Smart Cities Readiness Guide®
The planning manual for building tomorrow's cities today
SmartCitiesCouncil®

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Energy

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Cities can't function without energy. It fuels our cars, subways and trains. It cools, heats and lights our homes and businesses. It pumps our water and processes the food we eat. And it powers the technologies that are the foundation of a smart city. To ensure a smart energy future, cities and utilities must work together – regardless of whether the utility is part of local government or a private investor-owned utility that supplies the city's energy.

So it's easy to see why energy is integral to all city responsibilities and profoundly impacts livability, workability and sustainability. This chapter covers energy's critical role in smart cities, from enabling small-scale power plants that generate energy close to where it's used to advanced technologies that help keep the lights on during power outages. We use the term "energy" broadly throughout to encompass all infrastructures that cities use to produce and deliver energy – electricity, gas, steam, renewables, etc. Whether or not your city directly provides electricity or natural gas as a city service (as in a municipal utility), you'll want to make energy the foundation of your smart city planning.

Energy as a smart cities starting place. Since city leaders are well aware of their own city's pain points, we said in the introduction to this Readiness Guide that we won't recommend which responsibility areas cities should tackle first. But given the critical role energy plays in just about everything that happens in a city, leaders uncertain where to start their smart city journey should consider making smart energy a priority.

That's because the success of a smart city relies on creating and supporting a smart energy system. That's a system that knows in real time where a transformer has blown and automatically reroutes power to keep the lights on in homes and businesses. It's a system that collects and manipulates data from sensors and smart devices to give operators a complete view of the energy infrastructure – for instance, how much power solar installations are generating or when they need to signal a demand response call to help balance the load on the electric and gas grid.

ICT's role in smart energy. Information and communications technologies (ICT) help cities optimize these energy systems, making them more efficient and more resilient. Implementing smart energy systems also helps preserve precious natural

ICT's role in more sustainable cities. Amsterdam leveraged public-private partnerships to build a broadband platform for service delivery to resources and gives residents, businesses and cities themselves a whole host of ways to monitor and control their energy consumption to save money.

achieve social, economic and environmental sustainability.

There are a number of components of a smart energy system. In the pages that follow we'll identify the technologies and technology-supporting practices involved and the array of benefits that cities accrue when they implement them.

Dependencies in energy

Improvements in a city's energy infrastructure – deploying a smart grid, for instance – can't occur without an understanding of dependencies between energy and other city systems and services. Three stand out: communications, transportation and the built environment.

A smart grid is by definition a specialized communications network that moves electricity and data to balance supply and demand and maintain reliable service. The distribution lines and underground cables that are part of the energy grid often follow the layout of city streets (part of the built environment), creating dependencies between utility services and the various transportation systems that also rely on streets.

The built environment is also a major consumer of electricity and natural gas – and potentially a producer of electricity too. As distributed generation evolves and building owners adopt solar, fuel cell and related technologies, utilities and city governments will form even closer alliances.

Benefits of realizing the energy targets

What kind of results can smart cities expect once they've walked down the smart energy path? We've highlighted many of them below, based on their relevance to livability, workability and sustainability.

Livability

Empowering customers with choice and control. Instrumentation, connectivity and analytics combine to give electric and gas customers more information about when and where they are using energy, plus tools to help them control that usage so they can lower their bills.

Improving reliability and resilience. Smart grids can "self-heal" from simple problems, making them more resilient to storms and disasters. With outage management systems, trouble areas can be pinpointed, shaving hours or even days from restoration times. And most smart grids make it easy to combine centralized, "long-distance" generation with local distributed generation, making the system more resistant to supply interruptions.

Lowering costs for citizens. Operational optimization means fewer resources are consumed and paid for. These savings can be passed along to citizens, resulting in lower energy bills.

Workability

Improving competitive advantage. A U.S. Department of Energy lab estimates that economic losses from outages cost $80-130 billion per year in the U.S. alone. Businesses in cities with modern, ultra-reliable energy systems have a competitive advantage.

Creating new jobs. Renewable energy and local energy typically produce more local jobs than "traditional" energy (where energy may be shipped from large centralized plants outside the region).

Generating business investment in cities. A study of the correlation between smart grid – a key component of the smart city – and economic growth discovered that cities with a smart grid have an annual GDP growth rate that is 0.7% higher, office occupancy rates 2.5% higher, and an unemployment rate 1% lower when compared to less advanced cities.

Creating new jobs. Solar installations and other forms of renewable energy and distributed generation create new, green jobs.

Sustainability

Using less energy. Smart energy means energy that is cleaner, more efficient and produces less impact on the environment. A smart grid makes it easier to use wind, solar and other renewable sources and waste less energy during transmission and delivery. A smart energy strategy gives customers tools to reduce their energy usage and costs. So a key benefit of a smart energy system – e.g., smart grid plus distributed generation plus ways to engage the consumer – is in reduced carbon production from avoided fossil fuel-based generation.

Decreasing reliance on nonrenewable energy sources. Smart grids make it far easier for customers to generate energy on premise (for instance, via rooftop solar) and to trade energy back and forth with the grid. Implementing the right devices and instrumentation, such as improved solar meters, have led many financiers to offer $0 down residential and commercial solar programs, reducing the barriers to solar generation. And smart energy, with the help of reliable two-way communications, makes grids more flexible overall to customer demand.

Lessening energy operating costs. Smart energy reduces operating costs compared to traditional methods. For example, sensors and monitors can report on the actual condition of expensive equipment so it can be serviced based on actual condition and not a guess. This kind of asset management can squeeze many extra years of use from an asset, without compromising safety. For another, smart systems can manage peak times by briefly reducing demand (called demand response) instead of building new standby power plants that will only get used a few times per year, and can even dim LED street lights to enable lower operating costs.

Instrumentation and control

We start our discussion of this chapter's targets with optimal instrumentation which, when applied to smart energy, refers to smart devices such as sensors and smart meters that gather information about the flow and condition of power and about the condition of equipment within the energy infrastructure.

Implement optimal instrumentation. Thanks to real-time information supplied by smart devices, system operators can predict, diagnose and mitigate issues that might previously have caused an outage or blackout. Examples of energy instrumentation include the deployment of smart meters and distribution system sensors.

Smart meters, which are installed on homes and businesses, are perhaps the most visible instrument in a smart energy network and certainly the most controversial due to concerns about potential health impacts and privacy. All of which points to the importance of developing an effective citizen engagement strategy long before you start deploying them.

Today there are smart meters for electricity, gas and water. They provide two-way communication between the customer premise and the utility. In the old days meters had to be read manually; smart meters transmit energy usage details directly to the utility. When smart meters are combined with smart thermostats, smart appliances and/or energy management devices, consumers can participate in energy-saving demand response programs where they voluntarily allow the utility to send a signal to the smart meter or other device to temporarily make a modest adjustment in energy usage.

Connectivity

Not only are the smart meters and sensors part of the smart energy network, they are also part of a citywide two-way communications system – that "system of systems" discussed earlier.

Connect devices with citywide, multi-service communications. Connectivity allows data collected throughout the smart energy network to be transmitted for analysis and action. For example, connectivity might mean that your smart meters, distribution system sensors and utility are connected through two-way communications.

Interoperability

Utilities around the world have started building out smart electric grids and smart gas grids, both of which are part of what this Guide refers to as the all-encompassing smart energy network. But one of the stumbling blocks early on was a lack of standards – and as you can imagine there are numerous pieces of a smart grid that have to work together and talk to each other. Thanks to a number of standards bodies around the world that undertook the task of developing specifications, a lot of the issues that plagued the smart grid pioneers have been resolved. Below is a quick look at interoperability targets, including one that specifically applies to energy.

Adhere to open standards to increase choice and decrease costs. With open standards products can be mixed and matched from different vendors. There are hundreds of standards just for the energy responsibility of a smart city. As we discussed in the Universal chapter, selecting standards is a job for specialists. Your job is first to insist on using them whenever possible and second to hire a supplier with a demonstrated knowledge and commitment to open standards.

But the standards selection process is easier in the energy sector than in others thanks to the free Smart Grid Standards Mapping Tool [1] from the International Electrotechnical Commission, a Council advisor. You can simply point and click to identify any standard in relation to its role within the smart grid. New standards are added regularly. Also see the Sensor Web Enablement standards [2] of the Open Geospatial Consortium.

Enable distributed generation with interconnection standards. Recent decades have seen the proliferation of "distributed generation" – of small, decentralized power plants located at or near the spot energy is used. Think rooftop solar installations on high-rise apartment buildings or wind turbines helping power a shopping mall.

What are required to make distributed generation work effectively are straightforward, easy-to-use interconnection standards that define how the energy sources tie in to the energy grid. It's a relatively new business model for utilities, although many have or are in the process of developing protocols to accommodate distributed generation. Getting it right gives the city and its residents more options for economical and clean power generation without compromising secure and reliable grid operations.

Cities that own their local energy or gas utility can prioritize development of interconnection standards. Those with energy providers that are not municipally owned may need to find ways to encourage them to modernize their interconnection standards to accommodate what is clearly the wave of the future.

Distributed generation has enormous potential, including higher efficiency and greater resilience against natural or man-made disasters. It also reduces dependence on fossil fuels.

Security and privacy

There are at least three extremely compelling reasons why smart cities take security and privacy seriously in the context of energy as these three targets demonstrate.

Publish privacy rules. Smart meters have raised privacy concerns around the world. People worry that their daily habits are being tracked by their local utility via smart meters, which is why smart cities not only publish and adhere to privacy rules but they let citizens know about it proactively. Making privacy a priority can help ward off consumer backlash that could stall smart energy deployments.

Create a security framework. Security breaches can have a ripple effect. Developing a comprehensive security framework mitigates risk by identifying and addressing threats before they can cause damage. This is critical in the energy infrastructure – even more so given its inherent importance to the operation of other key infrastructures.

Implement cybersecurity. Cyber attacks against energy companies in the U.S. have been well-documented. But what were once thought to be attempts to steal information or trade secrets are now focused on causing serious damage to networks and equipment, according to warnings from the U.S. government. [3] The take-away here for cities is that implementing cybersecurity safeguards early on maximizes protection while avoiding the potentially significant costs associated with an attack.

Create and adhere to a citywide data management, transparency and sharing policy. When utility customers have access to data about when and how they use energy they can make choices and tradeoffs that can reduce their energy usage and utility bills.

Data management

There is a tremendous amount of data pouring in from sensors, smart meters and other intelligent devices deployed throughout the energy infrastructure of a smart city.

Create and adhere to a citywide data management, transparency and sharing policy. Energy usage data should be integrated in the policy that was discussed in detail in the Universal chapter. And as noted in the previous section, energy usage data needs to comply with overall security and privacy rules.

That said, access to timely, accurate energy usage data is an essential component of a cleaner, more efficient energy system. So it's imperative that local utilities grant cities access to aggregated, summary usage data which can be invaluable for city planning, for carbon reduction programs, for energy efficiency programs, for low-income assistance programs, for improving city performance and for many other purposes.

To promote energy efficiency, it's also important for smart cities to encourage utilities to give electric and gas customers access to their own usage data. For example, cities can provide a web portal for viewing and managing energy usage in real time. That way customers can drill down on when and how they use energy to make choices and trade-offs that can reduce their energy usage and utility bills.

Computing resources

Basically all of the computing resources that cities use rely on energy in some way, shape or form, so it makes sense for cities to constantly monitor for efficiencies and economies as they use, deploy and procure computing resources. As discussed in detail in the Universal chapter:

Consider a cloud computing framework to enable scalability of systems, reduce costs and improve reliability.

Use an open innovation platform to empower innovators, increase accountability, generate new revenue streams and stimulate economic growth.

Have access to a central geographic information system (GIS) to improve decision-making capabilities, enable efficiency gains through more intelligent scheduling and routing, provide improved accuracy of essential records and boost resiliency of key assets.

Have access to a comprehensive device management system to improve infrastructure security and resiliency, deliver cost savings and enforce compliance with city data management, security and privacy policies. This target, as we noted, takes on special importance in the energy discussion due to the numerous smart devices and other computing resources deployed throughout smart cities.

Analytics

As we've said previously, analytics are absolutely critical to smart city success and perhaps nowhere is that more evident than in a smart energy network that powers so much of what a city is and does. We'll quickly review three of the analytics targets already discussed in the Universal chapter and then introduce two more that speak volumes about energy's importance in a smart city.

Achieve full situational awareness. This refers to giving operators a complete picture of their energy system at any given moment to increase its reliability and resiliency and quickly respond to trouble. A complete operating picture is incredibly important to city energy systems. One example: It helps operators detect energy theft and thereby conserve resources.

Achieve operational optimization. Building the very best smart energy network possible is what cities want to achieve from the instrumentation and connectivity investments they make in their energy infrastructure.

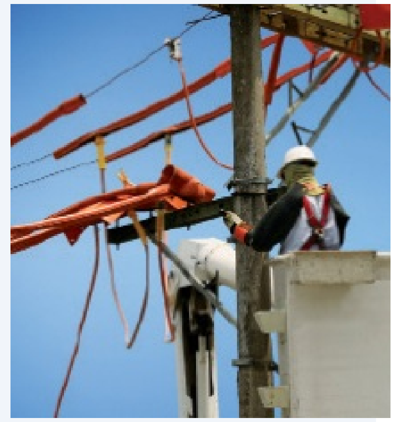
Optimized energy systems help conserve energy, delivering cost savings to cities, residents and businesses and also reducing the drain on energy resources.

Achieve asset optimization. This target plays an important role in the energy sphere, helping cities maximize the value of their assets by 1) calculating which energy assets need to be repaired or replaced and when, and 2) by predictive maintenance, which uses analytics to spot equipment that is close to failure so it can be repaired or replaced before problems arise.

Pursue predictive analytics. Drawing from instrumentation deployed across a city, analytics can enable advanced forecasting and management of a diverse, secure and resilient energy system. ICT helps cities account for demand, weather, effects from distributed resources that may be variable and other operational considerations. Understanding what to expect helps cities save on costs, conserve resources and prepare for extreme events.

Now we'll introduce two new energy-specific targets that are critical to smart city success.

Automate fault and outage management. This is about the "self-healing" grid we referred to earlier. The idea is that the utility that serves your city would enable remote sensors, smart meters and other advanced smart grid technologies deployed throughout the energy network to automatically reduce the number of outages and the duration of those that do occur. For instance, a sensor might detect a fault on the electric grid and be able to locate it and isolate it before it has time to affect other areas. Or smart meters may alert a utility's outage management system of trouble, allowing the utility to immediately dispatch crews and keep customers updated during and after the incident. Before the advent of these advanced technologies, utilities oftentimes didn't know about an outage until customers started calling in.



Automate fault and outage management. Automated solutions help make the energy supply more reliable and improve outage response.

A quick look at economic losses incurred from power outages explains why this is so important. A study by the Berkeley National Lab back in 2004 estimated that outages cost $80-130 billion per year in economic losses in the U.S. alone. After Superstorm Sandy, which wreaked havoc across the northeastern U.S. in 2012, the U.S. Congress approved more than $60 billion in emergency aid [4], which is roughly what state governments reported in damages and other losses.

By encouraging automated solutions a city or utility can make the energy supply more reliable, improve response to outages which in turn makes businesses more competitive and residents more comfortable.

Segment and personalize programs for customers. This is one of the big pluses of today's smart energy networks. They can consider multiple variables – like a utility customer's preferences, system parameters, weather, cost of energy – to optimize and personalize rates and programs. As part of that personalization, a smart city's utility, whether municipally owned or a private utility that operates in the city, can identify energy use patterns and then make customized recommentions to help customers get the best possible rates or assist with fraud and service connection issues.

Today many electric and gas utilities charge a single rate for every residential customer at every time of the day. In reality, the cost of energy varies widely depending on the time. In particular, electric energy can be very inexpensive at night when demand is low and the output from wind farms is high. But it can be very costly during hot summer days when air conditioners are cranked up, demand is very high and energy is scarce.

Smart meters and smart grids make it possible for utilities to offer a variety of programs to encourage energy efficiency and cost savings. Examples include time-of-use rates, peak-time rebates, efficiency incentives and demand response programs.

CenterPoint Energy in Texas completed installation of more than 2.2 million smart meters from Council member Itron as part of its smart grid initiative, which was designed to give consumers more control over their energy consumption.

Now CenterPoint customers have 15-minute interval access to their energy data from the Smart Meter Texas online web portal and have wireless capabilities to install in-home energy management devices.

"Our smart meter deployment has been extremely successful. Not only have we had compliments from our customers and the Public Utility Commission of Texas, we've also had compliments from the Department of Energy," said Kenny Mercado, division senior vice president of Grid and Market Operations for CenterPoint Energy.

The Smart Grid Consumer Collaborative [5] is a nonprofit organization focused on advancing a consumer-safe, consumer-friendly smart grid and has researched consumers and published reports on smart grid consumer education and segmentation. SGCC's research shows that consumers fall into five broad segments ranging from Concerned Greens, those people who want a cleaner energy portfolio, to Do-It-Yourself and Save,

those people who want to save money and are likely to enroll in programs that will help them take action to do that. Both of these segments would likely be responsive to personalize programs that match their values around energy.

Give consumers more control. CenterPoint Energy customers have 15-minute interval access to their energy data via an online portal.

Joining with organizations like SGCC to obtain materials, collaborate with others and learn best practices for citizen engagement is one way to increase the likelihood that smart energy projects receive consumer support.

Facility helps public and private sector researchers scale up clean energy technologies

Located at the National Renewable Energy Laboratory's campus in Golden, Colorado, the new 182,500-square-foot Energy Systems Integration Facility [6] (ESIF) is the first facility in the United States to help both public and private sector researchers scale-up promising clean energy technologies – from solar modules and wind turbines to electric vehicles and efficient, interactive home appliances – and test how they interact with each other and the grid at utility-scale. The U.S. Congress provided $135 million to construct and equip the facility.

ESIF, which opened in 2013, houses more than 15 experimental laboratories and several outdoor test beds, including an interactive hardware-in-the-loop system that lets researchers and manufacturers test their products at full power and real grid load levels. The facility will also feature a petascale supercomputer that can support large-scale modeling and simulation at one quadrillion operations per second.

ISO 37120: A yardstick for measuring city performance

In 2014, the International Organization for Standards announced an ISO standard that applies strictly to city performance. The document – known as ISO 37120:2014 – establishes a set of open data indicators to measure the delivery of city services and quality of life. It defines common methodologies that cities can use to measure their performance in areas such as energy, environment, finance, emergency response, governance, health, recreation, safety, solid waste, telecommunications, transportation, urban planning, wastewater, water, sanitation and more.

In the table at right we have indicated how the standard related to energy [7]intersect with the Council's Energy targets identified on the next page. While there are many aspects of energy to consider, ISO 37120 focuses on a city's energy efficiency, energy availability and energy mix.

Energy	Implement	Enable	Create energy data	Achieve	Achieve	Pursue	Automate fault and outage	Achieve full situational

Indicator	optimal instrumentation	distributed generation	management policy	operational optimization	asset optimization	predictive analytics	management	analysis

Core

7.1 Total residential electrical energy use per capita (kWh/year)	■■■■■■
7.2 Percentage of city population with authorized electrical service	■■
7.3 Energy consumption of public buildings per year (kWh/m^2)	■■■■■■
7.4 The percentage of total energy derived from renewable sources; as a share of the city's total energy consumption	■■■■■■

Supporting

7.5 Total electrical energy use per capita (kWh/year)	■■■■■■
7.6 Average number of electrical interruptions per customer per year	■■■
7.7 Average length of electrical interruptions (in hours)	■■■

TECHNOLOGY

	Energy Targets	Implementation Progress
Enabler	How smart cities deploy and use ICT to enhance their energy infrastructures	NonePartialOver 50%Complete
Instrumentation & Control	Implement optimal instrumentation	
Connectivity	Connect devices with citywide, multi-service communications	
Interoperability	Adhere to open standards	
	Use open integration architectures and loosely coupled interfaces	
	Prioritize use of legacy investments	
	Enable distributed generation with interconnection standards	

Security & Privacy	Publish privacy rules Create a security framework Implement cybersecurity
Data Management	Create a citywide data management, transparency and sharing policy **(Supplement: including energy usage data)**
Computing Resources	Consider a cloud computing framework Use an open innovation platform Have access to a central GIS Have access to comprehensive device management
Analytics	Achieve full situational awareness Achieve operational optimization Achieve asset optimization Pursue predictive analytics **Automate fault and outage management** **Segment and personalize programs for customers**

ADDITIONAL RESOURCES

Target: Enable distributed generation with interconnection standards

Energy transition in urban environments: battling integration challenges with evolving technologies

[8]As urbanization challenges cities, key technologies and social innovations need further development. This white paper from Council member Alstom Grid puts integration of distributed renewable energy resources with utility grids among them.

Target: Automate fault and outage management

Canada’s First Utility-Scale Energy Storage System Islands Remote Town During Outages
[9]The remote town of Field relies on one 25-kV distribution feeder to supply its 300 residents with power. But providing reliable power to Field is challenging. Council member S&C Electric deployed a solution that provided extra benefits.

Target: Achieve operational optimization
Citywide Energy Efficiency and Sustainability in Boston
[10]To meet greenhouse gas reduction goals, the city of Boston leveraged Schneider Electric’s StructureWare software for citywide energy, greenhouse gas and sustainability management.

Target: Create a security framework
Big Data and Security in the Smart Grid
[11]In this brief video, Laurent Schmitt of Alstom Grid explains how big data and security are paramount to Alstom’s business and future objectives for smart grid systems and how Alstom’s collaboration with Council member Intel furthers those objectives.

Target: Consider a cloud computing framework
Donald’s Smart City with the PI System and MS Azure
[12]The PI System from Council member OSIsoft shares and combines building and utility data through the cloud. Learn more in this video about what that can mean for building managers, airports, stadiums and others.

Target: Automate fault and outage management
Modernizing the Grid: How a Utility Cured an Ibuprofen Plant’s Biggest Headache
[13]The Albemarle Ibuprofen plant is an anchor of the economy in the Orangeburg, S.C. area. But power outages were providing the facility’s biggest headache. The local utility worked with Council member Siemens to cure it.

Target: Achieve asset optimization
Connect-the-Grid [14]
Get insights in this video from Council member West Monroe Partners about how to better manage all assets connected to the grid. Connect-the-Grid is a scalable, cloud-based resource for utilities.

Target: Achieve full situational awareness
Bringing Software Defined Operations to the Industrial Internet [15]
Learn in this video from Council member Bit Stew Systems how its information processing engine, MIx Core™, enables complex event processing, advanced analytics and sophisticated machine intelligence.

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Links
[1] http://smartgridstandardsmap.com/
[2] http://www.opengeospatial.org/ogc/markets-technologies/swe
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[5] https://smartenergycc.org/
[6] https://www.nrel.gov/esif/
[7] http://smartcitiescouncil.com/article/dissecting-iso-37120-what-new-smart-city-standard-says-about-energy
[8] http://smartcitiescouncil.com/resources/energy-transition-urban-environments-battling-integration-challenges-evolving-technologies-0
[9] http://smartcitiescouncil.com/resources/canada%E2%80%99s-first-utility-scale-energy-storage-system-islands-remote-town-during-outages
[10] http://smartcitiescouncil.com/resources/citywide-energy-efficiency-and-sustainability-boston

[11] http://smartcitiescouncil.com/resources/big-data-and-security-smart-grid
[12] http://smartcitiescouncil.com/resources/donalds-smart-city-pi-system-and-ms-azure
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