From: Michael Cunningham
To: BOCrfc2015
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The Bay Area Council would like to submit its report *21st Century Infrastructure: Keeping California Connected, Powered, and Competitive* to the record of this proceeding. The document is attached.

Best regards,

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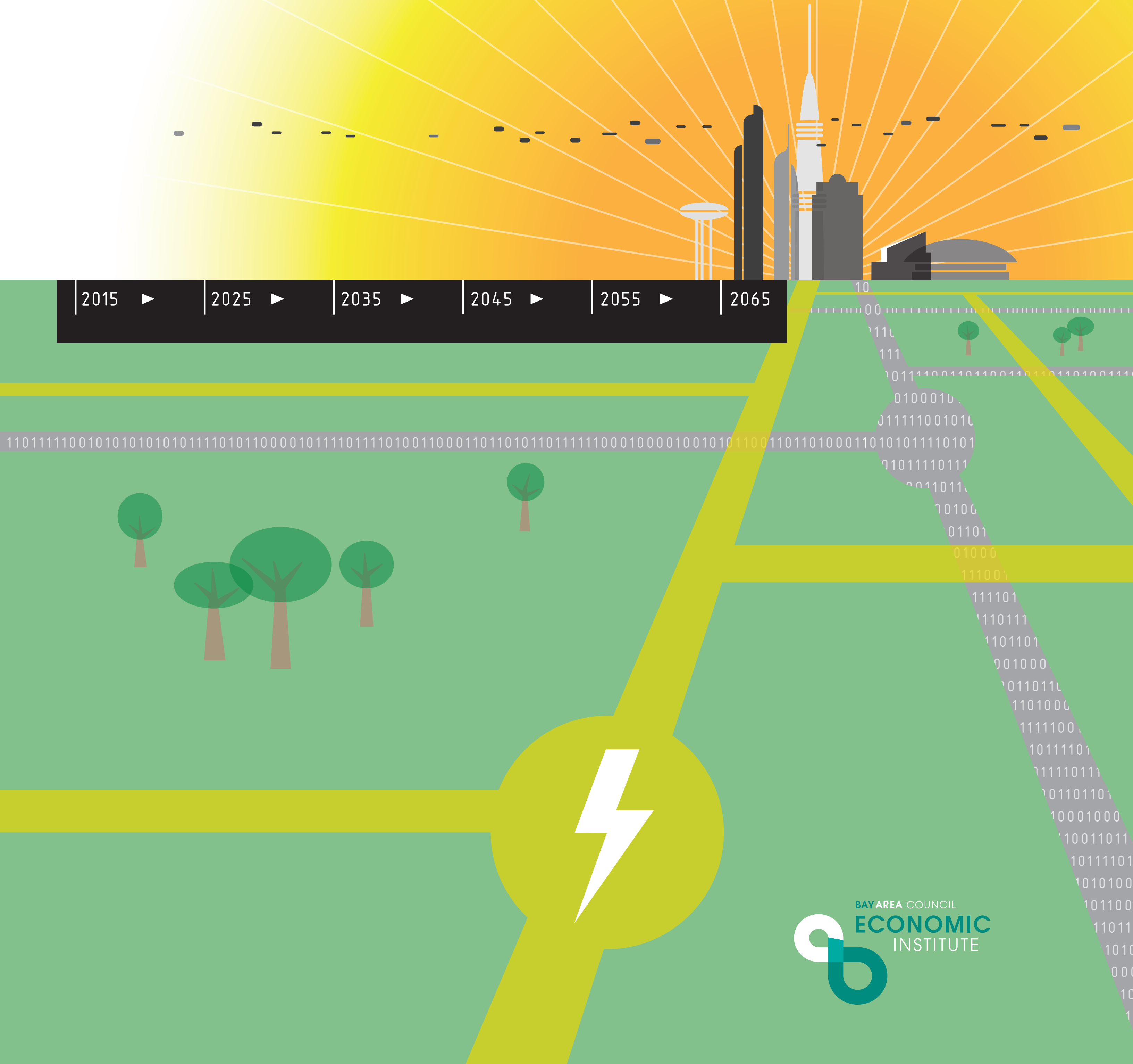
21ST CENTURY INFRASTRUCTURE

Keeping California Connected, Powered, and Competitive



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Sean Randolph (Senior Director) oversaw the development of the study. Tracey Grose (Vice President) directed the analysis and completion of the report. Jeff Bellisario (Senior Research Associate), Alex Foard (Research Associate), Saori Hamidi (Research Associate), Carolyn Garrett (Intern), and Alex Hartzell (Intern) contributed to the data analysis, qualitative research, and overall narrative of the report. Consulting contributors Matt Chwierut and Brinda Dalal (President, Dhoopa Ventures LLC) played key roles in the research and narrative development. Bay Area Council staff members Michael Cunningham, Adrian Covert, and Amel Zahid provided valuable input throughout the research process. The Bay Area Council Economic Institute would also like to thank Olaf Groth, a Bay Area Council Economic Institute Research Council member, for his guidance and support.

THE BAY AREA COUNCIL ECONOMIC INSTITUTE

Bay Area Council Economic Institute is a partnership of business with labor, government, higher education, and philanthropy that works to support the economic vitality and competitiveness of the Bay Area and California.

The Association of Bay Area Governments (ABAG) is a founder and key institutional partner. The Economic Institute also supports and manages the Bay Area Science and Innovation Consortium (BASIC), a partnership of Northern California's leading scientific research universities and federal and private research laboratories.

Through its economic and policy research and its many partnerships, the Economic Institute addresses key issues impacting the competitiveness, economic development, and quality of life of the region and the state, including infrastructure, globalization, science and innovation, energy, and governance. A public-private Board of Trustees oversees the development of its products and initiatives.

TABLE OF CONTENTS

FOREWORD

When it comes to investing in the future, in the last 50 years California has done many things right. It built a great university system, the world's best highway network, and a water system that has served a rapidly expanding population well. Private companies have developed telecommunications systems that are among the most advanced in the US, and we lead the nation in the development and deployment of renewable and energy efficiency technologies. This infrastructure has enabled our economic leadership, both domestically and globally.

The world is changing rapidly, however, and to sustain this leadership California must continue to invest. It must also innovate in ways that adopt and leverage advanced technologies—which are often created here. This is particularly the case in the connected fields of communications and energy. Connectivity is now an essential component of everyday life for both individuals and businesses, and with the pace of technological change accelerating, this dependence will only grow. As it does, devices will proliferate, machines will connect to each other, and new businesses and business models will emerge. All of this will entail vast amounts of data. While California is relatively well positioned today in terms of communications infrastructure—at least in the United States—it lags many of its global competitors. And it is unprepared for the tsunami of applications that is approaching.

This wave will come not just from mobile communications and the Internet of Things, but also from our energy systems. New capacity and technology will be required to monitor and manage energy use, and to move energy through the grid in multiple directions as centralized, conventional generation is augmented by generation from both large and small renewable sources. Electrical vehicle charging and other smart grid applications will accelerate this process, and with it the need for flexibility, security, and reliability in the state's power grid. This is another change that California must anticipate and adapt to quickly.

California's regulatory structure for dealing with these challenges was designed in the mid-20th century, when many of today's technologies and economic drivers were unheard of, and deliberative processes could take years. But today's technologies are advancing with blinding speed and their implications are being felt immediately, with rapid adoption by both businesses and consumers. Other nations are moving quickly to embrace this new paradigm by adapting their regulatory processes to enable the development of advanced infrastructure for both communications and energy. California also needs to embrace a dynamic vision of the future, and accelerate and adapt its policies and processes.

California's ability to do this will impact the competitiveness of its businesses and the quality of life of its citizens. The results can be transformative, but only if California invests now in the technology and infrastructure that will lead it into the 21st century.

Sean Randolph

Bay Area Council Economic Institute, Senior Director

Recent advances in energy and communications technologies have outpaced anything the human race has seen since either the invention of the telegraph or the discovery of alternating current. Many of these advances have enabled technologies that were once the realm of science fiction—driverless cars, implanted medical devices, and vast supplies of renewable energy. Today, these and related technologies are shaping up to be as important to California's prosperity in the 21st century as roads and waterways were in the 20th. However, the pace of innovation is increasingly pushing up against the physical constraints of California's legacy energy and communications infrastructure. Without upgrading to 21st century infrastructure, California will not keep up with the level of competition and the rate of change in today's global economy.

INVESTMENT IN 21ST CENTURY INFRASTRUCTURE WILL ENABLE NEW TECHNOLOGIES THAT WILL IMPROVE THE LIVES OF CALIFORNIANS.

Advanced communications networks with greater bandwidth for mobile and internet communications can support a range of public benefits including entrepreneurship, education, public safety, healthcare, and civic engagement. Californians will benefit from advanced communications through:

Improved delivery of public services and broader civic engagement.

Improved access to healthcare through video conferencing, remote sensors, and diagnostic tools, reducing hospital and physician visits and saving costs.

Improved efficiency and access to education—particularly for working students and those in rural areas—through digital education platforms. Schools that have received network investments, and are able to utilize technology more widely, have reported academic gains.

Advanced energy technologies that enable the multi-directional flow of information and electricity can improve environmental quality and enhance consumer choice. Benefits to Californians include:

Greater resiliency and reliability in the face of natural disasters.

Greater environmental benefits through better integration of renewable energy into the grid.

Greater transparency across the electricity system from generation to use, improving power management and creating new business opportunities for innovative companies, especially in regard to data management and optimization.

Greater choice for consumers in how to manage their energy use, providing an opportunity for cost savings by matching pricing, time of use, and other preferences.

INVESTMENT IN COMMUNICATIONS INFRASTRUCTURE IS NECESSARY TO MAINTAIN CALIFORNIA'S GLOBAL COMPETITIVENESS.

The demands on communications networks are growing and changing rapidly. As more facets of the economy rely on the internet and mobile communications—including payment systems, entertainment, transportation, and the power grid—internet usage is rapidly growing. Consumers are driving the need for faster networks with more ubiquitous coverage, as today's internet is transmitting growing volumes of data that support the exchange of business data, personal communications, interactive learning, high-definition video, and advanced industrial processes.

Monthly internet traffic in 1995 was 180 terabytes (180 million megabytes); in 2015 it will have expanded by a factor of 450,000.

Global mobile data grew by 81 percent in 2013, after registering 70 percent growth in 2012.

Devices that share data from machine-to-machine will grow from 4.9 percent of all devices today to 19.7 percent by 2018.

Two billion devices, such as wearable technologies and industrial sensors, will be able to communicate with each other automatically by 2018.

Global annual cloud storage is projected to increase by 300 percent between 2013 and 2018.

Infrastructure must be built. To more seamlessly meet growing network demands, requirements include expanding access to and building out fiber optic and wireless networks. The communications infrastructure needed to accomplish this includes conduit to house cables, large and small cell towers to support wireless connectivity, and small cells and distributed antenna systems to expand the range of wireless access. The networks that these improvements support must also be secure, reliable, energy-efficient, ubiquitous, resilient, and high capacity.

Connectivity is critical to maintaining the state's economic competitiveness and high standard of living. Although official reporting by service providers indicates that 97.8 percent of California's housing units have the infrastructure necessary to access broadband with data speeds faster than 6 megabits per second, the increasing number and power of connected devices will require increased bandwidth. In addition, California will need to continue to address lingering gaps in speed and quality of access, including reaching rural and other areas without service.

Evolving telecommunications technologies and business models require a new regulatory framework. Building physical infrastructure requires large financial investments, navigation through permitting and other regulatory requirements, and a sustainable revenue model. Cost is the most cited hurdle in completing local broadband projects. A 21st century regulatory structure needs to be reflective of the character of modern infrastructure, changing demands on it, and evolving marketplace dynamics. For example, AT&T is investing in internet-based phone networks as part of its push to move to more powerful all-digital services, while Comcast is currently delivering all-digital telephone services within the state. However, in California, telecommunications operators must maintain their legacy wire telephone networks, creating an added cost burden that can slow investment in faster technologies.

INVESTMENT IN CALIFORNIA'S ELECTRICITY GRID IS NECESSARY TO ACHIEVE ENVIRONMENTAL GOALS, INCLUDING THE GREATER USE OF RENEWABLE POWER, AND TO ENSURE GRID RELIABILITY.

The power grid is transforming from a centralized model with a one-way flow of electricity to a model with geographically diverse generation systems and new roles for consumers, grid operators, and power generators. Driving factors behind this shift include:

Changing consumer expectations regarding the management of their energy use and the reduction of their environmental impact.

Public policy, including California's Renewables Portfolio Standard, the California Global Warming Solutions Act (Assembly Bill 32, or AB 32), the US Environmental Protection Agency's rules on reducing emissions from the electricity sector, and other policies that target reduced levels of carbon dioxide (CO_2) emissions.

Increasing penetration of renewable energy systems: As of 2012, renewable energy accounted for 13 percent of total electricity generation in California, and just 4 percent nationally. In 2013 alone, 2,145 megawatts (MW) of utility-scale solar capacity entered service in California (for comparison, large natural gas-fired power plants have an average capacity of 500 MW), giving the state total solar capacity of more than 8,500 MW. Topping the nation, 2,332 MW of solar capacity has been installed by residents and businesses in California, more than two times that of the next most-active states, Arizona and New Jersey.

Strong electric vehicle (EV) uptake in California, which is expected to account for 25 percent of all EVs sold in the US through 2020. EV charging is placing greater demands on the grid, with each vehicle's needs roughly equivalent to those of the average residential customer, though EVs also represent a potential source of distributed storage that can provide grid benefits.

California has made important progress in boosting energy efficiency and clean energy, but new infrastructure is required to leverage distributed energy resources and ensure grid reliability. The energy generated by wind and solar systems varies by time of day and season. This variability introduces new challenges for utilities and grid operators. An electricity system with high penetration of such resources therefore requires enhanced infrastructure to enable a smarter grid.

A smart grid improves the reliability and resilience of utility electricity networks, enables renewable generation, integrates storage, boosts energy efficiency, reduces negative environmental impacts, and creates new product and service markets. California has made progress on multiple fronts:

California leads the nation in smart meter deployment with over 12 million meters in use.

The California Public Utilities Commission (CPUC) issued a mandate in 2013 for 1.3 gigawatts (GW) of cost-effective energy storage to be integrated into the grid by 2020.

Between 2010 and 2012, the state's investor-owned utilities reported electricity use reductions of 6,548 gigawatt hours due to residential and commercial energy efficiency programs, equivalent to the electricity use of 725,000 US households for one year.

Some of the nation's most advanced microgrid projects—which allow institutions to operate independently of the traditional grid in the event of an outage—and EV charging initiatives are being piloted in California.

As the way electricity is produced and consumed evolves, utilities and regulators must address issues around rate design. The combination of rooftop solar, demand response, and electricity storage will make some consumers less dependent on grid-supplied power, but not necessarily on the grid itself. Since utilities' fixed costs of providing capacity—estimated at approximately 45 percent of average energy bills—are generally recovered in rates based on usage, the costs of maintaining electricity networks will be spread over fewer customers, leading to higher bills.

INVESTMENT IN COMMUNICATIONS AND ENERGY INFRASTRUCTURE CAN BE SUPPORTED BY STRATEGIC PARTNERSHIPS AND PUBLIC POLICY, IN THE FORM OF FORWARD-THINKING REGULATION AND INCENTIVES.

Options for advancing California's communications infrastructure:

Plan for networks and expedite local permitting processes. With better information about the location of their own assets, cities, states, and the federal government should encourage the co-location of infrastructure and sharing mechanisms to expand broadband infrastructure. Specialized treatment of communication infrastructure in local planning can encourage investment and reduce delays. Cities can also explore blanket permitting approaches, which would provide approval for system wide upgrades throughout a municipality rather than on a project-by-project basis.

Reassess governance model. There is a broad consensus among experts that the current regulatory system is not well suited for today's broadband network and competitive marketplace, much less for the networks of the future. The telecommunications network across the country has long been transitioning away from legacy systems toward IP-based services. However, regulation still requires incumbent telecommunications carriers to maintain their legacy telephone network, despite low numbers of current users or how superior internet-based communication might be. A new, technology-neutral oversight structure is needed that preserves the public interest in connection to emergency services without applying outdated mandates on providers.

Create an Advanced Networks Task Force. There is opportunity for the formation of a diverse group of stakeholders to explore a new model for California's networks within the current California Broadband Council. A statewide task force composed of existing network operators, state and municipal leaders, public-interest groups, regulatory bodies, and those developing new products and services dependent on the network should consider standardized infrastructure permitting guidelines across the state, capital expenditure needs statewide, security and privacy, and right-of-way rules and prioritization. Such a group could also be used to bring together cities throughout California that are currently exploring new ways to engage with internet service providers to create 21st century network models.

Steps for transforming the power grid into a multi-directional flow of information and energy:

Pursue innovative approaches in ratemaking and regulation. In order for the grid to be maintained and enhanced, all users must equitably share in the costs and benefits of grid investments. Rate structures that were originally built around the centralized model are no longer adequate. If cost components and grid-level benefits are more transparent, price signals and rate mechanisms can be devised in a way that does not leave consumers or utilities with uncompensated costs. Providing flexibility for utilities to operate outside of their regulated framework could enable a more extensive suite of energy-related services, such as the management of EV charging infrastructure, beyond simply the sale of electrons.

Leverage storage technologies and electric vehicle charging as grid supporters. The adoption of storage technologies can create a more resilient grid, though their current high cost keeps them from gaining wider market adoption. In the same way that solar panel installations have been subsidized in California through residential rebates, similar programs can spur the adoption of grid-scale storage technologies. Infrastructure should also respond to the new demands and opportunities EVs will create. To begin this process, all California investor-owned utilities should submit vehicle-grid integration plans to the CPUC targeting time-of-use rates for EV charging with consideration for how EV energy storage could be used as an ancillary asset for local grid stability.

Allow utilities to function as Distribution System Operators (DSO). Greater control, management, and security will be needed as the power grid shifts away from a centralized generation model. Similar to the role that the California Independent System Operator plays in managing the bulk power system, regional DSOs can manage and coordinate behind-the-meter energy generation and storage from multiple sources and better project the amount of power consumers and other generators of renewable power could place back on the grid. As a DSO, utilities could also develop and manage data platforms for collecting and analyzing information on a large scale, while ensuring that multi-layered security strategies are built into the grid as security intrusions become more complex. Implementation of this new function needs to carefully consider the costs and benefits to avoid adding unnecessary costs for electricity consumers.

Enable energy data to be used in new ways. Utilities should be encouraged by the CPUC to collect, analyze, and share data, while respecting customer confidentiality considerations. Data standardization and ownership policies can lay the foundation for a robust information-oriented energy market, allowing new types of customer engagement and energy-related services. With new data-centric platforms, users can choose from a variety of service options, from managing their daily consumption via mobile device to automating timing of energy-intensive appliances.

Communications and Energy in the 21st Century

Much of California's vital infrastructure for moving people and resources was built over the last century, with a 20th century economy and its technologies in mind. As California moves deeper into the 21st century, new technologies have changed the way that people interact with infrastructure—especially in the fields of communications and energy. Mobile phones and the internet have changed the nature of communication, and renewable energy has altered the traditional model of energy production and distribution—putting greater stress on the physical infrastructure that moves information and energy.

At the core of modern infrastructure is a central nervous system of connectivity.

At the core of modern infrastructure is a central nervous system of connectivity. This includes the development of a faster and more reliable communications network linking people and their tools. The infrastructure of the future also requires the development of connectivity across a resilient, flexible, and diverse electricity grid, which will need to support a clean energy future while also powering a growing number of advanced communication demands.

Given California's unique industry mix of communications, information technology, clean energy, advanced materials, and other technical sectors, the state is well positioned to harness infrastructure innovations for significant state and regional benefit. This new infrastructure will create test beds from which innovative concepts, strategies, and products can be launched, which will transform the way that California's citizens and businesses interact with and utilize information and energy.

New technologies will help to enable this shift, while innovative public policy and nimble regulation will play key roles in advancing California's infrastructure future. To capture the full economic benefits of 21st century infrastructure investments, the state will need forward-looking planning and a regulatory structure that can adapt to rapidly changing technologies and consumer demands.

THE ROLE OF INFRASTRUCTURE IN A COMPETITIVE ECONOMY

Today's economy is increasingly dependent on the flow of digitized information to support business transactions, education, environmental sustainability, public safety, healthcare, and energy use. The technologies utilized in each of these areas will require a growing amount of reliable electricity, sourced from a power grid that will need to balance a shift toward de-carbonization. As the power distribution network integrates an increasingly diverse mix of generation and storage models, communications and information technology will also become central to ensuring efficient grid management.

Investing in the expansion and improvement of communications and energy infrastructure generates multiple economic benefits:[1]

Physical infrastructure expenditures: Constructing, maintaining, and operating infrastructure requires workers and materials. This spending produces multiplier effects across the economy. The US Department of Energy has reported that the $2.96 billion invested to support smart grid projects as part of the American Recovery and Reinvestment Act of 2009 has generated at least $6.8 billion in economic output and an additional 47,000 jobs.[2]

Productivity gains: Access to advanced communications and energy capabilities enables firms to deliver goods and services more efficiently, leading to more output per input. This occurs at the firm level, where connectivity can increase efficiency, and at the market level, where connectivity can give rise to increasingly complex and innovative transactions. Studies have found that an increase in broadband penetration of 10 percent yields between a 0.25 and 1.21 percent increase in gross domestic product for high-income countries.[3,4]

Business growth and economic competitiveness: As communication and energy platforms expand and evolve, new business models emerge, creating new business growth and driving technological advances. High-speed connectivity availability and electricity affordability are also closely tied to a state's economic competitiveness, as they can be key considerations in location decisions made by energy- and information-intensive firms.

Social and environmental benefits: Broadband gives consumers benefits that are not necessarily captured in economic statistics, such as enhanced access to information, entertainment, personal communication, and public services. Advanced energy infrastructure facilitates the broader integration of renewable energy generation onto the electric grid.

BROADBAND CONNECTIVITY AS A FOUNDATION FOR ECONOMIC DEVELOPMENT

CASE STUDY: STOCKHOLM, SWEDEN

Stockholm is one of the most connected cities in the world. In 1994, the government of Stockholm decided to build its own high-speed internet network, which would be open to all on an equal basis. The city dug new conduit networks (the physical ducts where cable and wires can be laid), installed fiber optic cables, and offered transmission capacity to competing internet service carriers. Today, the network serves approximately 90 percent of the city's households, and it has over 100 telecom operators and more than 700 companies as customers.

The Stockholm region is now home to cutting-edge technology, a highly skilled workforce, and Europe's fastest growing startup companies, with city leaders estimating a three-to-one economic return on their investment. In 2011, PricewaterhouseCoopers identified Stockholm as the city with the best network connectivity for schools, the best availability and usage of IT solutions, and the second best broadband quality of 26 large cities around the world. Large technology companies have chosen to make Stockholm their home—with IBM, Microsoft, and Ericsson headquartering their European operations or R&D centers in the city—while many innovative, fast-growing technology companies, such as Skype and Spotify, also have their origins in Sweden.

KEEPING CALIFORNIA CONNECTED, POWERED, AND COMPETITIVE

The following sections of this report focus separately on communications infrastructure and the advanced power grid. Each section provides an overview of 21st century infrastructure, including the trends that are driving a need for upgrades; the benefits that Californians can derive from improved infrastructure; and the state's current infrastructure landscape. The sections close with policy recommendations that can move the state forward in promoting 21st century infrastructure investment. The spread on the following pages highlights the communications and energy technologies that will be enabled by advanced infrastructure.

+ **SMART TRANSPORTATION SYSTEMS**
- Autonomous vehicles
- Car-to-car, car-to-infrastructure, public transportation-to-infrastructure communication
- Adoption driven by public safety, partnerships, standards

+ **MICRO-MEDICINE NETWORKS**
- First wave: Remote diagnostic capabilities
- Second wave: Biologic sensor systems
- From data sharing to active health maintenance

+ **FEDERATED SENSOR NETWORKS**
- Shared sensor networks dynamically serving multiple users
- City, home, infrastructure as app platform

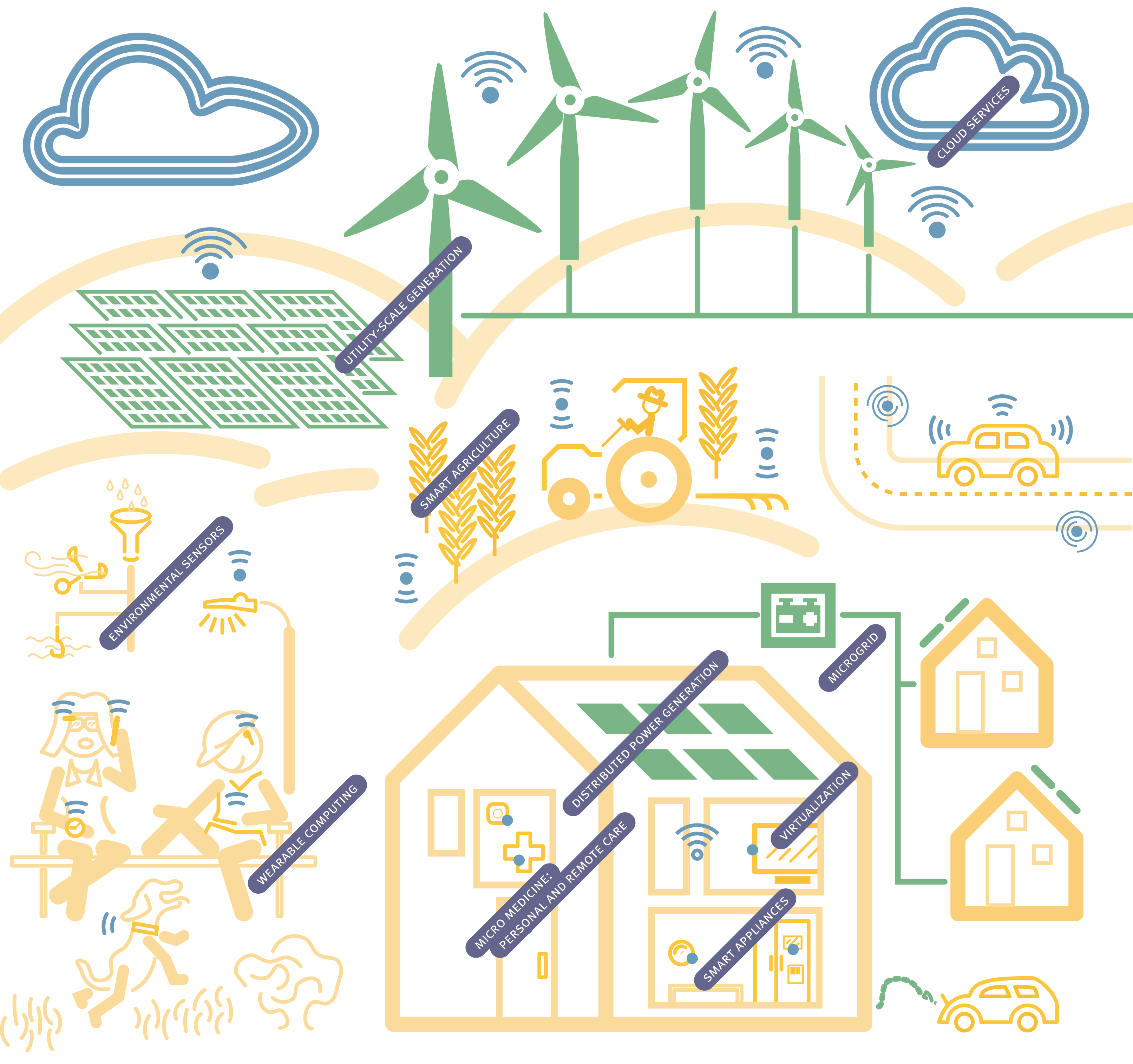
+ **NEXT-GENERATION ROBOTICS AND ARTIFICIAL INTELLIGENCE**
- Utility drones: UAVs and autonomous machines assume routine tasks from infrastructure surveillance to industrial manufacturing processes

+ **URBAN INFORMATION MARKETPLACE: ABUNDANT CITY DATA IS A RESOURCE FOR ENTREPRENEURS**

+ **INTERNET OF EVERYTHING: BILLIONS OF DEVICES ACROSS HOMES AND FACTORIES, NOW CONNECTED TO THE NETWORK**

+ **WEARABLE COMPUTING: ALWAYS-ON CONNECTED CLOTHES, GLASSES, SENSORS**

THE CONNECTED LANDSCAPE



+ DISTRIBUTED GENERATION:

- Utility-scale and residential DG connect seamlessly
- Plug-and-play capabilities for third-party applications and services

+ CLOSED-LOOP SYSTEMS: REDUCING OR ELIMINATING WASTE ENTIRELY FROM LARGE SCALE PRODUCTION SYSTEMS

+ INFRASTRUCTURE SECURITY RISK MANAGEMENT

- Electricity grid assets are targets for physical and cyber attacks
- Internet of Things and automated/connected cars are soft targets and heighten security risks exponentially

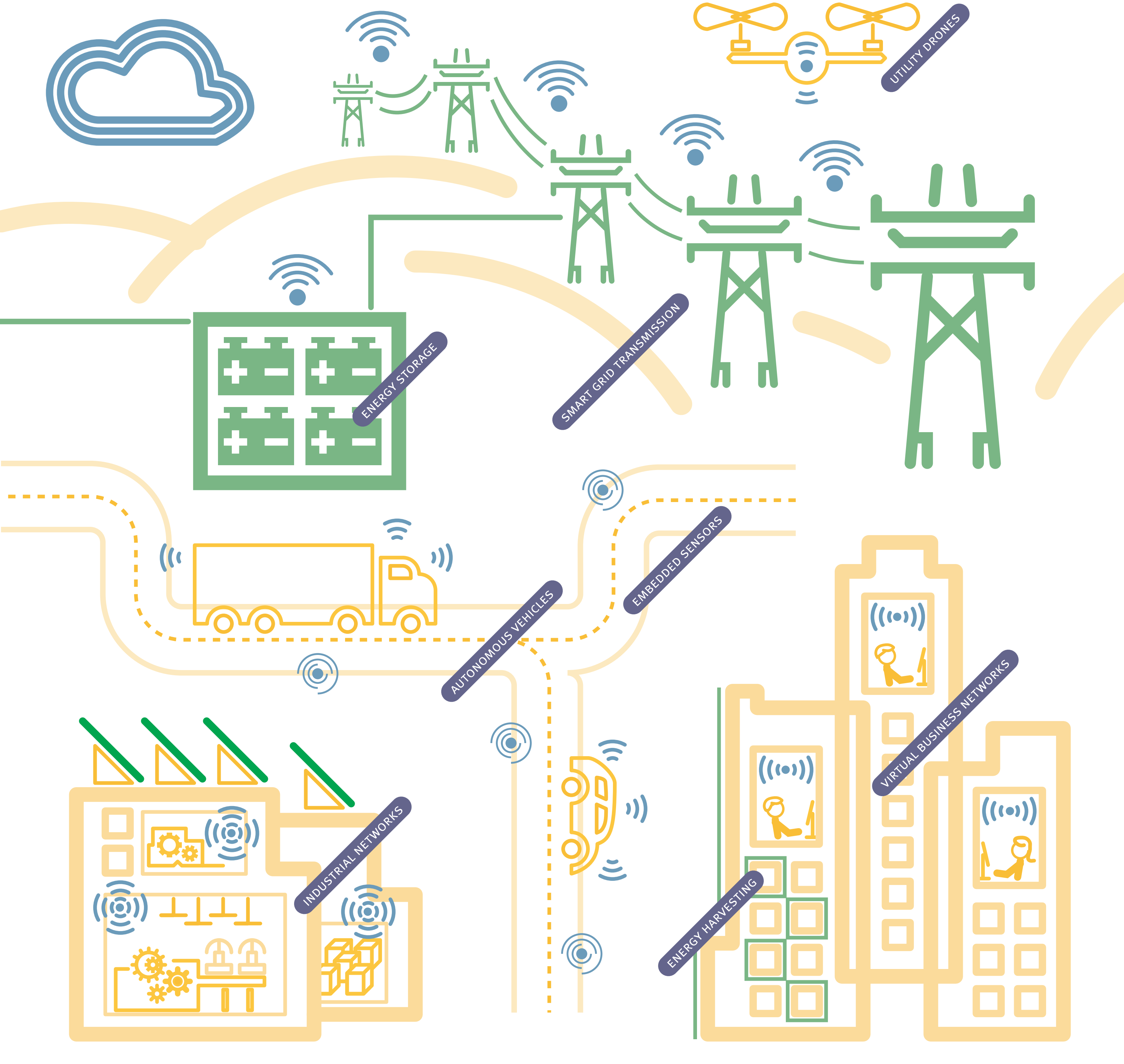
+ MULTIPLE "SMART" SECTORS: ENERGY, TRANSPORTATION, WATER, AGRICULTURE ALL INCREASINGLY NETWORKED

+ MASS ENERGY STORAGE: ASSETS ARE INTEGRATED ONTO A CONNECTED GRID

+ ENERGY ANALYTICS: DATA OPTIMIZES GENERATION, TRANSMISSION, AND DISTRIBUTION

+ DEMAND RESPONSE SYSTEMS AND ENERGY MARKETPLACES: PRICE SIGNALS INCENT USERS TO VARY ENERGY PRODUCTION AND CONSUMPTION

OF THE 21ST CENTURY



Communications Infrastructure:

Expanding Quality and Capacity

On the evening of April 3, 1860, the citizens and dignitaries of St. Joseph, Missouri were parading to speeches, fireworks, and the steady charge of a marching band. At 7:15 p.m., cannon fire inaugurated the night's main event: a rider on horseback carrying 49 letters, five telegrams, and a handful of miscellaneous papers departed for San Francisco, California. The celebrated cargo arrived at midnight on April 14. In 11 days, the Pony Express had perfected horseback messenger service and revolutionized transcontinental communication.[5]

It would not last. Two months following the maiden voyage, President Buchanan signed the Pacific Telegraph Act, paving the way for the first transcontinental telegraph. Within the space of two years, the most advanced communications technology in the world—a system of horsemen at regularly spaced intervals—had been designed, built, and rendered totally obsolete.

Like the Pony Express before, consumer and business demands have eclipsed the utility of yesterday's communications technology in favor of advanced digital broadband service. By 2018, global consumer and commercial internet demand is projected to increase threefold over 2013 levels and will be 64 times the internet traffic volume produced in 2005.[6] Today's network will need upgrades to accommodate this surge.

"We need a structure that will result in ubiquitous, diverse, and constantly improving broadband. Achieving a 21st century network will allow broadband to be used as a platform to deliver social and government services more effectively and efficiently."

Blair Levin, The Brookings Institution and former FCC Commissioner

COMMUNICATIONS TIMELINE

Since the 1970s, landmark events and state and federal policies have shaped the character of communications infrastructure and the demands placed on it. The timeline spanning this section highlights those transformational events and policies.

Much of the recent growth in network demand has been driven by the increasing number and power of mobile devices. Global mobile data grew by 70 percent in 2012, and 81 percent in 2013—a deluge that caught several communications companies off-guard. "Overnight, we're seeing a radical shift in how people are using their phones," remarked John Donovan, Senior Executive Vice President of AT&T, after the release of Apple's 3GS iPhone caused repeated network failures, adding, "There's just no parallel for the demand."[7] By the end of 2013, data traffic from mobile devices was nearly 18 times the size of the entire global internet in 2000 and is projected to increase another 11-fold by 2018.[8]

Californians stand to reap broad social and economic benefits from recent and imminent advances in communications technology. However, the power and popularity of these devices will need to be supported by new infrastructure that enables faster and more reliable connectivity speeds. As other parts of the country and the world take steps to improve their connectivity, policy initiatives that foster increased infrastructure investment can optimize California's global economic competitiveness.

21st Century Infrastructure in Practice – Good Government

In the future, "smart city" sensors installed across urban infrastructure will create enormous quantities of data about everything from traffic and parking, to utilities usage and crime. Optimizing such data can vastly improve government services and reduce inefficiency, freeing government resources to be repurposed to other priorities. Such data could also be utilized for consumer applications, from painlessly locating free parking spaces to navigating along the safest routes.

The Infrastructure of 21st Century Communications

Twenty-first century communications infrastructure refers to the advanced network of cables, towers, and antennas needed to meet new demands and to prepare the state's networks for the future generation of digital communications. These advancements will support broadband and mobile internet connections that are high speed, high capacity, reliable, ubiquitous, and secure. While technology and standards are continually evolving and advancing, below are several examples of 21st century communications infrastructure.

Advanced Copper Wires: Telecommunications providers offer broadband service over the legacy copper wire system used for phone service, known as a digital subscriber line or DSL. Copper wire technologies have advanced through many generations of service, with VDSL (very-high-bit-rate DSL) now supporting high-definition television, Voice Over Internet Protocol (VOIP) phone service, and internet access. Data traveling on copper wires is vulnerable to interference and loss of signal quality the further it travels. As a result, copper networks require periodic boosters to amplify the signal over long distances, the installation of remote terminal cabinets moving hardware closer to the customer, and ongoing carrier maintenance. Future generations of copper wire service that can match speeds achieved by more advanced fiber optic cable are currently under development, which can give carriers another option in delivering gigabit-per-second (Gbps) services to homes and businesses.[9]

1972 ELECTRONIC MAIL INTRODUCED

EVENT

SEP 1975 FIRST PERSONAL COMPUTER INVENTED

EVENT

APR 1982 FIRST FULL-COLOR, TWO-WAY VIDEO TELECONFERENCE SERVICE OFFERED

EVENT

Advanced Coaxial Cables: Cable companies are able to offer broadband service through their analog cable television infrastructure, generally consisting of fiber optics strung to a central local area in a neighborhood with lower-capacity coaxial cables wired to individual homes and businesses. Similar to the evolution of copper wire, cable technologies have reached their third generation and can now support gigabit connections. Infrastructure investments in network hardware and upgrades to both the fiber and coaxial networks are required for the broader deployment of these higher capacity networks.

Fiber Optic Cable: Fiber optic cables are composed of small strands of glass or plastic that conduct light signals, which can produce download speeds up to 100 times faster than traditional copper wires. Fiber optics have supported communications for years as the backbone of the internet, connecting key servers, routers, and networks. Increasingly, both cable and telecommunications operators are moving to enhance broadband rollouts through fiber-to-the-home connections, or to a neighborhood node location with copper providing the final leg to the customer (known as fiber-to-the-node).[10] These fiber cables are generally placed on existing telephone or utility poles, in existing conduit running underneath municipalities, or in newly trenched conduit.

Mobile Broadband: With 58 percent of American adults owning a smartphone as of January 2014,[11] wireless internet access is growing in importance as a means of connectivity. Mobile network performance depends on a combination of wireless and wired networks that allow signals to travel as radio waves and over cables to connect to the internet. Mobile data transmission is predominantly achieved through a wired connection ending in a wireless site, which broadcasts and receives radio frequency signals in its service area. Wireless capabilities have progressed to the 4G/LTE (Long Term Evolution) standard, which provides mobile broadband internet access. As these systems move toward an LTE-Advanced standard to achieve gigabit speeds, carriers will be required to upgrade cell towers, build more wireless sites, and improve the fiber connections that link wireless antennas to the internet.

Microcells and Distributed Antenna Systems: These advances increase the density and capacity of cell coverage. By deploying multiple microcells and distributed antenna systems—tiny antennas sometimes as small as a wireless modem—carriers can improve wireless reception and help to better manage internet traffic on crowded cellular networks, such as in airports, office buildings, and stadiums. Microcells help augment the coverage of larger cell towers by enabling the more efficient use of the limited amount of wireless frequency spectrum that each carrier is allotted.

DOWNLOAD SPEED COMPARISON TABLE

LENGTH AND TYPE OF MEDIA	APPROXIMATE SIZE	DOWNLOAD SPEED BROADBAND				DOWNLOAD SPEED FIBER	
		1 MBPS	5 MBPS	10 MBPS	20 MBPS	100 MBPS	1000 MBPS (GIGABIT)
4-minute song	4 MB	30s	5s	3s	1.5s	0.3s	0.03s
5-minute video	30 MB	3m	40s	26s	13s	2.5s	0.2s
9-hour audiobook	110 MB	10m	2m	1.5m	46s	9.2s	0.9s
45-minute TV show	200 MB	20m	5m	3m	1.5m	16s	1.7s
45-minute HDTV show	600 MB	1h	15m	8.5m	4m	50s	5s
2-hour movie	1.0 - 1.5 GB	2h	24m	21.5m	10.5m	1.5m	8s
2-hour HD movie	1.0 - 4.5 GB	3h	72m	60m	32m	4.5m	25s

Data Source: Fastmetrics

JUN 1982 **FIRST CELL PHONES AVAILABLE FOR SALE**

EVENT

AUG 1982 **MODIFICATION OF FINAL JUDGMENT IN UNITED STATES V. AT&T**

US POLICY

Required AT&T, operator of the Bell System, to separate competitive activities from its non-competitive monopoly markets and set the stage for industry deregulation

1984 **BREAKUP OF THE BELL SYSTEM**

EVENT

The Bell System's many operating companies were merged into seven independent regional holding companies, also known as "Baby Bells", and divested from AT&T

New and Emerging Trends Driving Increased Network Demand

The past decade has been characterized by the emergence of smart phones and smart devices, powerful laptops and tablet computing, advances in data storage, social networks, and the rise of online commerce. According to projections, these demand drivers represent only the beginnings of the soaring network demands on the horizon, as the next generation of connected devices prepares to hit consumer and industrial markets. In a 2013 McKinsey report that evaluated the 12 most transformative technologies of the next decade, most were based fundamentally on communications technologies and almost all relied on information technology in some way.[12] Below is a brief examination of four key technologies and trends that will drive network demand into the next phase of the 21st century.

CLOUD STORAGE SERVICES AND REMOTE PROCESSING

Today, many technologies rely on data-collection processors that communicate with central cloud repositories—for example, smart phones rely on cloud connectivity for their core features, voice and gestural recognition. In 2014, Cisco Systems projected that annual global cloud traffic would increase four-fold between 2013 and 2018, from 1.6 zettabytes (one billion terabytes) to 6.5 zettabytes, and account for 76 percent of total data center traffic by 2018.[13] This growth will be driven by steep increases in global business spending for cloud services, which is expected to reach $235 billion in 2017.[14] Finally, the market insights and savings attributable to "Big Data"—data collections that are too large, complex, and dynamic for conventional data tools to capture, store, manage, and analyze—will drive demand for sensing devices, data repositories, and the bandwidth to coordinate and access them.

CONSUMER INTERNET OF THINGS

One of the most striking changes that will impact both society and communications infrastructure is the "Internet of Things"—billions of automated devices, such as sensors and wearable technology, constantly sharing and requesting data over the internet. There were an estimated 22 million wearable devices—such as Nike's FuelBand and the Fitbit—connected to networks in 2013, a figure expected to grow to 177 million devices by 2018,[15] as the wearable market transitions toward more sophisticated devices like Google Glass and the Apple Watch. These and other devices that share data from machine to machine (M2M) will grow from 4.9 percent of all devices today, to 19.7 percent by 2018.[16] In other words, 2 billion devices may be able to communicate with each other without any human intervention, competing with traditional human-driven data use for limited network space.

21ST CENTURY INFRASTRUCTURE IN PRACTICE – MOBILE HEALTH

In the future, individuals will be able to wear, implant, and ingest technologies that produce vast amounts of diagnostic information. With ultra high-speed internet connectivity, individuals will be able to instantly send data captured from these devices to medical experts anywhere in the world—ensuring they get the best possible care. Data from these and other automated technologies will also increase demand for workers trained in data analytics.

WHAT'S A ZETTABYTE?

	NUMBER OF BYTES
1 KILOBYTE	1,000
1 MEGABYTE	1,000,000
1 GIGABYTE	1,000,000,000
1 TERABYTE	1,000,000,000,000
1 PETABYTE	1,000,000,000,000,000
1 EXABYTE	1,000,000,000,000,000,000
1 ZETTABYTE	1,000,000,000,000,000,000,000

Data Source: Cisco Systems

NOV 1990 — **WORLD WIDE WEB INVENTED**

EVENT

1994 — **US GOVERNMENT PRIVATIZES INTERNET MANAGEMENT**

US POLICY

FEB 1996 — **TELECOMMUNICATIONS ACT OF 1996**

US POLICY

The first major overhaul of telecommunications law in almost 62 years let any communications business compete in any market

GENERAL ELECTRIC BATTERY MANUFACTURING PLANT
Photo Credit: Albany Times Union

The Internet of Things also includes sensor technology, which will allow roads to communicate maintenance needs to construction crews, parking spaces to interact with smart phones, and autonomous vehicles to know road conditions. Mobile communications company Ericsson projects that there will be 50 billion sensors by 2020, applied across industries and multiple facets of daily life.[17] In the Internet of Things, people are not only talking to people but also to machines—and machines are talking to each other—with possible applications ranging from environmental sensors to aerial drones.

INDUSTRIAL INTERNET

The Industrial Internet, the network required to bring industrial processes online, could be considered a subset of the Internet of Things with a focus on large-scale processes, complex machinery collecting data, and massive robots. Equipping many of these processes with interconnected computing produces large efficiency gains, as algorithms can automate decision-making and change the way information is leveraged in the workplace. The Industrial Internet can also help to prevent unnecessary downtime—which can cause manufacturing stoppages, grounded airplanes, and delayed deliveries—by signaling when preventative maintenance should occur. For example, a General Electric factory in Schenectady, New York, uses 10,000 sensors to support greater efficiency in the manufacturing of advanced batteries. Industrial Internet technologies also facilitate the expansion of the smart energy infrastructure necessary to expand California's renewable energy portfolio, which is discussed in greater detail in the Energy section of this report.

STREAMING MEDIA

Streaming video serves many practical applications, including online education, medical evaluations, entertainment, telecommuting, and enhanced citizen engagement with government processes and services. It is also one of the biggest drivers of bandwidth demand. In the first quarter of 2014, Netflix and YouTube together accounted for one-third of all fixed-access internet traffic and 36 percent of mobile access.[18] Internet networking company Cisco Systems projects that by 2018, mobile video will account for over two-thirds of mobile data traffic.[19] UltraHD video, which is at least four times the resolution of a typical video display, will demand more data and require higher connection speeds.

OCT 1996 **CALIFORNIA TELECONNECT FUND**

CA POLICY

Provides a 50% discount on select communication services to schools, libraries, hospitals, and other non-profits

SEP 2006 **ASSEMBLY BILL 2987: DIGITAL INFRASTRUCTURE AND VIDEO COMPETITION ACT**

CA POLICY

Calls for the CPUC to issue cable television franchises, rather than cities and counties

2006 **CALIFORNIA BROADBAND TASK FORCE**

CA POLICY

Following Governor Schwarzenegger's Executive Order, a task force produced reports on key actions California should take to stay competitive in broadband provision

Benefits of 21st Century Communications Infrastructure

Investments in 21st century communications infrastructure will create potentially huge economic and social benefits to average Californians. Advances in cloud computing, the Internet of Things (consumer and industrial), and streaming media will unlock new opportunities and reshape business models, creating new jobs, products, services, and experiences. Below, areas of society are examined that will be improved through advanced communications technology as made possible by 21st century infrastructure.

Supplementing Knowledge Workers: Videoconferences, smartphones, private networks, and cloud-based computer processing have been the hallmarks of the last decade's virtual office. These technologies allowed 13.4 million people in the US to work from home in 2010, an increase of 4 million workers from 2000.[20] In 2008, Cisco Systems instituted a telework program that helped the company to save money on collaboration technologies, and also raised employee satisfaction. Cisco estimates that its employees garner total fuel cost savings exceeding $10 million per year.[21] New, high-speed broadband infrastructure, however, promises to deliver even greater collaborative potential and efficiency among colleagues located all over the world, including holographic conferencing.

Sophisticated processing techniques communicated through high-bandwidth fiber can also replicate simple human judgment in repetitive tasks. Automating legal discovery, Clearwell Software sifted through over a half-million legal documents in two days, at much lower cost than law professionals.[22] Mobile connectivity expands the reach of such capabilities, and the resulting productivity gains allow workers to focus on more complex tasks.

Agriculture: California's volatile, semi-arid climate regularly produces periods of prolonged drought with significant negative economic impacts. For example, in 2014, one of the driest years on record, the drought resulted in a net water shortage of 1.5 million acre-feet, which cost statewide agriculture $2.2 billion and the loss of 17,100 seasonal and part-time jobs.[21] However, new advances in precision-agriculture, driven by 21st century communications technology, promise to yield huge efficiencies in California's water usage. Field sensors and drones are beginning to provide farmers with precise weather, crop, soil, and air quality data that can be used to greatly improve use efficiency and reduce runoff. Because agricultural water use accounts for nearly 80 percent of all water used in California, conserving even small percentages can lead to large net savings.

Sensor- and communications-based precision agriculture will yield further benefits beyond water efficiency. California-based 3D Robotics and TerrAvion are pioneering the use of aerial drones in targeted pesticide use and remote monitoring of crops, allowing more precise and limited use of pesticides and fertilizers that yield production gains in an environmentally sustainable manner.

Education: In 2013, 78 percent of students and 83 percent of faculty and staff in the US brought a personal device to the classroom and used the campus network for access to the internet.[23] However, more than 50 percent of teachers say that slow or unreliable internet access presents obstacles to their use of technology in the classroom.[24] Additionally, 63 percent of public schools in the US do not have adequate internet infrastructure to support digital learning.[25] In contrast, South Korea has invested in high speed internet for all of the country's classrooms; all teachers are trained in digital learning; and all paper textbooks will be phased out by 2016.[26]

21st century communications infrastructure will expand access to educational materials, improving student tracking and making it possible to tailor lessons to individual pupils. Increasingly, education technologies are assuming a role akin to private tutors, as web-based applications such as the Khan Academy enable access to open education resources. This type of learning also frees up time for teachers, who spend fewer hours grading homework—because the program scores it automatically—and more time interacting one-on-one with students. For example, Rocketship, a network of nine charter schools in San Jose, California, has had success in blending traditional teaching methods with individualized online instruction in low-income areas. Its schools are now in the top five percent of school districts serving low-income students in California.[27]

DEC 2007 **CALIFORNIA ADVANCED SERVICES FUND**	FEB 2008 **SENATE BILL 1191: MUNICIPAL BROADBAND**	MAR 2010 **NATIONAL BROADBAND PLAN**
CA POLICY	CA POLICY	US POLICY
Supports projects that will provide broadband services to areas currently without broadband access and build out facilities in underserved areas	Authorizes a community service district to construct, own, and operate broadband facilities if a private person or entity is unable or unwilling to deploy broadband services	The FCC produced a set of initiatives to stimulate economic growth and boost America's broadband capabilities

Online learning has also played an important role in higher education, where massive open online courses (MOOCs) and other digital tools have been utilized to more efficiently bring teaching resources to a broader student population. Online programs create greater learning accessibility and affordability for those students who have a need for a learning environment outside the traditional classroom.

Health: Data captured from emerging non-invasive health-monitoring sensors, such as disposable bandages and ingestible pills, will support expanded mobile-based care, self-care, and more accurate diagnostics—all of which have the potential to both improve care and reduce costs, and can only be achieved through improved network connectivity. When paired with remote physician monitoring, these innovations could save the US health care system $197 billion over the next 25 years.[28]

Some of these benefits are already being realized on small scales throughout the country. For example, a US Veteran's Health Administration experiment in remote monitoring of chronic diseases combined video chats with physician visits and found that these patients had a 40 percent reduction in bed days of care.[29] Meanwhile, in Kansas City, the Google Fiber project recently announced a partnership with the University of Kansas City Medical Center to develop health applications based on Google's local gigabit network. Officials envision a reduction in physician visits for elderly patients and persons with mobility challenges, as those visits could be replaced by video conference over the high-speed internet connection. Doctors and various medical units will also be able to share large files, such as retina scans, x-rays, and vascular imaging that could speed diagnosis and lower patient costs.

Public Services and Safety: Smart city infrastructure relies on connectivity technologies and can create efficiencies in water, power, transportation, and waste management. For example, Cleveland and Cincinnati have implemented successful waste-collection programs with the help of radio-frequency identification (RFID) tags on garbage and recycling bins, cutting operating costs and increasing recycling rates.[30] In Amsterdam, investments in communications infrastructure have allowed the city to create urban living labs where new products and services can be tested and knowledge can be widely shared through open data. The Amsterdam Smart City project has already witnessed successes in open modeling platforms for urban planning, vehicle-to-grid integration for electric vehicles, and improved traffic routing applications.

Enhanced broadband communications can also be a backbone for autonomous and near-autonomous vehicles, which must communicate with infrastructure, each other, and the internet to make the best routing decisions. Already, immense amounts of transportation data are being utilized in dynamic pricing and congestion reduction initiatives, though a future link providing real-time road information directly into the vehicle could optimize transportation use. In Brussels, a fiber optic network is being put in place to ensure communication and safety for a fully automated, driverless rail system. The fiber optic network increases resiliency and will enable a new signaling system, automatic platform gates, and more than 10,000 interconnected video cameras.[31]

In addition to improved public services, 21st century communications infrastructure will improve network reliability during natural disasters and other catastrophic events, making public safety technologies, such as mass-notification systems and Google's Person Finder, more dependable and accessible during emergencies.[32] A recent example of communications infrastructure's relationship to public safety followed the bombings at the Boston Marathon finish line in 2013. In the aftermath of the attack, cell phone networks in the area were overwhelmed with traffic, leaving many at the scene unable to contact family or friends.[33] With more ubiquitous and robust wireless broadband coverage, carriers can route overflow calls during times of high demand over the broadband network rather than through traditional cell channels.

SEP 2010 **SENATE BILL 1462: CALIFORNIA BROADBAND COUNCIL**

CA POLICY

Establishes the California Broadband Council to maximize the state's broadband funding, increase coordination, and expand broadband accessibility

OCT 2011 **NUMBER OF MOBILE PHONES EXCEEDS US POPULATION**

EVENT

SEP 2012 **SENATE BILL 1161: VOICE OVER INTERNET PROTOCOL**

CA POLICY

Prohibits any organization of the state from regulating VOIP or other IP-enabled service unless delegated or required by a state or federal statute until January 1, 2020

Where California Stands Today

For California to realize the social and economic benefits of emerging and future communications technologies, it must have an equally advanced communications infrastructure to support them. As other states and countries take steps to facilitate network upgrades, California's communications infrastructure will need to be updated or risk being unprepared for future requirements placed upon it.

THE STATE OF CONNECTIVITY IN CALIFORNIA

Connection speeds across California are variable, as they are dependent on the level of internet service provider investment. Generally, 6 megabits-per-second (Mbps) download speed is considered sufficient bandwidth for emails, most websites, and even streaming videos for one device. But if multiple devices are connected to the network, internet speeds of 15 to 50 Mbps are desirable to maintain access without interruption. As more advanced uses, such as video conferencing, become more prevalent, even faster speeds will be necessary. For example, the National Broadband Plan has a stated goal of achieving 100 Mbps download speeds in 100 million US homes by 2020.[34]

21ST CENTURY INFRASTRUCTURE IN PRACTICE – ENVIRONMENT

In the future, farms will be able to use drones, sensors, and direct-to-root irrigation systems to produce better crops with less water—provided their acreage has adequate broadband connectivity. Through conservation, excess water can be used to either replenish oversubscribed groundwater basins, or kept in rivers and creeks to help aquatic ecosystems.

FEB 2015 **FCC PROPOSES NET NEUTRALITY RULES**

US POLICY

FCC Chairman proposes new regulations that would bar internet providers, both fixed broadband and wireless, from offering differentiated levels of service to content providers

As of the end of 2013, 97.8 percent of California households could access fixed broadband infrastructure (consisting of wirelines and fixed wireless technologies) with download speeds greater than 6 Mbps.[35] The average speed for those households with broadband connections in California is estimated at 12 Mbps. At this speed, California ranks 18th by average speed against the other 50 states.[36] While ranking internet service by geography is an inexact science (for example, rankings do not typically control for factors such as population density and geographic peculiarities—both of which affect California's rankings), such listings do demonstrate the difficulty in bringing high-speed access to California's geographically- and economically-isolated populations. Significantly, California's middling rank among US states suggests it is lagging even further behind parts of Europe and Asia,[37] which tend to outrank the US in terms of speed and access. It has also been consistently found that US broadband at high speeds (above 12 Mbps) is more expensive than similar service in Europe.[38,39]

EFFORTS TO EXPAND BROADBAND QUALITY AND CAPACITY

The majority of Californians today are connected to the internet through services provided by either telecommunications providers, such as AT&T, or cable television providers, such as Comcast.[40] With these providers offering overlapping services and a new wave of technology companies beginning to pilot their own networks, greater competition has resulted in the faster, more reliable internet technologies described previously. Kansas City provides an illustrative example of this increased competition. Following Google's deployment of fiber connections throughout the city, AT&T, Comcast, and Time Warner Cable have all developed investment plans that will result in faster speeds for their local services.[41]

The nation's four largest communications and cable companies, AT&T, Comcast, Time Warner Cable and Verizon, invested more than $46 billion in capital expenditures within the US in 2013 alone, more than any other sector of the economy.[42] In fact, AT&T and Verizon are estimated to be the two largest investors in US infrastructure, as AT&T invested significantly in its U-verse fiber network, and Verizon built out its 4G/LTE wireless network.

NATIONAL BROADBAND SPEED RANKINGS

	State	Avg. Mbps		State	Avg. Mbps
1	Delaware	17.4	11	New Hampshire	12.5
2	Washington	16.3	12	Oregon	12.5
3	Connecticut	15.3	13	New York	12.3
4	Utah	14.8	14	Maryland	12.3
5	District of Columbia	14.6	15	North Dakota	12.2
6	Virginia	14.5	16	Wisconsin	12.2
7	Massachusetts	14.4	17	Pennsylvania	12.1
8	Rhode Island	13.5	**18**	**California**	**12.0**
9	Michigan	12.7	19	Indiana	11.8
10	New Jersey	12.5	20	Minnesota	11.7

Source: Akamai State of the Internet, Third Quarter 2014

PRIVATE COMPANY INVESTMENT IN 21ST CENTURY INFRASTRUCTURE

In response to the US government's National Broadband Plan, which recommended bringing internet speeds greater than 100 Mbps to over 100 million homes, private companies began a push to upgrade their networks. Google was the first to announce that it needed a city to pilot its new high-speed fiber in early 2010. Kansas City was selected as the site for the Google Fiber network. Google Fiber now offers three residential packages: free internet for at least seven years with a $300 construction fee, $70 per month gigabit-per-second (Gbps) internet, or a $120 per month bundle of television and 1-Gbps internet, which can be up to 100 times faster than a traditional network.

Kansas City was selected for its optimal infrastructure, such as the strategic location of utility poles, conduit, and existing water, gas, and electricity lines, which makes laying the fiber less intrusive and expensive. In addition, government officials promised regulatory streamlining that would speed construction. Kansas City has generated significant buzz around the economic possibilities that the high-speed network will create. Kansas City Startup Hub received the first installation of the fiber in November 2012 to pilot the product, and the Kansas City Startup Village has been created with the vision to help advance Kansas City as the premier startup city in America. Google has subsequently announced future fiber deployments in Austin, Texas and Provo, Utah.

While few residential broadband customers actually require 1-Gbps connections today, other providers have recognized the future opportunity and threat that gigabit speeds pose. Shortly after Google's announcements, AT&T made public its plan to expand its footprint of gigabit capable fiber networks, called GigaPower, to 100 cities and municipalities, including Cupertino in California. Through advances in cable technology, Comcast plans to offer gigabit speeds to home customers in 2015, and Time Warner Cable has announced that it will provide gigabit internet in Los Angeles by 2016 as it prepares its network for increasing customer demands and new technologies.

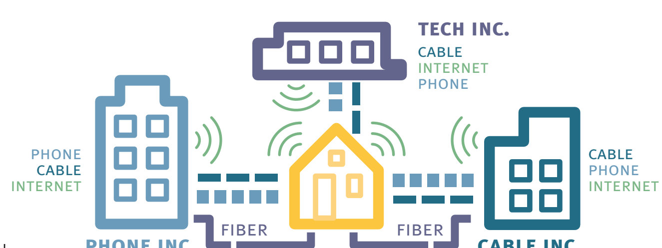
Regional players, such as Bay Area-based Sonic.net, have also entered the market for fiber-to-the-premises broadband connections. Sonic.net, the largest independent internet service provider in Northern California, currently offers gigabit speeds to homes in Sebastopol in Sonoma County. The company has also announced an expansion of its gigabit network to Brentwood in the East Bay. Sonic.net will offer gigabit fiber internet and unlimited phone service for $40 per month, which will give Brentwood residents and businesses the fastest, cheapest internet in the US.

Within California, AT&T has made investments totaling $7.1 billion between 2011 and 2013. These expenditures have been spread across a range of wireless and wired network upgrades for both residences and businesses. In 2013, capital expenditures for Comcast and Verizon's California divisions totaled $175 million and $514 million, respectively, with Comcast investing over $9 billion in California infrastructure since 1998. While this level of investment is large, California has not enticed broadband providers to aggressively push the newest and best technologies within the state. Instead, places like Kansas City, Austin, Dallas-Fort Worth, Raleigh-Durham, and Winston-Salem have been the first to receive gigabit networks. These cities received network investments by collaborating directly with providers and offering favorable conditions for build-out.

Municipalities have also entered the market for internet provision, though with mixed results. City efforts to provide broadband connections to homes and businesses have previously been derailed by limited uptake that has not recouped the costs of placing and maintaining infrastructure. For example, Provo's municipally owned network was producing financial losses for the city; it was eventually given to Google as part of the company's fiber rollout. Few cities in California have been able to fund large-scale broadband projects, though the following page does highlight successful examples

20TH CENTURY COMMUNICATIONS INFRASTRUCTURE

21ST CENTURY COMMUNICATIONS INFRASTRUCTURE



ADDRESSING THE GAPS

Even with new investments in California's broadband networks, the state's geographic features can make it difficult to connect households to 21st century communications infrastructure. Additionally, parts of the state remain where customer concentration is too low to attract private broadband infrastructure investments. Even where few geographic barriers exist, high-speed internet can be too expensive for low-income residents. As of June 2012, the CPUC calculated that 73.6 percent of all California households had adopted a broadband connection—compared to the 97.8 percent of households served by the infrastructure necessary for connectivity. In rural areas, less than half of all households were connected to the internet (44.8 percent), while certain neighborhoods of major cities, such as Sacramento and Los Angeles, had connectivity rates far below citywide averages. For some Californians without dedicated broadband access, mobile phones provide a means of connectivity—it is estimated that mobile devices are the only form of internet access for 6 percent of Californians.

Governments and businesses have been pioneering ways to close this digital divide. In 2011, Comcast—California's largest internet service provider—launched the Internet Essentials program for low-income households. Families that qualify for free or reduced price school meals through the National School Lunch Program can receive internet service for $9.95 per month and enroll in free computer literacy classes. To date, Comcast has served over 46,000 households in California through the Internet Essentials program.

In the public sector, the CPUC created the California Emerging Technology Fund (CETF) to expand access and adoption in hard-to-reach rural communities, economically disadvantaged urban communities, and disabled populations that lack technology accessibility. To reach these goals, CETF organizes regional consortia to attract investment and improve adoption. To this end, CETF's broadband consortia and internet providers have been able to utilize funds from the California Advanced Services Fund (CASF) for connectivity projects. CASF was authorized by the CPUC in 2007 and funded through a surcharge placed on telecommunications carrier revenues. Initially, $100 million was offered in grant funding that internet service providers could apply for in order to expand services to areas that do not have such service, and to improve the quality of service to those places that are underserved. CASF funding was expanded by the California legislature in 2010 by $125 million and again in 2013 by $90 million. To date, CASF has provided funding for broadband access to approximately 287,000 California households.

Broadband access is also increasingly important in California schools, as the state has moved to a new computer-based assessment model. In 2014, more than 60,000 students were unable to participate in these assessments due to a lack of adequate internet connection at approximately 300 California schools.[43] To address this gap, Assemblywoman Susan Bonilla (D-Concord) authored legislation to create the Broadband Infrastructure Improvement Grant, which will provide a total of $27 million in grant funding for internet upgrades at 227 schools in 2015.

PUBLIC-PRIVATE PARTNERSHIPS AND MUNICIPAL NETWORKS

The provision of broadband is largely accomplished through connections provided by cable and telecommunications companies, and nearly all US investment in broadband is made by private carriers. However, some California cities have taken innovative steps to provide businesses with the high-speed service they need to compete in global markets.

San Leandro, a city of approximately 90,000 people just south of Oakland, California, was traditionally a manufacturing town. A public-private partnership between the city and a local entrepreneur has brought an 11-mile fiber optic loop to San Leandro's commercial and industrial users. In 2011, OSI Soft, an application software company headquartered in San Leandro, began discussions with the mayor about installing a fiber optic loop in the city. By the end of the year, Lit San Leandro was created, and by 2012, the fiber loop was providing 10-Gbps broadband to the city's industrial center.

While San Leandro was reliant on a private investment to build its fiber network, other cities have built municipally owned infrastructure to achieve faster speeds. Loma Linda, in Southern California, opened one of the first municipal fiber optic loops in 2006. Through the Loma Linda Connected Community Program, the city built a fiber optic network capable of achieving 1-Gbps speeds at end nodes. It then partnered with builders and commercial developers to include standard fiber technology within new construction so that residents and businesses could easily utilize the network. Other examples include the cities of Santa Monica and Santa Clara, which provide access to city-owned fiber to local businesses and to internet service providers.

Municipalities across the country are also exploring public wireless networks as a means to provide their residents with more seamless connectivity. San Jose upgraded and extended its free public Wi-Fi network in 2014 with greater capacity and coverage in its airport and convention center. Boston has announced plans to connect its 20 commercial districts with outdoor hotspots. In New York, payphones across all five boroughs will be converted to 10,000 hotspots with charging stations. In each case, partnerships with providers or a revenue-generating mechanism, such as advertising, has made the project financially viable.

Communications Policy Considerations

In order for a provider to install physical assets, it needs to make large financial investments, navigate through policy and permitting, and create a viable revenue model that balances both. However, the shift to advanced broadband infrastructure has been complicated by public policies. Many of the policies and regulations intact today were put in place to govern telecommunications companies that were operating as monopolies. As internet, cable, and telecommunications companies have evolved to now compete against each other over similar services, market forces are driving improved quality and access, and regulations can serve as an impediment to investment. Below is an examination of several important considerations currently facing local, state, and federal policymakers, followed by specific policy recommendations.

INFRASTRUCTURE COST ISSUES

Installing fiber optic cables in conduits beneath existing streets and from utility poles is an expensive undertaking. In Kansas City, for example, Google Fiber spent an estimated $84 million on its first-phase fiber build out to reach 149,000 households—approximately $500 per connection.[44] Without guaranteed customer adoption of broadband, these high up-front costs can result in long payback periods. As a way to reduce infrastructure costs, registered telecommunications providers are required by federal regulations to allow shared access at reasonable rates to poles, ducts, and conduit, provided their use is not compromised. Taking a similar approach, some municipalities across the country have put procedures and plans in place that open access to city-owned conduits and light poles where fiber can be laid and wireless antennas can be placed.

Municipal processes can also impact the costs of capital investment in the network, as some municipalities view broadband infrastructure more in terms of a revenue generator from the sale of right-of-way rather than an engine of economic development. At the state level, the California Environmental Quality Act (CEQA) is considered another cost and delay factor in any infrastructure development that involves trenching or surface disturbance. CEQA compliance processes can take years, often the result of legal challenges and local opposition to the project. "Many fine California city proposals for the Google Fiber project were ultimately passed over in part because of the regulatory complexity here brought about by CEQA and other rules," said Milo Medin, Google's Vice President of Access Services, following the company's decision to launch its service in Kansas City. He added, "Other states have equivalent processes in place to protect the environment without causing such harm to business processes, and therefore create incentives for new services to be deployed there instead."[45]

STATE GOVERNANCE MODEL COMPLEXITY

Following the invention of the telephone, regulations were placed on telephone companies to ensure universal access to service regardless of income or geography. While many such rules can be credited with the telephone's rapid adoption, the telephone-carrier model—in which the network delivers one primary service—no longer applies to today's communications technologies, and the rules governing it impede the advancement of communications infrastructure. For example, California's "carrier of last resort" mandate requires phone companies to maintain legacy telephone service as a matter of public safety and 911 access. Due to this mandate in California, telecommunications companies are required to spend funds on legacy infrastructure, with less flexibility to invest in new technologies. With the Centers for Disease Control and Prevention estimating that 41 percent of all US households are no longer utilizing traditional phone service, many carriers are prepared to transition to new digital technologies that are superior and more cost effective to match consumer trends. For example, AT&T is piloting all-digital internet-based phone networks as part of its push to move to new, more powerful services; however, these pilots are not occurring within California.[46]

COORDINATION BETWEEN FEDERAL AND STATE POLICIES

Issues of broadband connectivity involve policymakers from many different jurisdictions. At the national level, the Federal Communications Commission (FCC) regulates network competition and sets many of the policies that impact broadband infrastructure and its use. Nationally, broadband is considered an information service, not a utility, and providers face limited regulation; however, the FCC is reviewing how it should treat broadband services going forward.

The California Public Utilities Commission (CPUC) has oversight over telephone service access and quality, with no formal jurisdiction over broadband services. As technology advancement—specifically, VOIP voice service delivered over the broadband network—has blurred the distinction between telecommunications and broadband, the state has taken steps to prevent the regulation of internet services. In 2012, the California legislature passed Senate Bill 1161, which forbade the CPUC from regulating VOIP services until January 1, 2020. Without extension of this law, the CPUC could institute greater governance over VOIP beginning in 2020, potentially creating a more strict California broadband regulatory environment when compared to FCC standards. If this regulatory asymmetry were to occur between state and federal oversight, carriers that operate nationally would have to navigate separate, more onerous policies in California that would ultimately slow investment.

Recommendations

With the coming wave of digital demand, investments in 21st century infrastructure are needed to seize the benefits that new communications technologies offer. To meet these shifting demands and to keep California economically competitive, policies can be put in place that will give communications providers greater flexibility to innovate and reduce barriers to investment. Through regulatory reforms and policy actions, governments can help to facilitate these investments in several ways.

PLAN FOR NETWORKS

Cities should plan for networks by improving knowledge and utilization of existing municipal network infrastructure, expanding sharing of passive infrastructure, and adding flexibility to infrastructure siting policies. For example, many cities have departments already managing communication networks with cables threading throughout the city—systems that manage traffic light signals, for example. These cables rest in city-owned conduit that could be dual-purposed to carry fiber cable. Unfortunately, cities often lack systematic and precise mapping of these conduit networks, blinding the public and private sector from opportunities to expand broadband access with greater speed and with much less cost.

Cities, states, and the federal government can also more strongly encourage co-location and shared infrastructure, such as mobile services towers and large conduit. Government entities can identify their own ducts, poles, and even tower sites and lease out space with fewer or more targeted restrictions regarding which companies can use them. At the state level, the Caltrans highway network provides a good example of an asset that could be outfitted with fiber cables during any construction program.

Beyond mapping, cities can improve upon make-ready ordinances for laying broadband infrastructure. These include variations of "dig once" policies, which require conduit installation whenever physical development in the city is opening up the ground. The City and County of San Francisco has a "trench once" policy, under which a five-year moratorium is placed on re-opening a roadbed once construction has been completed. While these policies are well intentioned, moratoriums can keep providers from updating infrastructure when new technologies become available. Instead, these types of ordinances should have exceptions for repair and upgrade work to ensure that infrastructure can be maintained.

EXPEDITE LOCAL PERMITTING PROCESSES

Today, building advanced communications infrastructure—conduits, fiber cables, and cell towers—in California is costly, complicated, and slow. Part of the reason is that CEQA requires potential construction projects to undergo a formal environmental review, which can be challenged in court by anyone. As a result, development in California is often protracted as project opponents exploit CEQA's many avenues for litigation, and proponents try to ensure an environmental review that will withstand court scrutiny. Because broadband infrastructure does not have a special classification under CEQA, it is treated as any typical development and is fully exposed to possible litigation. This risk discourages private investment, even though broadband infrastructure generally has a lower environmental footprint compared to roads, tracks, large pipes, and other heavy infrastructure.

Local governments can alleviate the burden of permitting and environmental review for communications infrastructure by reclassifying it as public works in municipal codes. For example, Santa Clara County is attempting to shift oversight of broadband infrastructure from its planning department to public works department with the hope of facilitating faster project approvals. Cities can also explore blanket permitting approaches, which would provide approval for system upgrades throughout a municipality. Currently, carriers are required to go through permitting processes on a project-by-project basis. These changes would add greater certainty to broadband infrastructure projects and reduce permitting costs and potential delays that currently slow investment, and should be viewed as a model that can be expanded statewide.

REASSESS GOVERNANCE MODEL

The telecommunications network across the country is transitioning away from legacy systems toward IP-based services. However, regulation still requires incumbent telecommunications carriers to maintain their legacy telephone network, despite how few individuals may use it or how superior internet-based communication might be. A new, technology-neutral oversight structure is needed that preserves the public interest in connection to emergency services without applying mandates on providers that operate in a competitive marketplace.

Additionally, the passage of Senate Bill 1161 forbade the CPUC from regulating VOIP services until 2020. However, an uncertain regulatory path beyond 2020 can cause providers to delay or suspend further service upgrades for fear of more stringent regulations being placed on IP-based phone services in the future. Extension of the oversight structure set out in Senate Bill 1161 beyond 2020 would give providers greater regulatory clarity as they plan for investments in 21st century infrastructure.

Taken together, these policies can allow California cities and carriers to begin participating in regional all-IP-based trial networks that take into account policy directions from the federal government. This new governance model will also ensure that California remains aligned with other states in a communications marketplace that is increasingly not bound by state borders.

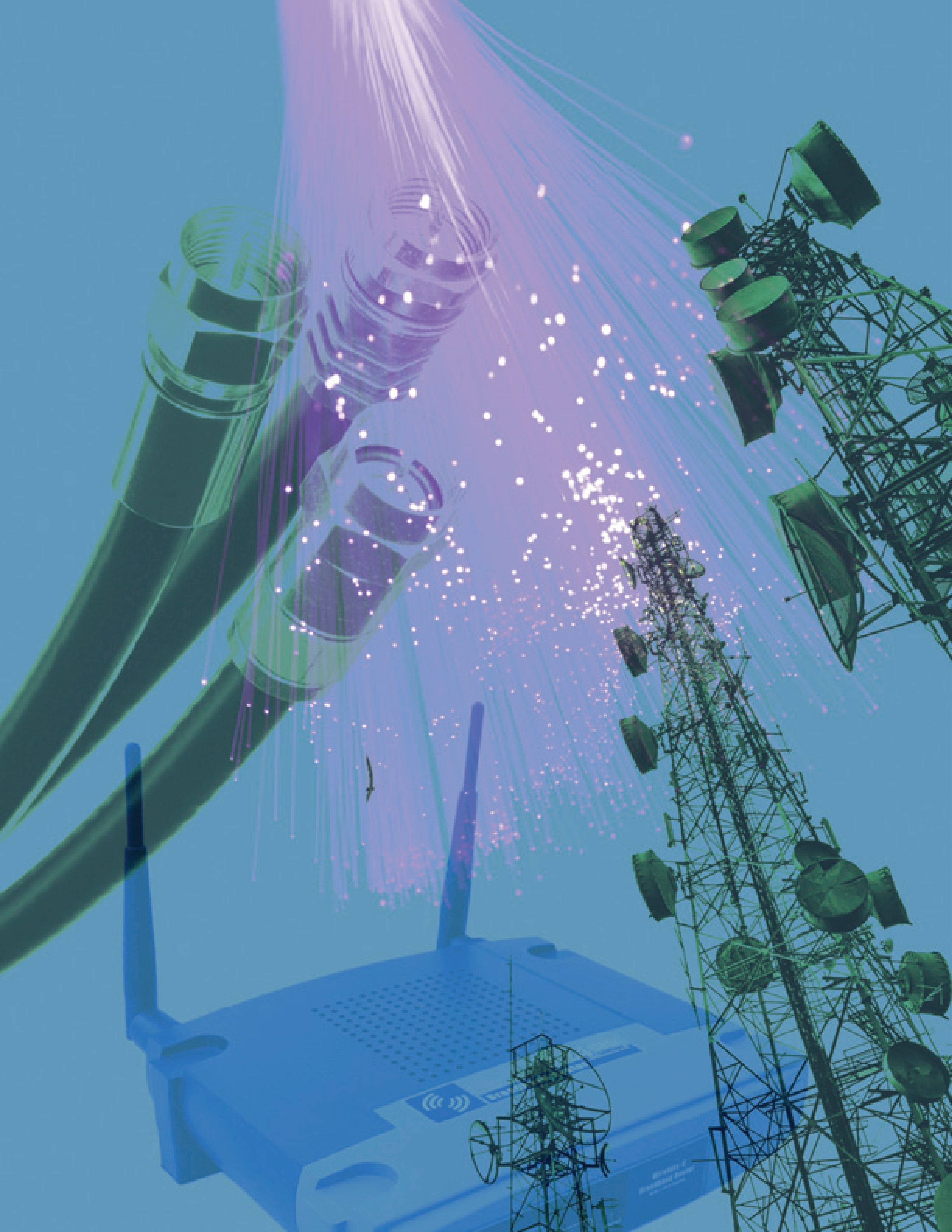
CREATE AN ADVANCED NETWORKS TASK FORCE

The emerging communications network will cross multiple purposes, relaying information about energy, infrastructure, health, and manufacturing processes—in addition to calls, emails, and internet downloads. There is opportunity for the formation of a diverse group of stakeholders to explore a new model for California's networks. This group could form within the current California Broadband Council to contend with the political dimension of the communications network through a consensus-building process with stakeholders about future planning and capacity. A statewide task force composed of existing network operators, state and municipal leaders, public-interest groups, regulatory bodies, and those developing new products and services dependent on the network should consider the following:

- Standardized infrastructure permitting guidelines across the state
- Technology evolution and choices
- Capital expenditure needs statewide
- Security and privacy
- Right-of-way rules and prioritization

Creating goals and strategies in these areas would offer a number of benefits such as raising public, political, and business awareness of emerging communications infrastructure issues; encouraging strategic partnerships among diverse players; and allowing flexibility as communications business models evolve.

Such a group could also be used to bring together cities throughout California that are currently exploring new ways to engage with internet service providers to create 21st century network models. By distributing best practices from these places, the Advanced Networks Task Force could help educate cities on the social and economic opportunity broadband infrastructure presents and local leaders on the gaps in public policy. A public education campaign that emphasizes the expansiveness of the network could potentially open innovation in financing schemes if social and economic benefits are enumerated in a more transparent manner.



Energy Infrastructure:

Balancing Environmental Needs and Consumer Demands

California's first energy systems were constructed high in the gold country to drive mining operations. While adequate for the localized power production of the mines, Thomas Edison's direct current technology could not transmit electricity over the long distances necessary to power California's early towns and cities. Nicolai Tesla's alternating current power system solved this problem, and by 1892, the City of Pomona became the first city in California powered by the long-distance transmission of alternating current.

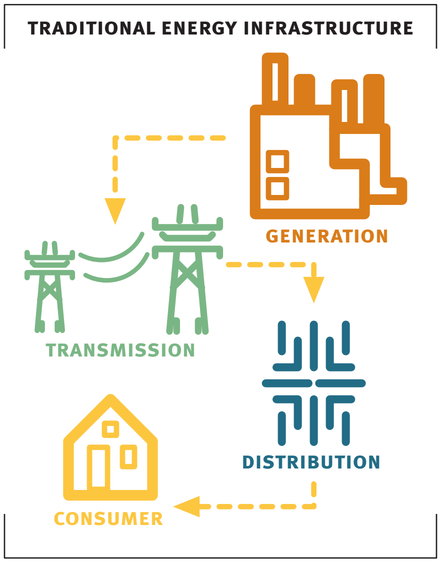
California remained at the vanguard of electricity infrastructure for the next half-century, building America's first commercial three-phase power plant and the first hydroelectric power plant in the West. By 1901, California energy utilities were setting distance records by transmitting electricity hundreds of miles from the Sierra Nevada Mountains to San Francisco. America's post-World War II boom led to heavy investments in energy infrastructure across the nation, which in turn powered the economic and cultural growth over the following generation.

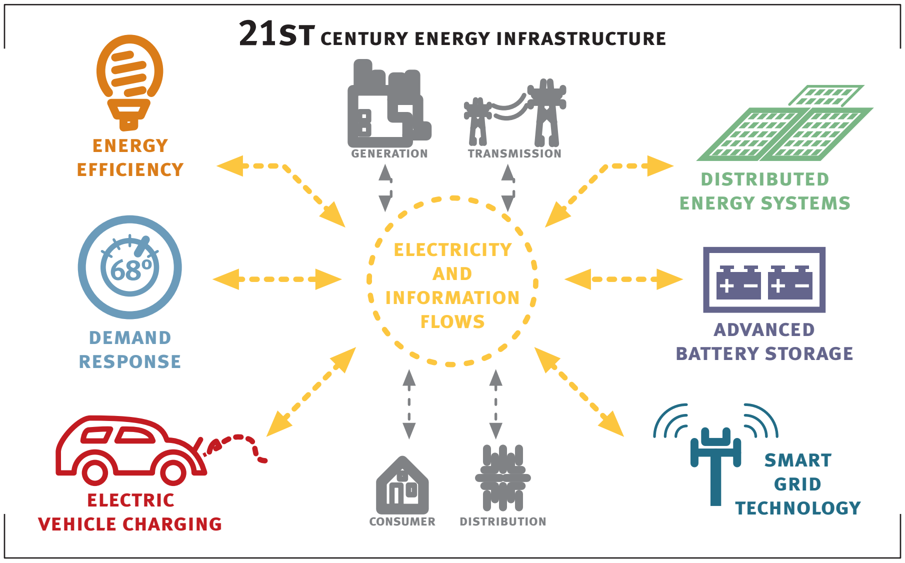
"Energy innovations have to work in a future world where we are building infrastructure and providing electricity in a carbon-free way. We need both updated hardware and a utility business model to enable that transformation by making it attractive for utilities to invest."

Daniel Kammen, UC Berkeley, Energy and Resources Group & Goldman School of Public Policy

ENERGY TIMELINE

Since 1970, landmark events and state and federal policies have had significant impacts on California's electricity use and the infrastructure needed to meet demand. The timeline spanning this section highlights transformational events and policies that have shaped the state's energy infrastructure and will continue to do so in the future.





Decades later, California's electricity infrastructure has evolved with the development of new energy sources. Originally, a network of substations and wires connected homes and businesses to large, centralized power plants. In recent years, that system has been augmented with wind farms and large solar plants, which sometimes require investments in new transmission lines to carry electricity from remote locations (e.g., the Tehachapi Renewable Transmission Project). Today, as both large ("utility scale") renewable systems are installed and smaller generation systems develop closer to where electricity is consumed ("behind the meter"), new investments are needed that can better manage an electricity grid fueled by variable sources and in which consumers are increasingly becoming producers. These investments are also critical to improving overall environmental performance, as a growing amount of behind-the-meter and utility-scale renewables will be necessary for California to reach its carbon goals beyond 2020.

21ST CENTURY INFRASTRUCTURE IN PRACTICE – CONSUMER CONTROL

In the future, "smart grid" energy infrastructure will allow individuals to customize their energy resources to meet preferences. For example, individuals looking to cut costs will be able to select for their homes only the lowest cost energy produced by the utility, while individuals seeking to minimize environmental impact will be able to select preferences for increased reliance on renewable sources.

The Infrastructure of 21st Century Energy

For California's electricity customers and the state's electric utilities, 21st century infrastructure is needed to maintain access to reliable, affordable electricity. This electricity will be developed from a cleaner power system bolstered by diverse generation sources and digital information and analytics. "21st century energy infrastructure" refers to the advanced equipment and tools needed to manage and expand renewable energy's role in the power grid, enable advanced grid management for reliability and safety, and empower energy users with real-time data. Several examples of this infrastructure include:

Smart Grid: "Smart grid" describes a next-generation electrical system that is typified by the increased use of communications and information technology in the generation, transmission, delivery, and consumption of energy. Smart grids are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. Multiple technologies can contribute to a smarter grid, though smart meters and smart inverters serve as important building blocks for improved grid communication.

1970 CLEAN AIR ACT

US POLICY

Authorized regulations to limit emissions from stationary and mobile sources

1977 TITLE 20: APPLIANCE EFFICIENCY STANDARDS

CA POLICY

1978 PUBLIC UTILITIES REGULATORY POLICIES ACT

US POLICY

Enabled non-utility generators to produce power for use by customers attached to a utility's grid

Smart meters allow data about electricity use to be transmitted back to the utility, and are considered a first step toward building a smart grid. California is the national leader in smart meter deployment with over 12 million in use throughout the state.[47] Across the United States, almost 46 million smart meters had been installed as of July 2013,[48] or about 30 percent of all US households. While smart metering is now fully deployed in California, utilities and consumers have only begun to scratch the surface of its capabilities.

Smart inverters provide a 21st century upgrade to traditional inverter technology. Inverters are placed on the grid at generation connection points to convert direct current input to usable alternating current output, ensuring that power is efficiently supplied to the grid while also providing key safety features. A smart inverter acts in the same manner, but utilizes streaming data to automate grid-balancing functions in ways that allow greater volumes of variable generation, such as from wind and solar, onto the grid.[49]

Smart grid modernization also entails building digital sensing and communication mechanisms into every part of the system. These technologies are used to precisely measure power output and usage, collect data from customers, and understand and convey data back to grid operators and consumers. Smart grid technologies offer many benefits—mostly seen in improvements in grid transparency that can translate into greater efficiency from generation to use for grid operators and reduced expenses for consumers.[50] They also can enable many of the technologies and tools described in this section to be integrated onto the grid.

Distributed Energy Systems: A typical 20th century electricity system involves a large, centralized power plant dispatching energy when needed in one direction to homes, businesses, and industrial facilities. Distributed energy systems, such as combined heat and power, solar, wind, and natural gas-fired fuel cells have altered this traditional model. Distributed generation systems can span from utility-scale plants with megawatts (MW) of capacity, to rooftop systems on homes and businesses with kilowatts of energy-generating potential. Some of these distributed assets produce electricity from renewable sources, thus they can create electricity that is variable in nature and not available to be turned on and off depending on demand.[50] Behind-the-meter generation systems are also placing unused electricity back onto the grid, creating a two-way energy flow that historic grid infrastructure was not designed to accommodate.

Electric Vehicle Charging Infrastructure: The closer integration of electric vehicles (EVs) and the electricity grid can be achieved through networked charging infrastructure that communicates information to customers and power providers. The Electric Power Research Institute, along with 16 utilities and regional transmission organizations and eight automakers, have demonstrated an advanced software platform for integrating EVs onto the smart grid. The software provides a standardized, open platform for managing EV charging that would signal customers to charge their vehicles during “off-peak” periods to help manage grid reliability. These signals would also help the utility to adjust EV charging demand up or down to accommodate the availability of renewable sources.[52]

Advanced Energy Storage: While conventional generation can be ramped up or down in response to varying electricity demands, renewable generation is driven by external factors, such as the availability of wind and sunlight. To address the periods of abundance and scarcity that come with variable renewable generation sources, the California Public Utilities Commission (CPUC) issued a mandate in 2013 for 1.3 gigawatts (GW) of storage by 2020, provided it is cost-effective. After taking comments from key stakeholders in California’s energy market, the mandate was settled at 580 MW on Southern California Edison’s and PG&E’s grids and an additional 165 MW requirement on San Diego Gas & Electric’s. With the hope of stimulating merchant and customer storage markets, the CPUC ruling binds utilities to maximum ownership of half the mandated storage capacity.[53]

California entrepreneurs[54] and venture capital investors[55] are advancing battery storage—ranging from lithium ion technologies to rechargeable flow batteries that use electrolyte to store energy—which can create cheaper, scalable storage that can capture energy to make supply from renewable sources more predictable and maximize their utilization. However, these advancements have not accelerated the pace at which energy storage is being integrated into the grid.

Microgrids: Microgrids are self-contained, localized electricity systems that can disconnect from the traditional grid to operate autonomously. Generally owned and operated by a university, corporation, or hospital, microgrids can provide islands of energy security during grid outages, and typically run on diesel, gas, or renewable power. As Hurricane Sandy and other weather events created sustained outages across the northeast in

1978 **TITLE 24: BUILDING EFFICIENCY STANDARDS**

CA POLICY

1979

EVENT

Solar One creates first large-scale thermal solar tower in Daggett, CA

1982 **CPUC UTILITY REVENUE DECOUPLING**

CA POLICY

To promote energy efficiency programs, CPUC ratemaking procedures remove the link between electricity sales and profitability

2011 and 2012, the presence of microgrids allowed the power to stay on in certain locations.[56] Microgrids also support a flexible and efficient electric grid by enabling the integration of growing deployments of renewable energy sources. Many large institutions—Wal-Mart, Apple, eBay, and the US Food and Drug Administration[57]—are generating more of their own power on-site in a drive toward greater energy independence.

The microgrid operated by the University of California, San Diego (UCSD) is one of the leading examples where local control is achieved while maintaining a connection to the traditional electric grid. The UCSD microgrid manages up to 42 MW of generating capacity from a cogeneration plant, solar installations, and a fuel cell, creating approximately 95 percent of the electricity used on campus. When a blackout hit parts of Southern California in September 2011, the microgrid was able to maintain power supply on parts of campus by isolating its power output. Microgrid projects have also been created at the University of California, Irvine and the Santa Rita Jail in Alameda County to test their interactions with a smart grid of the future.

Energy Efficiency and Demand Response: Though not a piece of physical infrastructure, energy efficiency measures are seen as an important tool in reducing overall electricity consumption and pressure on the power grid throughout the US. National estimates indicate that investments in energy efficiency measures can cut consumption by 23 percent by 2020 as compared to projected levels.[58] While energy efficiency programs have been successful at reducing consumption—standards for new buildings and appliances have saved California customers an estimated $75 billion since 1975[59]—they can be supplemented by demand response programs, which use price changes to incentivize users to modify usage for optimal grid operation. California's utility demand response policies have historically focused on reducing consumption in order to maintain reliability during emergency situations caused by generation outages or extreme weather, and they have been tailored mainly to large industrial users. Combined efficiency and demand response measures could be especially helpful in matching variable supply from renewable sources with user demand.

Drivers of Change in the Electricity Grid

Multiple forces are driving the power grid from its historic position as a centralized system toward a network of variable, distributed, and diverse energy sources and grid management tools. The factors behind this shift include the urgency to reduce greenhouse gas (GHG) emissions, increasing competitiveness of solar generation, changing consumer expectations, grid security concerns, and the growth of electric vehicles.

CLIMATE CHANGE AND GREENHOUSE GAS EMISSION POLICY

Electricity generation accounts for approximately one-third of all GHG emissions in the US through the combustion of fossil fuels, such as coal, oil, and natural gas. In California, electric power generation accounted for 20 percent of GHG emissions in 2012. This number is lower than the national average due to a cleaner fuel mix[60] and energy efficiency efforts dating back decades—including pioneering policies on building and appliance efficiency standards and regulatory incentives for utilities to promote more efficient electricity use.

California has also taken bold steps to set GHG reduction goals, such as through Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006, which requires the state to reduce its GHG emissions to 1990 levels by 2020. A subsequent executive order targets GHG levels at 80 percent below 1990 levels by 2050, though this target is not binding. Renewable portfolio

21ST CENTURY INFRASTRUCTURE IN PRACTICE – ELECTRIC AND DRIVERLESS CARS

In the future, batteries on electric cars will become extensions of the power grid—recharging from excess energy in off-peak hours, while contributing some of that energy back into the grid during hours of peak energy demand. Meanwhile, ubiquitous wireless broadband will greatly expand the popularity of driverless cars, with potentially huge congestion and environmental benefits.

1993

EVENT

PG&E created 500 kW photovoltaic system in Kerman, CA considered the first distributed power installation

DEC 1995 CPUC ELECTRIC RESTRUCTURING POLICY

CA POLICY

CPUC issues an order opening state electricity markets to competition

1996 EMERGING RENEWABLES BUYDOWN PROGRAM

CA POLICY

First state-sponsored program to offer rebates on solar installations standards (RPS) for generation and carbon trading markets have also furthered a shift toward renewable energy sources like wind, solar, and hydropower. First enacted in 2002, California's RPS is one of the nation's most aggressive standards, requiring the state's electric utilities to procure 33 percent of their retail sales from renewable resources by 2020.[61] Subsequently, energy companies across California have made large investments in wind and solar generation. In 2013, renewable energy procurement accounted for almost 22.7 percent of retail electricity sales.[62] With the state on target to reach the goals set out by AB 32 and the RPS, Governor Brown has announced further targets for the state to increase renewable energy use to 50 percent by 2030.[63]

Federal policies, most recently the Environmental Protection Agency's (EPA) proposed updates to Section 111(d) of the Clean Air Act, will also require further cuts in power plant emissions. The EPA's plan will achieve a 30 percent reduction in carbon dioxide emissions from the US electric power industry by 2030 relative to 2005 levels. The rule change is expected to have minimal impact on California utilities due to the success of AB 32. However, new regional markets may provide an opportunity to sell clean energy generated in California to meet requirements in other states.

INCREASING COMPETITIVENESS OF SOLAR GENERATION

California's successful adoption of renewable energy has been supported by a dramatic drop in the cost of solar photovoltaic (PV) systems, the product of improved technologies and global supply and demand dynamics. According to the *Renewables 2013 Global Status Report,* the price of solar PV has dropped by 80 percent in the last six years.[64] In California, the installed cost of residential solar panels has decreased from $10.43 per watt in 2008 to $5.36 per watt in 2014.[65] In many parts of the US, utility scale solar PV installations now have an attractive cost profile when compared against new gas- and diesel-fired plants.[66]

With falling prices and high demand, the state's incentive programs have also supported a boost in the construction of renewable energy systems—for rooftop residential use and at utility scale. California offered several tax credit incentives and rebate options for residential and commercial users through the California Solar Initiative. Utility programs have also rewarded the production of renewable energy through rate design, net metering, and feed-in tariffs—which are described further in a later section.

Additional innovations in financial instruments have allowed customers adopting solar energy to avoid many of the up-front costs of solar installation. Power purchase agreements, solar leases, and Property Accessed Clean Energy (PACE) are some of the options now available for spreading the cost of solar installations over their financial payback period and lowering barriers to adoption. Power purchase agreements give a third party the ownership in exchange for the installation and upkeep costs of the solar system; customers then buy back the generated electricity from the third party. In California, 17 counties offer PACE programs in which property owners are able to repay the cost of the system's installation through their property tax bills.

RISING EXPECTATIONS OF CONSUMER CHOICE AND ENGAGEMENT

Just as consumers value choices when shopping for groceries, communications services, and travel options, many consumers are seeking more choices in how they consume electricity. Forty percent of all energy consumers are now interested in services that automatically adjust home energy use based on price fluctuations, and 55 percent of consumers cite themselves as likely to purchase solar panels or sign-up for residential solar programs.[67] Growing consumer demand for better data and greater control of energy use is also a product of consumers' desire to lower their total energy use and their electricity bills. With new in-home devices and software services from Nest and Opower already entering homes, consumer perceptions about energy services are beginning to shift.

GRID SECURITY

The importance of electricity to the US economy makes energy assets a prime target for attack. An April 2013 sniper attack on an electrical substation south of San Jose, California revealed the need for better power grid security, from both physical and cyber attacks. Under a new rule adopted in 2014 by the federal agency that regulates interstate electricity transmission, power companies nationwide must identify key transmission substations that could cause service interruptions if knocked out of service. Utilities must then put defenses and security plans in place by 2016, or be subject to fines and penalties. While most substation vulnerabilities can be mitigated with fortified walls,

SEP 1996 **ASSEMBLY BILL 1890: DEREGULATION OF UTILITIES**

CA POLICY

Gives customers right to choose power supplier and creates California Independent System Operator to manage grid

JUN 2000 – JAN 2001 **CALIFORNIA ROLLING BLACKOUTS**

EVENT

SEP 2002 **SENATE BILL 1078: RENEWABLES PORTFOLIO STANDARD**

CA POLICY

Requires utilities to procure 20% renewable energy by 2017 better surveillance, and other physical protections, updates to the grid can provide an ability to convey and react to real-time information that will make the grid's operation and control more secure from generation to end-user.

GROWTH OF ELECTRIC VEHICLES

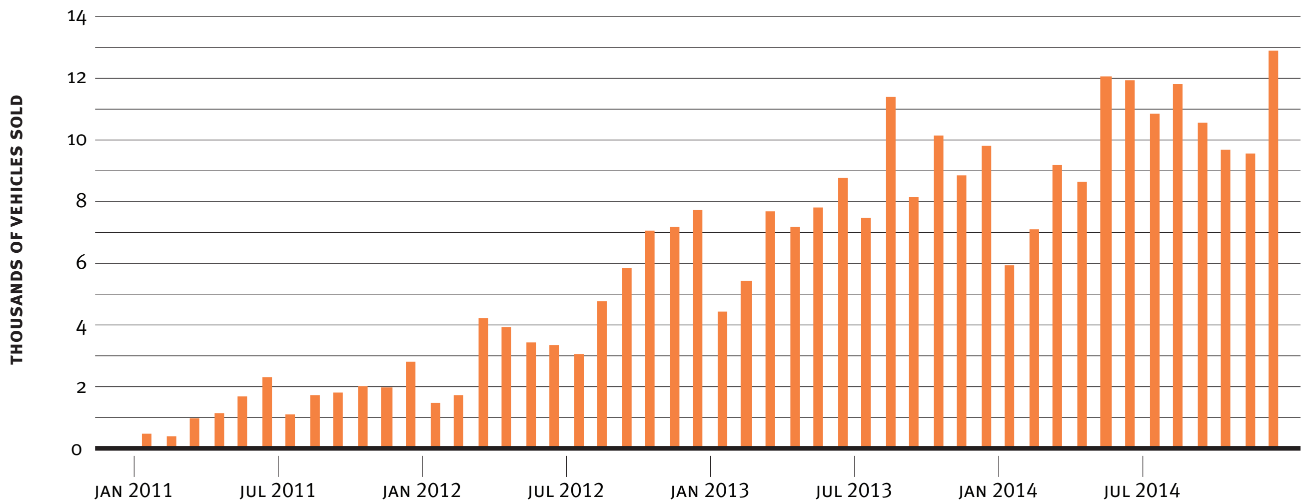
Electric vehicle (EV) uptake has been particularly strong in California, where statewide EV sales since 2011 are approaching 110,000 vehicles, or 40 percent of national sales.[68] Looking ahead, the state also has a goal of 1.5 million zero-emission vehicles on the road by 2025, and it is expected to account for 25 percent of all EVs sold in the US through 2020.[69] The California Air Resources Board has been instrumental in driving the supply of EVs by mandating that auto companies produce a minimum percentage of zero-emission vehicles for sale in California.

With the use of EVs growing, utilities are preparing for increased loads on the grid. For example, the 2014 Nissan Leaf can travel 100 miles on 34 kilowatt-hours (kWh),[70] and would add an average of 425 kWh per month to a residential household's power usage.[71] Monthly residential utility usage in California averages 573 kWh,[72] thus EVs require nearly as much energy as a residential unit and have the ability to overload transformers with only low levels of adoption. Utilities across the state are now looking at how to transform infrastructure to meet the new requirements of plug-in EVs, while also exploring the potential for EVs themselves, specifically their batteries, to be an important form of storage capacity for the grid.

Utilities face challenges with the integration of EVs that investments in 21st century infrastructure can help to overcome.[73] If the majority of EV owners charge vehicles at the same time of day (e.g., in the evening after returning from work), peak demand shifts can occur that could cause grid instability. Clusters of EVs in one neighborhood can also place significant stress on local distribution systems.

THE GROWTH OF ELECTRIC VEHICLES

EV Nationwide Monthly Sales – 2011-2014



Note: Includes all electric and hybrid vehicles
Data Source: Alternative Fuels Data Center
Analysis: Bay Area Council Economic Institute

2003 ENERGY ACTION PLAN I

CA POLICY

Accelerates 20% RPS timeline to 2010; later made into law in 2006 by SB 107

2005 ENERGY ACTION PLAN II

CA POLICY

Pushes RPS target to 33% by 2020; put into law in 2011 by SB 2

SEP 2006 ASSEMBLY BILL 32: GLOBAL WARMING SOLUTIONS ACT

CA POLICY

Requires California to reduce its GHG emissions to 1990 levels by 2020 — a reduction of approximately 15 percent below expected emissions

Benefits of 21st Century Energy Infrastructure

Advances in smart grid technology, energy storage, and the integration of growing amounts of renewable energy and electric vehicles promise to provide broad social and economic benefits to average Californians. Below, several areas of society that will be improved through advanced energy technology as made possible through 21st century energy infrastructure are detailed:

Cost Savings: As data-capturing infrastructure and analytics capabilities are further developed, utilities will gain better end-to-end visibility of their system economics. This can allow for more efficient generation asset management and can help the utility predict where power is needed and what its most economical source might be given load factors, weather conditions, and generation capabilities. For example, additional detail on consumer energy consumption can be combined with local solar rooftop generation data and local EV charging needs to help a utility provide better, more efficient services. An Accenture analysis of advanced metering infrastructure showed potential benefits of $40 to $70 per electric meter per year.[74]

The evolution of smart grid technologies will not only allow customer loads to be managed more efficiently by the utility. Demand response programs can also be expanded to all users at all times. Customers will be able to minimize costs by modifying behavior in response to these signals. During times of predicted high demand, users would know their real-time energy costs and could be incentivized to reduce usage. Conversely, in times of high availability of variable generation and low grid stress, price signals sent to smart appliances could automate electricity-intensive activities, like air conditioning, electric water heaters, and laundry.

Increased Transparency and Consumer Choice: Today, distributed generation systems are only connected to each other through their links to the power grid. Data collection, analytics, and a platform to access this information could produce new energy markets that are both real-time and distributed. In the same way that Zipcar, Lyft, and Uber have revolutionized transportation through car sharing and ride sharing, energy markets could also evolve to a point where the grid could facilitate the buying and selling of electricity from specific renewable generation systems. These sources could be around the corner from a home or hundreds of miles away, sent to specific usage points as small as a washing machine to as large as industrial facilities.

The ubiquity of mobile phones and the evolution of communications technologies are already able to give residential and commercial users of electricity information on their usage. More transparent, time-of-use price signals from software-based metering will create incentives for users to adjust their demand based on information they receive from their electricity provider. Customers who choose to be heavily involved in their energy choices could utilize in-home devices to send and receive information, while other users could automate their systems to make optimal choices that match pricing, environmental, and time-of-use preferences.

Resiliency to Electricity Disruptions: Between 2003 and 2012, the US suffered an estimated 679 weather-related outages, leading to billions of dollars of lost productivity and costs. Outages are likely to be even more costly in the future as more facets of the economy are digitized. Twenty-first century energy infrastructure will reduce the incidence and duration of power outages. For example, in the aftermath of Hurricane Sandy in 2012, Baltimore Gas and Electric utilized smart meter data to dispatch service crews more effectively by identifying areas where power had already been restored.[75] Following the August 2014 earthquake in Napa, California, PG&E leveraged its smart meters in a similar fashion. The company was able to estimate the number of its customers without power within 15 minutes and restore nearly all power within 24 hours using signals from smart meters.[76]

2010

EVENT

California is first state to install more than 1 GW of customer-generated solar energy

SEP 2010 — **STATE WATER RESOURCES CONTROL BOARD ONCE-THROUGH COOLING WATER POLICY**

CA POLICY

Calls for 19 existing power plants to reduce the harmful effects associated with cooling water intake structures

SEP 2010 — **ASSEMBLY BILL 2514: ENERGY STORAGE**

CA POLICY

Requires CPUC to create a cost-effective energy storage target for utilities

Where California Stands Today

California is a global leader in the shift toward a low-carbon future. The state's energy efficiency standards going back to the 1970s, its targets for renewable energy, and forward-thinking climate change policy have boosted energy productivity. Given its position on the cutting edge of many of these trends, California will face new challenges and opportunities in its electric grid before other states.

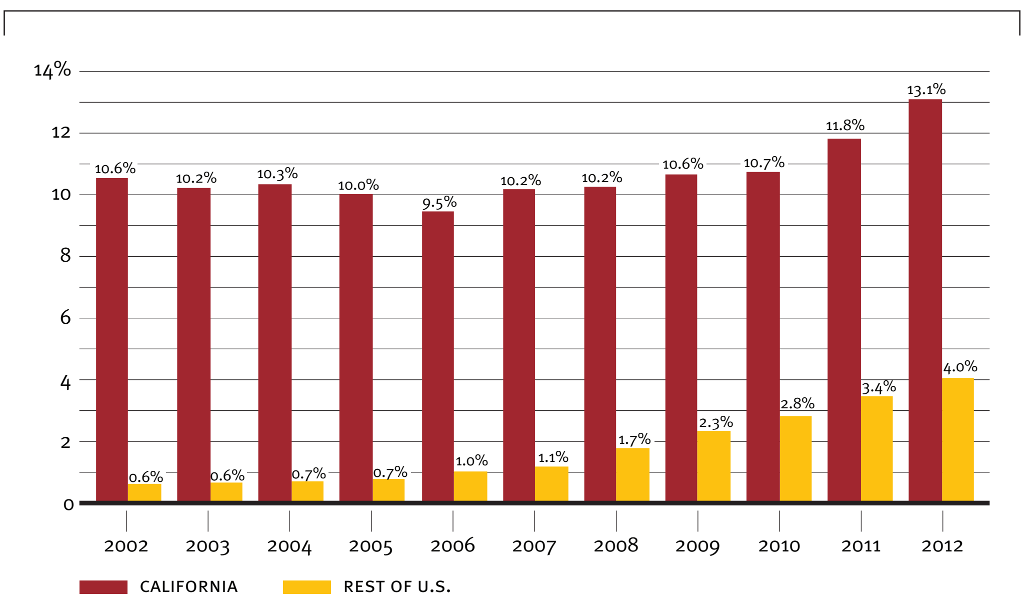
RENEWABLE GENERATION

As of 2012, renewable energy—excluding large hydropower plants as defined in California's portfolio standard—accounted for 13 percent of total electricity generation within the state. For the rest of the US, only 4 percent of electricity is generated from renewables.

While only Texas generates more wind energy than California's 5,829 MW—a level that has more than doubled since 2009[77]—solar generation has been the main driver of the state's renewable generation success. California currently has 8,544 MW of total solar energy capacity, more than any other state.[78]

In California, growth of utility-scale solar generation has been rapid. In May 2014, average peak hourly generation from utility-scale solar was 4,086 MW—representing 6 percent of the total California electricity load—a 150 percent increase over May 2013.[79] Additionally, homeowners and businesses in California are also adding to the electricity network, as they operate over 240,000 distributed, on-site solar systems that can interact with the grid.[80] As of January 2015, 2,332 MW of solar capacity had been installed by residents and businesses in California, more than two times that of the next most-active states, New Jersey and Arizona.[81]

PERCENT OF TOTAL ELECTRICITY GENERATION FROM RENEWABLE SOURCES
California & United States, 2002 - 2012



Data Source: Energy Information Administration, U.S. Department of Energy
Analysis: Bay Area Council Economic Institute

OCT 2013 **ASSEMBLY BILL 327: RESIDENTIAL RATE REFORM**

CA POLICY

Authorizes the CPUC to reform the net metering program and explore time-of-use rates and fixed capacity charges

JUN 2014 **EPA RULE 111(D)**

US POLICY

Each state must develop standards of emissions performance for existing stationary electricity sources

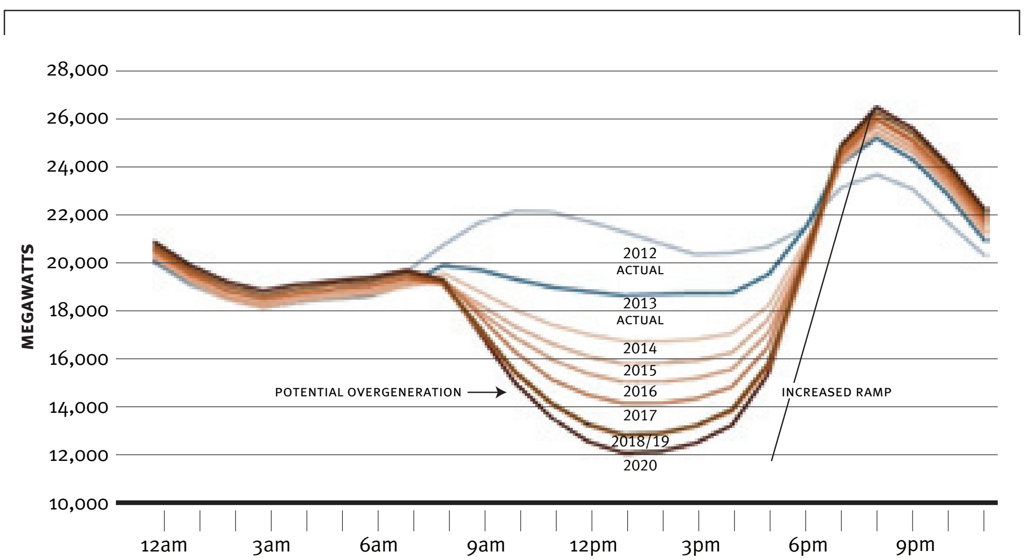
IMPACT ON GRID MANAGEMENT

Although utility scale and rooftop solar generation contribute significant renewable energy to the grid, these systems are not dispatchable—meaning power output cannot be adjusted to meet demand. Wind and solar system generation also varies by time of day and season, thus making it less than ideal to handle minimum power requirements around the clock. As a result, an electric grid taking on increasing amounts of variable renewable energy presents new challenges for managing peak loads and overall reliability.

Those challenges are illustrated by projections of net energy demand produced by the California Independent System Operator (see chart). The chart shows how the profile of net energy demanded will shift annually to 2020 as more renewables are added to the grid, assuming grid operations are not modified. It highlights the significant growth of renewable generation that will be able to address mid-day energy needs, driving net demand from non-renewable sources lower. As a greater proportion of daytime electricity needs will be met by solar systems, a sharp jump in net demand will be created in the evening when these sources are not available. If not addressed, two challenges emerge for grid operators who must maintain reliability, but also meet environmental statutes. First, the risk of over-generation is present at mid-day, creating mismatched supply and demand. Second, steep ramp-ups of demand in the evening are not easily addressed by renewable systems and require dispatch of additional standby generation assets that can be turned on quickly—generally natural gas-fired generators known as peaker plants—which could compromise the state's renewable energy goals. These challenges underscore the importance of 21st century infrastructure to help grid operations evolve so that the power system can accommodate greater amounts of variable generation.

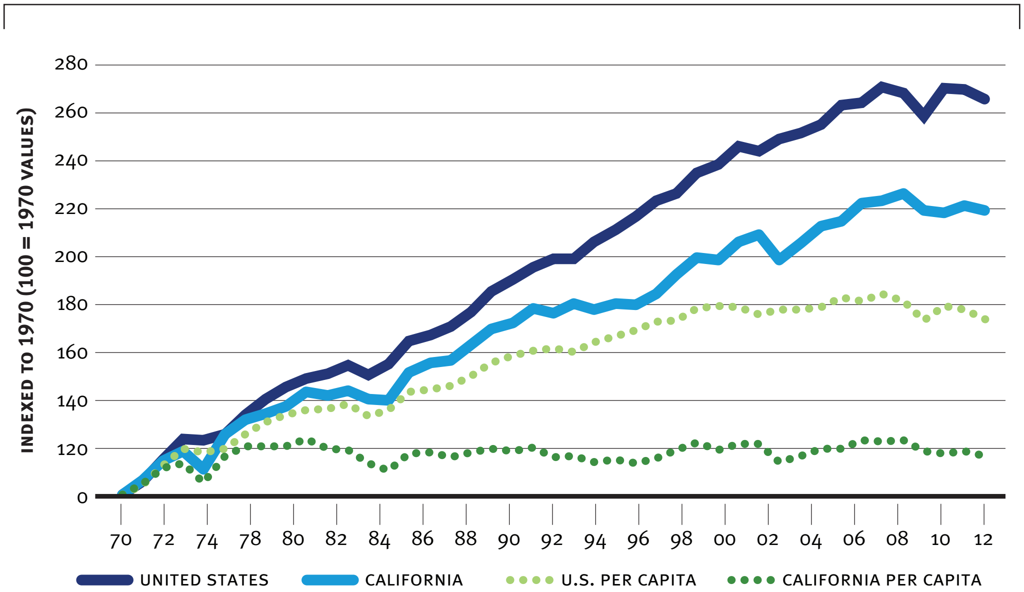
To address these issues and flatten the load curve, there are many possible options. At the transmission level, flexibility can be gained through more robust regional energy marketplaces and the use of bulk energy storage. At the customer level, energy demands can be shifted to mid-day when power will be abundant and less expensive through demand response programs that incentivize use during periods of low grid stress.

NET LOAD PROJECTIONS FOR CALIFORNIA



Data Source: California Independent System Operator

TOTAL ELECTRICITY CONSUMPTION RELATIVE TO 1970
California & United States



Data Source: Energy Information Administration, U.S. Department of Energy; U.S. Census Bureau; California Department of Finance
Analysis: Bay Area Council Economic Institute

The steep ramp in evening demand suggests that targeted energy efficiency programs will have an increasing role to play in managing the grid. In California, a wide array of efficiency programs related to industrial processes, home and building construction,[82] lighting and appliances, community infrastructure, and heating have already been successful in driving lower general energy needs across residential, commercial, and industrial end-users. In 2010, per capita annual electricity usage in California was 55 percent of the national average.[83] Between 2010 and 2012, the state's investor-owned utilities reported further electricity use reductions of 6,548 gigawatt hours due to residential and commercial energy efficiency programs, equivalent to the electricity use of 725,000 US households for one year. Governor Brown has put forth a target of doubling the energy efficiency of existing buildings that could widen the electricity usage gap between California and the rest of the nation.

EXAMPLES OF INTELLIGENT GRID MANAGEMENT

In 2013, California's three largest investor-owned utilities—Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric—invested nearly $10 billion in the state's electricity system.[84] Increasingly, these investments are being made in advanced metering technologies that allow information to flow between customer and utility, home area networks that create opportunities for more efficient in-home energy use, and energy storage that supplements renewable energy systems. Listed next are cases highlighting how emerging smart grid technologies have helped or will help California utility providers to optimize their grid management procedures through grid intelligence and innovations at the grid edge.

SOUTHERN CALIFORNIA EDISON: SMART GRID DEMONSTRATION PROJECT

Southern California Edison (SCE) is demonstrating a comprehensive smart grid network in Irvine, designed to better understand, quantify, and validate the feasibility of integrating new demand management technologies from utility to end-user. This demonstration seeks to evaluate the latest generation of utility distribution automation technologies using smart inverters—which utilize two-way information flows to provide grid operators access to solar system performance data and enable the remote control of these systems, turning them on or off to control voltage levels. The project will test in-home control devices as well, such as smart appliances connected through home area networks, and will assess the impact of device-specific demand response and the load management capabilities of energy storage devices and EVs.

21ST CENTURY INFRASTRUCTURE IN PRACTICE – SMART APPLIANCES

In the future, appliances will have direct communication linkages with the electric grid, enabling them to automate electricity consumption during times of low costs and low grid stress. For example, instead of turning off air conditioners during the day when not at home, consumers will be able to program systems to automatically cool homes to optimal temperatures during daytime hours—when electricity from solar sources will be abundant. They will then return to a comfortable home in the evening without having to utilize air conditioning at a time when other electricity uses are high.

SAN DIEGO GAS & ELECTRIC: VEHICLE GRID INTEGRATION PILOT

San Diego Gas & Electric (SDG&E) has filed a proposal with the CPUC that would allow it to install and own EV charging stations, charge variable rates to EV customers, and collect data on the market response to time-of-use pricing for vehicle charging. The $103 million vehicle-grid integration pilot calls for authorization to develop 5,500 charging stations across 550 facilities, targeting multi-family housing and workplaces where charging can occur in long durations. The proposal also includes a dynamic rate component based on electricity costs and capacity usage profiled across 1,100 SDG&E circuits. The utility will develop a mobile application to deliver hourly prices for the following day to customers and to allow users to select their charging preferences based on pricing. As an initial step in moving SDG&E's application forward,[85] the CPUC issued a decision in December 2014 that will ease the 2011 ban on utility ownership of EV service equipment by removing requirements that the utility prove a market failure or underserved market.[86] The CPUC decision paves the way for utilities to play an expanded role in EV infrastructure development and the integration of charging locations with the grid.

PACIFIC GAS & ELECTRIC: SELF-HEALING CIRCUITS

Pacific Gas & Electric (PG&E) has installed intelligent switch technology on almost 20 percent of its electrical distribution circuits throughout Northern and Central California. In the event of a power disruption, these circuits can reduce the duration of an outage from hours to minutes by re-routing power flows. Since the inception of the program, this self-healing technology has avoided more than 40 million customer outage minutes, and in 2013, PG&E customers experienced the fewest minutes without electricity in company history.

SACRAMENTO MUNICIPAL UTILITY DISTRICT: LINKING COMMUNICATIONS AND ENERGY

The Sacramento Municipal Utility District (SMUD) has invested $350 million on communications technology and new software in order to upgrade its smart grid capabilities. The investment involves the development of a wireless mesh network to handle the much larger volumes of data generated by the 600,000 smart meters SMUD has installed. A key component to the system is a Situational Awareness and Visual Intelligence Program that anticipates and responds to demand with improved efficiency. This program helps organize and analyze real-time grid data from sensors, meters, and control platforms.

21st Century Energy Infrastructure Policy Considerations

Grid modernization policies must continue to advance as the state grapples with issues related to utility procurement of variable renewable energy, customer demand for clean distributed generation, and new technologies interacting with the grid. Each of these areas is closely connected to the need to support further carbon reductions, which will be a driving force in the continued evolution of the electric grid.

Upgrading California's energy system with 21st century infrastructure will create policy considerations on multiple fronts. First, as commercial, residential, and public sector owners of solar systems reduce their demand for centrally-generated power and pay operators less, new pricing mechanisms will be needed to cover the costs of network maintenance. Additionally, this shift toward a more distributed model with greater customer participation suggests that the traditional utility business model needs to evolve.

UTILITY RATE DESIGN

The combination of rooftop solar, energy efficiency, and electricity storage will make some customers less dependent on power provided over the electric grid. Under this scenario, and based on current rate design, utilities' capacity costs—the cost to operate and maintain the wires and generating plants apart from the cost of the electricity itself, estimated at approximately 45 percent of average energy bills[87]—will be spread over a smaller pool of electricity users that are drawing from the grid. This shift could result in higher rates for those consumers who do not install behind-the-meter generation.

New legislation that enables the reform of residential electricity rates in California, Assembly Bill 327, was approved in October 2013, and the CPUC launched its associated rulemaking procedure in August 2014.[88] This bill addresses infrastructure investment planning at the distribution level and corresponding rate design issues. AB 327 gives the CPUC authority to uncap participation in the net metering program and also requires the CPUC to develop an alternative tariff structure for future owners of distributed generation. Previously, the net metering program was capped at 5 percent of a utility's customer aggregate peak demand. As clean self-generation is an important part of the state's carbon emission reduction goals, AB 327 is intended to support the sustainable expansion of customer generation while avoiding the potential for higher electricity prices caused by its growth.

Other highlights of AB 327 include adjustments to rate structures that will allow utility companies to better balance the costs that behind-the-meter generation place on the grid:

Authorizes the CPUC to allow a monthly fixed charge of up to $10 on all residential ratepayers, thereby lowering the otherwise applicable charges based on usage.

Removes a limit on rates for ratepayers who consume low amounts of electricity.

Allows for a separate rate structure for customers that generate their own electricity.

Authorizes the CPUC to allow voluntary time-of-use (TOU) rates, but prohibits mandatory TOU rates prior to 2018.

In addition to restructuring net metering, AB 327 directs the CPUC to lead a rulemaking process on distribution resource planning in anticipation of significant distributed generation and EV penetration. This aspect of the legislation will supplement the ratemaking portion of the bill by requiring utilities to develop cost-effective strategies to maximize the locational benefits and minimize the costs of managing a more distributed electricity grid. The distribution resource planning process, to be filed by investor-owned utilities at the CPUC by July 2015, is intended to help describe how utilities further enable the smart grid technologies outlined in previous sections of the report. As ratemaking evolves with utility market structure, rate designs should be developed in a manner that minimizes cost shifts to non-self-generating customers, while also providing proper compensation to utilities and electricity generators for achieving public policy goals related to clean energy and grid reliability.

CALIFORNIA RENEWABLE ENERGY RATE PROGRAMS

California has adopted numerous electricity rate policies that work to further the state's policy goals in energy efficiency or renewable energy.

Utility revenue decoupling: Disconnects the utility's earnings from the amount of power sold, effectively allowing the utility to recover its investments in critical infrastructure while encouraging customers to participate in energy efficiency and conservation programs that reduce overall consumption (and sales).

Net metering: Compensates homeowners, businesses, and schools for the energy they feed back into the grid. Electricity meters connected to these facilities are bi-directional and can measure current flowing in two directions. When the system's production exceeds customer demand, the excess energy generation automatically goes onto the utility grid, running the meter backwards to credit the customer account at the full retail value of that electricity. In California, the generating system's peak capacity output must be 1,000 kW or less (most residential systems range between two and four kilowatts) to qualify for net metering.

Feed-in tariff: Offers long-term contracts from utilities to renewable energy producers that are typically 15 to 20 years in duration with pre-defined prices. Only seven states across the US had some form of feed-in-tariff as of 2013: California, Florida, Vermont, Oregon, Maine, Rhode Island, and Hawaii. Renewable generation systems up to 3 MW in size are eligible for this program in California.

SHIFTING MARKET AND REGULATORY STRUCTURE FOR THE ELECTRICITY INDUSTRY

Utilities and regulators must navigate both the operational pitfalls and the financial problems that will arise from an evolving grid. Even as the field becomes more diverse, utilities will continue to play a critical role in the reliable and efficient distribution of electricity. Control of infrastructure connecting the supply and demand for electricity and management of signals from each will continue to be key functions for utilities. Additionally, utility resource planning will be a critical lever for executing carbon reductions, either through traditional electricity supply or via programs that enable cleaner usage, such as energy efficiency and EV charging.

The transformation of the utility industry is already taking place in California, as the state is leading the nation in a number of categories, including the expansion of renewable energy in its power mix, capturing use data from meters, and offering financial incentives for the adoption of cleaner, more energy efficient practices. Many of the policies that led to California's leadership in these areas are now being proposed in regulatory initiatives in Maryland and New York. Beyond this overlap, certain more innovative aspects of these reform proposals could be instructive to California as described below.

MARYLAND: UTILITY 2.0

The Utility 2.0 initiative offers an innovative rate model that could be applicable in California, as Utility 2.0 attempts to align utility compensation with customers' changing needs. The proposed rate model adopts a customer-driven, performance-based utility compensation structure governed by five parameters: cost, reliability, customer service, smart grid adoption, and alternative energy support. The relative weighting of these factors would be based on customers' rankings of their importance, and the utility's rate of return would vary by up to one percent based on meeting specified targets connected to these parameters. This system provides utilities with a better understanding of their customers' priorities by geography and a financial incentive to serve those priorities.

NEW YORK: REFORMING THE ENERGY VISION

One of the key components of the New York State Public Service Commission plan includes the concept of utilities becoming Distributed System Platform Providers (DSPP). While incorporating distributed generation resources, the DSPP would modernize its distribution system to create a flexible platform for new products and services. This would enable the creation of new markets and operational systems, along with facilitating monetization of behind-the-meter products and services. The DSPP could directly engage with distributed energy sources in the form of ownership, financing, operation, or contracting. Much like the role that Independent System Operators (ISOs) play in managing bulk power transmission, the DSPP can also play a similar role at the distribution level in creating system-wide efficiencies.

Recommendations

Over the coming years, the implementation of a more integrated electricity grid will hinge upon three key factors: adjusting pricing and regulatory structures for utility providers; developing a variety of incentives for investment in advanced grid technologies; and providing platforms that allow energy data and analytics to play a more prominent role in grid control and customer choice. Supporting these changes will also require new grid security measures, public literacy around energy efficiency and use, regional partnerships, and innovative technology that can extend the reach of legacy infrastructure.

These steps will need to take place within the backdrop of the state's long-term goals for clean energy and greenhouse gas emission reductions. State leaders and the CPUC will have an opportunity to clearly define their goals in the near future, as EPA Section 111(d) requires states to submit implementation plans by June 2016. Within this timeframe, the state can also take the broader step of codifying its energy and greenhouse gas reduction goals beyond 2020, which will allow for longer-term planning and promote greater investment across the grid. With a smarter, more flexible grid providing the avenue toward a cleaner energy future, the following policy levers should be explored.

FUTURE REGULATORY STRUCTURE: RATEMAKING CONNECTED TO ACHIEVEMENT OF POLICY GOALS

Rate structures that were originally built around one-way power transmission are increasingly inadequate to maintain California's diversifying energy system. To optimize the integration of distributed energy resources—including those that store power and shift its consumption—the CPUC's proceeding connected to Assembly Bill 327 should result in a residential rate structure that provides compensation for the achievement of grid benefits while spreading costs across all who benefit from and utilize a more interconnected, distributed electric grid.

While the required rate structure to take into account rooftop solar's contribution and associated cost to the grid continues to be debated, rates can be disaggregated on customer bills to provide transparency on the costs of generation and capacity availability. This approach can allow for improved matching of the fixed versus variable and time-variant nature of these costs. Improved understanding of costs will enable the creation of price signals and rate mechanisms that do not leave the customer or the utility with future unanticipated costs and can compensate them for positive grid contributions.

Finally, for 21st century infrastructure and tools to be leveraged to their fullest extent, research and development (R&D) on emerging grid technologies (e.g., smart inverters) should be considered core to the utility business model. This strategy is utilized in the United Kingdom, and allows utility regulators to provide more flexible cost recovery mechanisms for R&D activities to accelerate grid innovation.

LEVERAGE STORAGE TECHNOLOGIES AND ELECTRIC VEHICLE CHARGING AS GRID SUPPORTERS

The state can take steps to further encourage market acceptance of energy storage technologies that have the potential to alleviate the grid management issues presented by the successful penetration of variable generation resources. While the CPUC's new storage mandate is an important first step toward greater adoption of storage technologies, targeted rebates that lower the initial cost and clear parameters for long-term contracting or ownership of storage would accelerate development—much in the same way that financial incentives moved California into a clear leadership position in solar markets.

The proliferation and potential for EVs in California also offers an ideal test bed to improve grid performance. Already, initiatives are paving the way for these to occur, including a state commitment to an aggressive zero-emission vehicle program and the loosening of restrictions on utility ownership of charging infrastructure. Among the goals and regulations being promoted are:

> Interagency cooperation to build fueling structures and stations for plug-in EVs and fleets in residential and public areas;
>
> Streamlining demand response for EV charging to incorporate electricity rates based on time-of-use; and
>
> Supporting public outreach, education, and financial and non-monetary incentives to expand the market for EVs.

Even as the state promotes markets for EVs, utility companies need long-term regulatory clarity to become more involved in the coordinated build-out of EV infrastructure, including guidelines for billing, cost recovery, and administration. To begin this process, all California investor-owned utilities should submit vehicle-grid integration plans to the CPUC targeting time-of-use rates for EV charging with consideration for how EV energy storage could be used as an ancillary asset for local grid stability. As the power and transportation industries converge around the goal of clean energy, regulatory agencies also need to work with automotive companies to build standards for vehicle-to-grid applications and platforms so that EVs can more seamlessly serve to support the grid rather than put more pressure on it.

FUTURE MARKET STRUCTURE: UTILITIES AS DISTRIBUTION SYSTEM OPERATORS

Greater control, management, and security will be needed as energy production continues to shift away from a centralized model. Similar to the role that the California Independent System Operator plays in managing the bulk transmission system, a Distribution System Operator (DSO) can coordinate behind-the-meter energy generation and storage assets and better project and manage the amount of power that customers will place back onto the grid. Given the utilities' many current customer touch points and their core competency in distribution, their role could be expanded to fill the DSO capacity on a regional basis. Providing the utility with an ability to step outside of its traditional regulated model could allow companies that were once thought to be only providers of electrons to offer a more extensive suite of energy-related services.

DSOs can develop and manage platforms for collecting and analyzing information on a large scale, and act as a clearinghouse for consumer-to-consumer energy marketplaces where excess behind-the-meter generation capacity is sold directly to users. The DSO structure can also prove valuable for the management of EV charging infrastructure and the oversight of information captured from such systems. Finally, DSOs can establish security strategies for the regional grid, such that intrusions at any layer can be isolated and separated out from other resources. The increasing number of distributed resources makes increasing visibility and rapid, accurate stability analysis more critical than ever.

ENABLE ENERGY DATA TO BE USED IN NEW WAYS

It is estimated that the data analytics market for utilities worldwide could reach almost $4 billion by 2020, up from less than $1 billion in 2012.[89] In California, policies must develop that encourage utilities to aggregate data and make it available to third-party developers when customer authorizations are secured, clearly defining the ownership of that data and how it would be used.

OPTIMIZING THE ELECTRIC GRID FROM GENERATION TO END USE

The continuing adoption of in-home and mobile devices, the growing number of sensors across the electric delivery system, and greater customer interaction with the grid will contribute to the need for advanced energy analytics capabilities. Using the tremendous amount of system data that is created, processed, and analyzed, utilities must develop methods that cut across generation, transmission, and distribution silos to increase their analytical capabilities. Greater transparency around electricity demand and infrastructure use will allow utilities to optimally plan for and deploy future infrastructure, taking into account the most cost-effective locations and technologies.

ENCOURAGING DEVELOPMENT OF NEW MARKET OPPORTUNITIES

Standardization is essential in how data gets shared and displayed to end-users. Open data platforms may encourage more customers to opt-in and share their data. Utilities also have an opportunity to encourage entrepreneurs and third parties to create customer portals that offer a range of energy-related services, helping to bring about a convergence between smart grid infrastructure and the Internet of Things. New communications platforms can notify customers of the amount of solar energy they are producing and consuming; allow the utility to send price signals to EV owners to enable cost-effective charging; tell smart appliances when to run to have the least grid impact; and can inform planners when to replace local substation equipment.

CATERING TO A BROAD ARRAY OF CUSTOMERS

California can sponsor initiatives that promote energy literacy, customer education, and skills training across the state to ensure customer engagement across a broad spectrum of electricity users. Currently, some customers are more willing to participate in energy programs than others. The gradient of customers can range from those who want to minimize their utility expenses to highly technical consumers who contribute to local energy generation and want to maximize efficiency. By educating communities and promoting pilots, customers can more actively participate in the future grid, from managing their electricity usage through mobile devices, to automating appliance use during optimal times, to recharging EVs during low-cost windows.

METHODOLOGY

COMMUNICATIONS INFRASTRUCTURE: EXPANDING QUALITY AND CAPACITY

Download Speed Comparison Table: Table provided by Fastmetrics

National Broadband Speed Rankings: Table provided by Akamai

ENERGY INFRASTRUCTURE: BALANCING ENVIRONMENTAL NEEDS AND CONSUMER DEMANDS

The Growth of Electric Vehicles: Data covering electric vehicle sales was provided by the Alternative Fuels Data Center. Plug-in electric vehicles include plug-in hybrid electric vehicles, but do not include neighborhood electric vehicles, low speed electric vehicles, or two-wheeled electric vehicles. Only full-sized vehicles sold in the US and capable of 60 miles per hour are listed.

Percent of Total Electricity Generation from Renewable Sources: Data covering total electricity generation by source and location is provided by the US Energy Information Administration. Renewable sources do not include large-scale hydroelectric and pumped hydroelectric generation but do include small hydro (up to 10 megawatt capacity) plants. Also included are all forms of solar, biomass, wind, waste, and geothermal electricity sources.

Net Load Projections for California: Image provided by California ISO

Total Electricity Consumption Relative to 1970: Data covering total electricity consumption by state is provided by the US Energy Information Administration. Population data for the United States was taken from the US Census Bureau American Community Survey. Population data for California was provided by the California Department of Finance.

APPENDIX: EXPERT CONTRIBUTIONS

To inform the research process, the Bay Area Council Economic Institute held a series of four expert roundtables where thought leaders in energy and communications from business, academia, and the public sector discussed the future of infrastructure in California. The four roundtables were focused on:

Communications Technology – April 2, 2014

Communications Policy – May 14, 2014

Energy Technology – May 30, 2014

Energy Policy – June 27, 2014

Participants were asked to describe their vision for the future of California's infrastructure. Barriers to that future were then debated and policy opportunities were discussed. To supplement the information gained, additional interviews with other industry experts were completed as detailed below.

COMMUNICATIONS TECHNOLOGY ROUNDTABLE – APRIL 2, 2014

Farshid Arman, *Siemens TTB;* Director of Energy Technologies

Jamais Cascio, *Open the Future,* Founder

Tom DeMaria, *GE Software;* Director of Technology

Bob Iannucci, *Carnegie Mellon University;* Director, Silicon Valley Campus

Tony Lutz, *Qualcomm;* Director of Business Development

Michael McNerney, *Delta Risk, LLC;* Senior Consultant

Shannon Spanhake, *City & County of San Francisco;* Deputy Innovation Officer

Steven Tiell, *Accenture;* Technology Vision

COMMUNICATIONS POLICY ROUNDTABLE – MAY 14, 2014

Deborah V. Acosta, *City of San Leandro;* Chief Innovation Officer

Steve Blum, *Tellus Venture Associates;* President

Rachelle Chong, *California Public Utilities Commission & FCC;* Former Commissioner

Ryan Dulin, *California Public Utilities Commission Communications Division;* Director

Cathy Emerson, *Upstate California Connect Consortia;* Program Manager

Michael Fernandez, *Quant6;* Founder

Olaf Groth, Emergent Frontiers Group – *Founder & Managing Director;* Global Professor of Strategy, Innovation, and Economics – Hult International Business School

Michael Katz, *UC Berkeley;* Chair, Institute for Business Innovation

Michael Kleeman, *UC San Diego;* Senior Fellow

Blair Levin, *Communications & Society Fellow;* Aspen Institute

Michael McNerney, *Delta Risk, LLC;* Senior Consultant

Chris Riley, *Mozilla;* Senior Policy Engineer

Catherine Sandoval, *California Public Utilities Commission;* Commissioner

Derek Slater, *Google;* Public Policy Manager

Jonathan Spalter, *Mobile Future;* Chairman

ENERGY TECHNOLOGY ROUNDTABLE – MAY 30, 2014

Farshid Arman, *Siemens TTB;* Director of Energy Technologies

Jamais Cascio, *Open the Future;* Founder

Max Henrion, *Lumina Decision Systems;* CEO

Barbara Heydorn, *Energy Center;* Director

Walter Johnson, *EPRI;* Technical Executive

Daniel Kammen, *UC Berkeley;* Energy and Resources Group & Goldman School of Public Policy

Michael Kleeman, *UC San Diego;* Senior Fellow

Chris Knudsen, *Silver Springs Networks;* Vice President

Paul Lau, *Sacramento Municipal Utility District;* Assistant General Manager

Matt Lecar, *GE Energy Consulting;* Principal Consultant

Wade Malcolm, *Accenture;* Managing Director of Grid Operations

Walter McGuire, *McGuire & Co.;* President

Ryan Wartena, *GELI;* Founder/Chief Strategist

ENERGY POLICY ROUNDTABLE – JUNE 27, 2014

Joshua Bar-Lev, *CalCEF;* Vice Chairman

John Geesman, *California Energy Commission;* Former Commissioner

Olaf Groth, Emergent Frontiers Group – *Founder & Managing Director;* Global Professor of Strategy, Innovation, and Economics – Hult International Business School

Barbara Hale, *SFPUC Power Enterprise;* Assistant General Manager

Aaron Johnson, *PG&E;* Renewable Energy Policy

Walter Johnson, *EPRI;* Technical Executive

Michael Kleeman, *UC San Diego;* Senior Fellow

Walter McGuire, *McGuire & Co.;* President

Carla Peterman, *California Public Utilities Commission;* Commissioner

Sanjay Ranchod, *SolarCity;* Director of Government Affairs

Jim Sweeney, *Stanford University;* Director, Precourt Institute

Michael Wheeler, *Recurrent Energy;* Director of Policy Initiatives

EXPERT INTERVIEWEES

Scott Adams, *Comcast;* Director of External Affairs

Jonathan Aronson, *University of Southern California;* Professor of Communications

CJ Boguszewski, *Silver Springs Networks;* Smart City Solutions

Dan Conway, *AT&T;* Regional Vice President, California Public Affairs

Simon Giles, *Accenture;* Intelligent Cities Strategy

Lennies Gutierrez, *Comcast;* Director of Government Affairs

Sven Hackmann, *Siemens;* Cities Initiative

Gregory Haddow, *San Diego Gas & Electric;* Clean Transportation Manager

David Hague, *Gehrlicher Solar;* Senior Director of Technology Partnerships

Jeffrey Hamel, *EPRI;* Executive Director

Dan Hahn, *Accenture;* Managing Director

Becky Harrison, *Gridwise Alliance;* CEO

Brandon Hernandez, *PG&E;* Director of Corporate Affairs

Aaron Johnson, *PG&E;* Renewable Energy Policy

Rhonda Johnson, *AT&T;* Vice President, Regulatory Affairs

Michael Jung, *Silver Springs Networks;* Policy Director

Katie McCormack, *Energy Foundation;* Program Director

Cesar R. Molina, *South Asian Heart Center;* Medical Director

Shane Portfolio, *Comcast;* Vice President Engineering

Dennis Rodriguez, *Siemens;* Chief City Executive

David Rubin, *PG&E;* Director Renewable Energy

Rob Schilling, *Space-Time Insight;* CEO

Venkat Srinivasan, *Lawrence Berkeley National Laboratory;* Staff Scientist

Mary Stutts, *Comcast;* Vice President External Affairs

Michael Wheeler, *Recurrent Energy;* Senior Director of Policy Initiatives

Sunne Wright McPeak, *California Emerging Technology Fund;* President and CEO

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