Southern California Edison (SCE) is an electric investor-owned utility, with gas currently provided by Southern California Gas Company, a natural gas investor-owned utility.

Santa Monica: Cumulative score per dimension



The city of Santa Monica is a coastal city west of downtown Los Angeles. A popular tourist destination, Santa Monica is also one of the most environmentally progressive municipalities in the U.S. The city first proposed its Sustainable City Plan in 1992 and in 1994, was one of the first cities in the nation to formally adopt a comprehensive sustainability plan, setting waste reduction and water conservation policies for both public and private sector through its Office of Sustainability and the Environment.

The City of Santa Monica developed a 15 x 15 Climate Action Plan, with an updated Climate Action and Adaptation Plan for carbon neutrality by 2050 or earlier currently under development. The 15 x 15 Climate Action Plan identified strategies for the city to reduce emissions by 15% by 2015. The strategies included transportation, such as reducing greenhouse gas emissions from municipal fleet fuel use, converting the Big Blue Bus fleet to 100% natural gas, and implementing a car sharing programme that will reduce the size of the city's vehicle fleet. It also incorporated saving one million kWh from buildings and facilities annually through energy efficiency and conservation. This required updating and adopting a new energy efficiency plan for municipal facilities, constructing all new municipal buildings to achieve LEED® Gold level certification or higher, creating a revolving fund programme to finance energy efficiency retrofits, and implementing a strategy to reduce energy from electronic equipment, like office printer reductions. Beyond buildings, the plan calls for retrofitting 100% of streetlights using LED or induction technology, increasing the use of solar technology on city facilities, installing solar thermal systems on the Santa Monica Swim Center and all city fire stations, and installing an additional 500 kW of solar photovoltaic capacity on city buildings.

The city is also in the process of implementing a 5-year and 20-year Bike Action Plan with a goal of attaining 14 to 35% bicycle transportation mode share by 2030 through the installation of enhanced bicycle infrastructure throughout the city. Santa Monica has also instituted a green building-code equivalent to the U.S. Green Building Council's LEED Silver standards. The city's Main Library is one of many LEED certified or LEED equivalent buildings in the city that also serves as a renewable microgrid. City ordinances also require solar PV on new construction and the world's first ZNE requirement for new homes.

Incentive programme available for residents include: Energy Upgrade California (The Energy Network), Energy Savings Assistance Program (Utility: SoCalGas & SoCalEdison), Solar Santa Monica, and a Local Government Partnership programme.

In terms of resilience, the city has assessed vulnerability of critical assets and developed a resiliency plan, including identification of emergency shelter locations, with an assigned Chief Resiliency Officer.

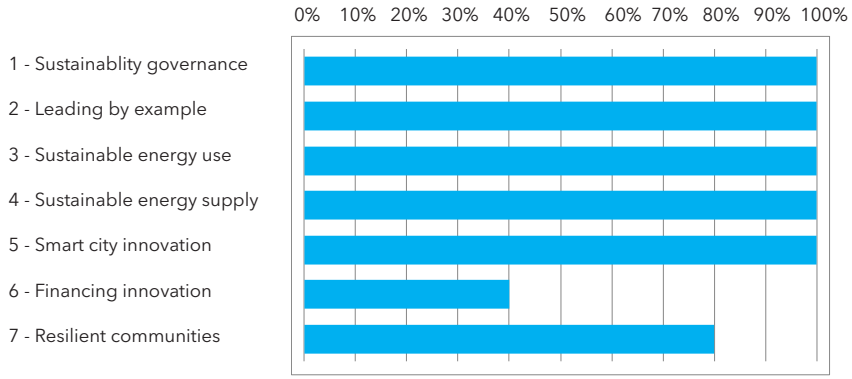
Cambridge, USA

POPULATION
107,289

UTILITY PROVIDER

Eversource is an investor-owned utility providing natural gas and electricity service.

Cambridge: Cumulative score per dimension



The City of Cambridge is known primarily for its two large universities: Massachusetts Institute of Technology (MIT) and Harvard. However, it has also been on the forefront of the energy transition for quite some time. While Boston, located directly across the Charles River, has been getting a lot of attention for its sustainability actions, Cambridge is equally, if not more active in this arena.

When looked at through the lens of the seven dimensions of the DNV GL Energy Transition Framework for Cities, Cambridge is active in all of them, including Dimension 6 - Innovative Financing, which a challenge for most cities.
The combination of the influence of MIT and Harvard, the presence of a myriad of technology, biomedical, and research institutions in the city, as well as its motivated citizens has led to a number of initiatives that are furthering it along the energy transition.

Cambridge has developed and implemented a Climate Action Plan since 2001, with a recent update in 2017, with multiple additional initiatives such as the Cambridge Sustainability Compact: Three-Year Work Plan, the 25-Year Net Zero Action Plan, and the Climate Change Vulnerability Assessment. Policies include city-specific regulations related to green building standards for municipal buildings, a commercial and domestic building energy use disclosure policy, and a Net Zero Emissions policy that requires new construction of municipal buildings to be net zero by 2020 and all other buildings by 2030.

The city is unique in that it is home to major universities that have included renewable energy goals as a campus policy. Although they are not city-run, Cambridge is home to two microgrids at Harvard and MIT.

Internally, the city is on track to supply more than 5% of municipal electricity with on-site solar by 2020. Cambridge has installed energy retrofits at close to 35 facilities, made process and equipment improvements at the Walter J. Sullivan Water Purification Facility, and converted streetlights to LED technology.
In addition, the Cambridge Energy Alliance (CEA) is a service provided by the City of Cambridge to help residents, businesses, and institutions become more energy efficient and access renewable energy services.

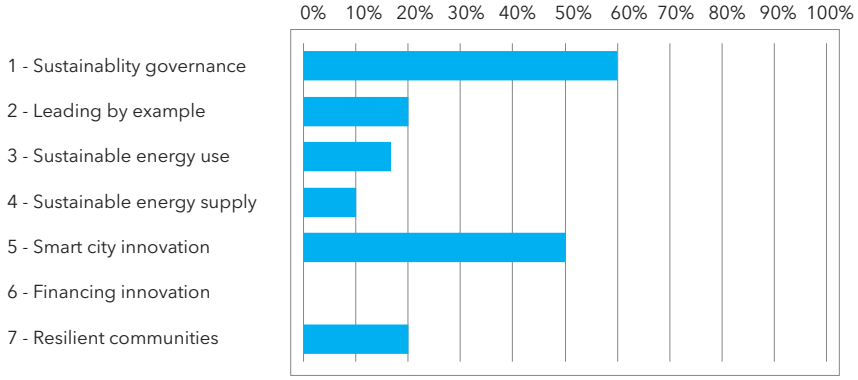
Curitiba, Brazil

POPULATION
1,879,355

UTILITY PROVIDER

Copel, which is owned by the State of Parana. The company serves over 3.5 million homes, and 450,000 commercial and industrial accounts. Copel is a vertically integrated electric utility.

Curitiba: Cumulative score per dimension



Curitiba is the capital and largest city of the Brazilian state of Parana and an important cultural, political, and economic centre in Latin America. Since 1853, when the city was declared capital of the State of Paraná, Curitiba has initiated several major urban planning projects to avoid uncontrolled growth and has since become an international model in dealing with issues of transportation and the environment.

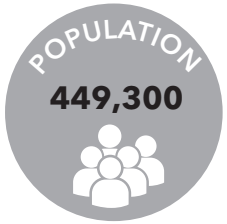
Curitiba developed and implemented the Curitiba Master Plan in 1968, and plans to develop a Municipal Plan for Mitigation and Adaptation to Climate Change. While there are currently no municipal solar PV installations, Curitiba receives 84% of its total electricity consumption from hydropower.

As a relatively dense city in Brazil, the city has focused on urban transportation planning. The transit service is used by more than 2 million people a day. Since 2014, Curitiba has been promoting 100% electric buses. The city also utilizes thirteen fully electric vehicles, including ten cars and three mini-buses. The city project "Ecoelétrico" has shown significant results – in the first five months, ten electric cars showed savings of 82 percent compared to the consumption of gasoline-powered vehicles, and avoided an estimated three tons of carbon emissions.

Curitiba is also undertaking a large-scale LED retrofit project which includes 160,000 illumination points across the city and LED replacements for 6,500 bus stops, 2,300 republican luminaries, 100 squares of 6 municipal parks and over 120 km of bike paths.

Curitiba has made significant headway with smart city initiatives, including the "Smart City Curitiba" project through the University of Twente's Institute for Innovation and Governance Studies. The University of Twente signed a Memorandum of Understanding with fourteen parties including the City of Curitiba and four local universities. The MoU symbolizes the start of a five-year collaboration consisting of exchange of knowledge and people and joint research projects to support a Smart Curitiba. The focus includes smart grids and energy transition, human-technology interface and behavioural approaches, big data analysis, remote sensing, open innovation and entrepreneurship, smart and sustainable transport, traffic and mobility.

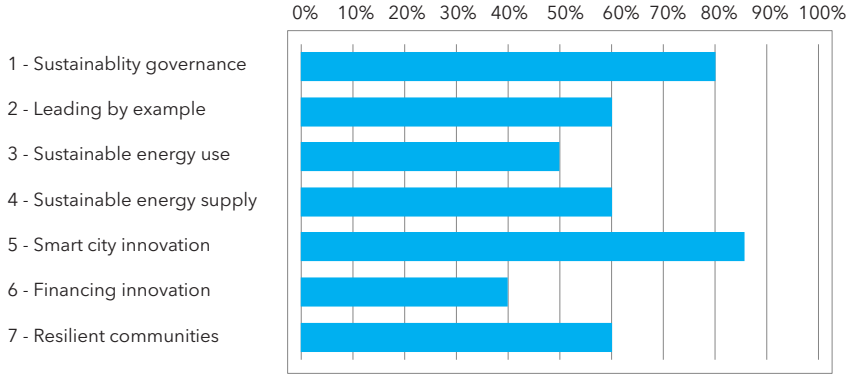
Bristol, UK



UTILITY PROVIDER

Western Power Distribution (WPD) is the electricity distributor, a subsidiary of the American utility corporation PPL, with 7.8 million customers in the Midlands, South West and Wales. There are also a number of retail electricity and gas suppliers.

Bristol: Cumulative score per dimension



Bristol is a city and county in South West England, and has played an extremely important role in sea trade since 1051, but as the scale of business and trade grew in the city, so did the need to develop the narrow and relatively small harbour. Today Bristol is a multicultural, vibrant hub that is ranked as Britain's most sustainable city. In 2015 Bristol was celebrated as the first city in the UK to win the prestigious award of European Green Capital in recognition of its "progressive, creative and conscious approach to urban living" in line with the city's Our Resilient Future: A Framework for Climate and Energy Security plan.

The city is directly involved in the development and/or ownership of utility-scale solar PV power plants. In October of 2013, the Bristol City Council (BCC) received approval for £5.96m to invest in solar projects. The funds were used for a 4.2 MW solar PV system at Severn Road Solar Park at Avonmouth and two sites at the Lawrence Weston Road site of 4.2 MW each. The Avonmouth system became operational in June 2016. The BCC also had plans to install 1.5 MW of solar PV on roofs by 2016. To date, over 700 kW of PV capacity was installed at six schools and 30 domestic properties. The city is also involved in development of several small-scale wind turbine projects.

In terms of city programmes, "Warm Up Bristol" delivers energy efficiency improvements to privately owned homes, through assessing home energy performance, identification of improvements, and advice for grant funding. Another successful programme, "Refill Bristol" was initiated to help reduce the amount of plastic water bottles. Residents can fill a reusable bottle at a number of refill stations across the city, identified by a blue window sticker on restaurants, hotels, stores, etc.

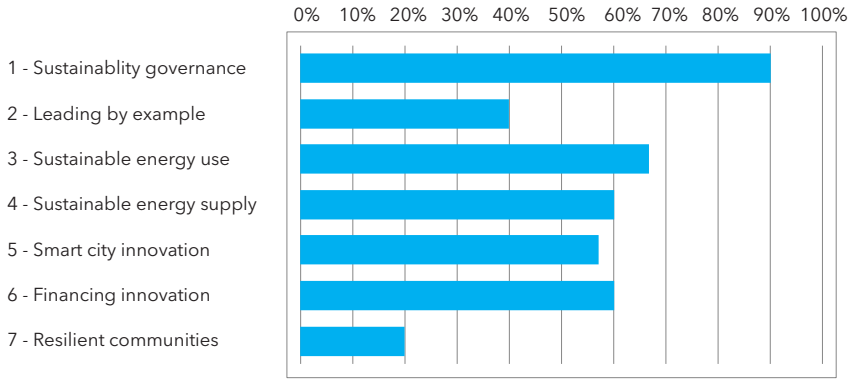
Lastly, the Bristol City Council created Bristol Energy, one of the UK's first municipal energy companies, wholly owned by Bristol City Council. Bristol Energy is the delivery vehicle for major energy efficiency and low carbon energy projects. They are piloting smart meters and offer 100% renewable electricity through their My Green Plus Tariff.

Groningen, the Netherlands

POPULATION
197,823

UTILITY PROVIDER
Enexis is the local grid operator. In the Dutch liberalized market consumers can choose their own supplier. Grunneger Power is the local energy supplier. It is a cooperative that supplies local sustainable energy.

Groningen: Cumulative score per dimension



Groningen is the capital city in the province of Groningen in the northern Netherlands. A historic region, first documented in 1040, the city is nationally known as the "Metropolis of the North." The city's current population and culture flow around the bustling University of Groningen, the second oldest Dutch university, as the large number of students living in Groningen contributes to a diverse cultural scene for a city of its size.

In terms of sustainability planning, the city of Groningen has established an energy neutral climate goal. The Masterplan Groningen Energy Neutral states that 37% of the CO_2 reduction target will be achieved through energy efficiency targets.

The city is directly involved in the development and/or ownership of utility-scale solar PV power plants and is a partner in the collaborative geothermal project. The Zernike geothermal heat project involves the supply of heating from the deep subsoil for 10,000 households. The project is being developed in collaboration with WarmteStad (municipality/water), four private corporations, Groningen University and Hanze University of Applied Science. The Dutch government supplied a grant of 32 million Euros to cover the non-profitable start-up phase of the project.

All municipal buildings in Groningen are equipped with smart meters. While implementing typical smart city programmes focused on sensors and communication technology, the city has also spearheaded a unique programme that uses data collection sensors to monitor and report earthquakes associated with natural gas extraction.

The City of Groningen is one of three finalists for the iCapital Award and was placed on the UN's 'Sustainia100', a global list of the hundred best sample projects in the area of energy, water, and food, for the 'Groningen Smart Energy City' plan. Smart Energy City is the European testing ground for intelligently linking supply and demand of electric power and heat and included 40 households in Groningen.

The city of Groningen established an ESCO for itself in 2014, called GRESCO. The money that is made via investments is returned to the municipality (revolving construction). All city buildings have been included in an inventory and, if maintenance is required, GRESCO includes energy solutions.

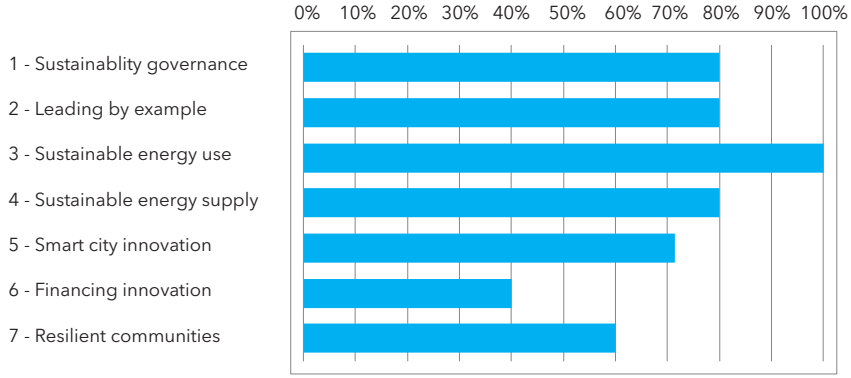
Antwerp, Belgium

POPULATION
521,496

UTILITY PROVIDER

Eandis and Infrax are the local grid operators responsible for distribution. In the liberalized energy market there are several suppliers active in the city.

Antwerp: Cumulative score per dimension



The City of Antwerp is part of the densely populated North-Western European area. It is the second-largest city in Belgium (after Brussels) and the largest city in the Flanders region. The city of Antwerp has a population of 521,946, with the wider metropolitan area having a population of 1.2 million. The citizens represent more than 160 nationalities. Antwerp is an important economical hub. Its three thriving economic engines are its port, the chemical industry and the diamond sector. The port of Antwerp is home to the second largest petrochemical site in the world, after Houston, Texas. The port is the second largest in Europe (after Rotterdam). The city centre is home to the largest diamond trade centre in the world.

Antwerp signed the Covenant of Energy in 2009, Mayors Adapt in 2014, and Covenant of Mayors for Climate and Energy in 2017. This means that the city of Antwerp made the commitment to reduce CO_2 emissions by 20% by 2020 compared to 2005, a 40% reduction by 2030, and to become fully carbon neutral and climate robust by 2050. For its own operations, the municipality aims to reduce CO_2 emissions by 50% by 2020, compared to 2005. Based upon the most recent emission inventory (2015), Antwerp is well on track in achieving its mitigation goals. As for adaptation, Antwerp is actively studying the impact of climate change on Antwerp and define a strategy in 2018.

The city runs its own ESCO, resulting in an increasingly energy-efficient portfolio of municipal buildings. In addition, the city's buildings are supplied with 100 percent green electricity. It also supports the Province of Antwerp in enabling the group purchase of green energy and solar panels for its citizens. The city is also constructing the largest heat network in Flanders in the New South district. This is the first step in linking the abundant heat produced by the port industry to the city network.

One of the unique pillars of the city's climate policies is to actively involve the people living and working in the city. Antwerp has initiated new innovative business models, like 'Samen Klimaatactief' (translated: Together active in climate'), a common private platform to speed up energy projects in the tertiary sector and light industry. The city developed the Ecohouse, which proactively helps citizens with their energy projects and is supported by climate ambassadors in the field. In 2017, the Ecohouse started with 'Climate streets and -districts' (with support of the EU), supporting the entrepreneurship of citizens who see common technical, economic, and ecological advantages in involving the neighbourhood in their personal energy project. Another new business model is being developed to assure a unique governance structure for the 2030 climate plan, where citizens, districts, the private sector, and the city government drive the climate plan as self-steering teams to achieve, and maybe even overshoot, the ambitious climate goals for 2030 and 2050.

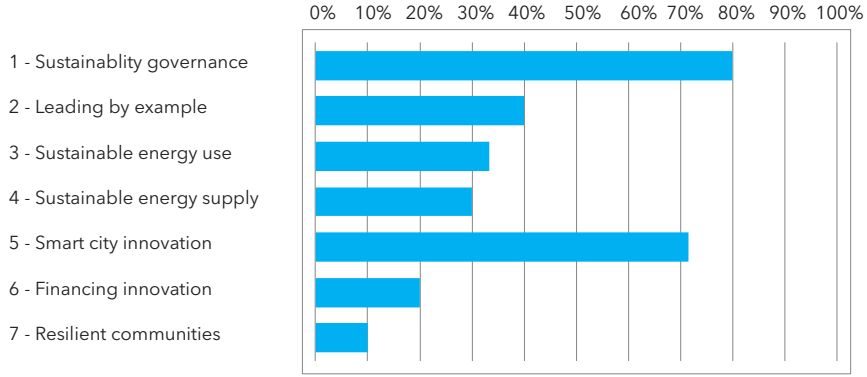
Melaka, Malaysia

POPULATION
484,885

UTILITY PROVIDER

Tenaga Nasional is the only electric utility company in Peninsular Malaysia and the largest power company in Southeast Asia, serving over 8.4 million customers as a vertically integrated utility.

Melaka: Cumulative score per dimension



The city of Melaka is a UNESCO world heritage site, with a rich trading history and multicultural heritage located about two hours from Kuala Lumpur. Melaka is known for its diversity, resilience, and innovation as it renovates its riverfront into a major tourist attraction and port.

In terms of sustainability, the city of Melaka has developed the Melaka Green City Action Plan, which includes a city-specific policy (similar to LEED) related to green building standards for municipal buildings and is developing its own internal operations GHG reporting system.

Recently, the city council initiated an energy audit of 10 public buildings to determine cost-effective energy efficiency measures and 30 secondary schools to increase energy efficiency. The audits will be expanded to all public buildings per the results of the initial effort. There are also plans to install two green roof demonstration projects on government buildings.

The city is also directly involved in the development and/or ownership of utility-scale solar PV power plants including one 5 MW solar farm in 2014 and an additional 5 MW solar farm in development. The city council has recently initiated a renewable energy programme to power 50% of existing street lighting with solar PV by 2020 and 100% by 2025.

Melaka is also the first city in Malaysia to install an EV charging station in 2013 with intention to install many more and focus on introducing EV buses. The City has also set up a Melaka World Solar Valley, an area of 7,248 hectares where a cluster of green technology industries specializing in solar energy will be created.

Additionally, Melaka is involved in global sustainability efforts, like the regional project "Clean Air for Smaller Cities (CASC) in the ASEAN Region, supported by funding from the German Federal Ministry for Economic Cooperation and Development and the Global Environment Facilities (GEF) Integrated Approach for Sustainable Cities Project.

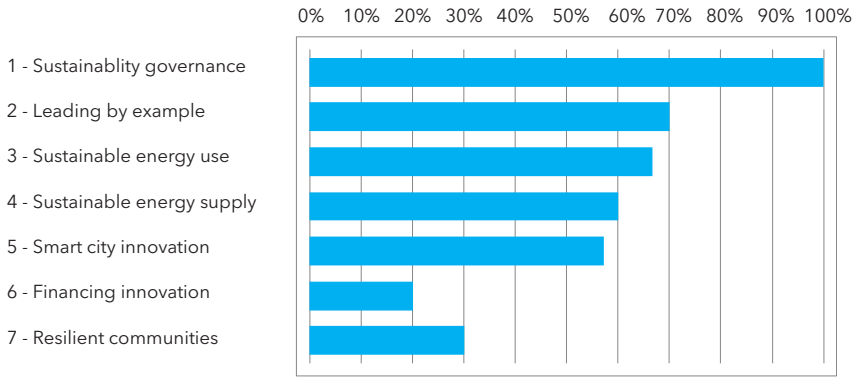
Lastly, the city of Melaka is one of the only cities exploring using captured landfill gas (at the Krubong Landfill) to generate electricity.

Adelaide, Australia

POPULATION
1,316,770

UTILITY PROVIDER
SA Power Networks operates a distribution network that stretches across South Australia. There are a number of electricity and gas retailers in Adelaide, including Lumo Energy (500,000+ customers) and AGL Energy (3,800,000+ customers).

Adelaide: Cumulative score per dimension



Adelaide is the capital city of the state of South Australia and the fifth largest city in Australia. Adelaide is a planned city, with an easily navigable grid layout and expansive green space in the city centre. The city has prioritized building its reputation as a green city that is prepared to adapt to climate change, reduce carbon emissions, and use resources sustainably.

In 2015, the city of Adelaide established the Carbon Neutral Adelaide Action Plan with the goals to be the world's first carbon neutral city. Initiatives include new energy efficiency investment programme for government buildings that mandate all agencies to identify and implement energy efficiency upgrade opportunities in government-owned buildings. Agencies retain the financial savings from upgrades once the initial funding has been repaid.

Adelaide is greatly involved in renewable energy, and notably, South Australia generates 18% of its electricity from wind power, and has 51% of the installed capacity of wind generators in Australia. Adelaide also recently received funding to install lithium batteries at three city sites and 100 EV charging stations across the city.

Adelaide is deeply involved with smart city initiatives. Cisco, a tech company, is working with the State Government and the Adelaide City Council to undertake several pilot projects including smart parking, smart public lighting, establishment of an Internet of Things Innovation Hub in Adelaide, monitoring traffic flows and pedestrian movements and monitoring power use in government tenanted buildings. Smart public lighting pilots are already underway. Adelaide City Council partnered again with Cisco and lighting specialist Sensity to modify more than 60 lights along Pirie Street and Hindmarsh Square.

Adelaide also provides multiple programme to residents, including the Building Upgrade Finance mechanism, the Home Energy Assistance programme for low income and new arrivals to Australia, and multiple energy efficiency incentives through the Sustainability Incentives Scheme. Co-funded by the Adelaide City Council and the Department of Environment, Water and Natural Resources, this incentive program provides rebates for investment in water and energy savings systems.
In the first year of the scheme $180,000 in rebates were paid, supporting more than $2.5 million worth of sustainability investments.

SAFER, SMARTER, GREENER

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