Deploying Smart Grid in Colorado

Recommendations and Options

As directed by Colorado Senate Bill 10-180

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Colorado Smart Grid Task Force as directed by Colorado Senate Bill 10-180

Prepared for the Governor of Colorado,
the General Assembly, and
the Colorado Public Utilities Commission

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Acronyms

AMI	Advanced Metering Infrastructure
CDLE	Colorado Department of Labor and Employment
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and the Environment
CHP	Combined Heat and Power
Coop	Electric Cooperative
CU	University of Colorado
CSM	Colorado School of Mines
CSU	Colorado State University
DR	Demand Response
DER	Distributed Energy Resources
DG	Distributed Generation
DOE	U.S. Department of Energy
DSM	Demand-Side Management
EV	Electric Vehicle
GEO	Colorado Governor's Energy Office
IOU	Investor-Owned Utility
Muni	Municipal Utility
NERC	North American Electric Reliability Corporation
NIST	National Institute for Standards and Technology
NREL	National Renewable Energy Laboratory
PHEV	Plug-in Hybrid Electric Vehicles
PUC	Colorado Public Utilities Commission
REA	Rural Electric Association
RES	Renewable Energy Standard
SCADA	Supervisory Control and Data Acquisition
SGIP	NIST Smart Grid Interoperability Panel
TOU	Time of Use
V2G	Vehicle to Grid

Executive Summary

The Colorado Smart Grid Task Force was created by Colorado Senate Bill 10-180 (SB 10-180) to offer recommendations on the "feasibility, cost, and timing of transitioning to a secure, resilient, and technologically advanced electric grid," also referred to in this report as the "Smart Grid." Over the course of deliberations, the Task Force developed consensus recommendations for the Governor, the General Assembly, and the Colorado Public Utilities Commission (PUC). The full body of consensus recommendations conveyed in this executive summary covers the topics delineated in SB 10-180. These are: (1) Challenges and Opportunities in Colorado, (2) Workforce and Economic Development, (3) Consumer Issues and Data Management, (4) Distributed Energy Resources and Grid Management (5) Technical Specifications, and (6) Grid Operations.

Challenges and Opportunities in Colorado (Chapter Two)

Colorado is positioned to play a premier role in the global development of Smart Grid. Leveraging its significant workforce and intellectual advantages, proactively exploring market opportunities, and revising market structures to provide incentives for Smart Grid could help Colorado became an intellectual and economic leader.

Recommendations

- ✓ Leverage Colorado's unique workforce and institutional advantages to create innovative products and services that lead to additional jobs and economic value for the state.
- ✓ To the extent practical, pursue a strategic market analysis from a statewide perspective of the impacts and benefits of Smart Grid on all stakeholders in the value chain.
- ✓ The appropriate governing bodies should explore options and market structures that would provide incentives for Smart Grid development.

Workforce and Economic Development (Chapter Three)

To facilitate the development and deployment of a workforce with the necessary combination of Smart Grid skills and understanding, including distribution/transmission grid network, communication network, and IT infrastructure skills, Colorado needs more coordination and commitments from universities, research laboratories, and the electricity industry. Effective use of regulatory structures to promote Smart Grid development and deployment will provide the enabling conditions for economic development.

Recommendations

- ✓ The Colorado Department of Labor and Employment (CDLE) should conduct a study to identify and define the scope, magnitude, and impact of Smart Grid on jobs within Colorado. The study should examine the net impact on jobs and workforce transition issues and attempt to validate and expand on recent studies that have been conducted that rely on utility and utility supply chain job creation.

- ✓ Institutions of higher education should pursue funding opportunities to further develop professional training and degrees that support the necessary integration of professional economic, engineering, and technical skills necessary to support the progression of Smart Grid deployment within Colorado.
- ✓ The state should investigate incentives to promote the entrepreneurial creation of new Smart Grid businesses, existing businesses, and business relocations with proof-of-concept seed grants, technology transfer programs, and other entrepreneurial initiatives.
- ✓ The PUC and other governing bodies should examine and develop regulatory structures that will provide utilities with incentives to innovate and foster small-business development (for example, helping with curriculum development, pilot programs, and/or technology demonstrations).

Consumer Issues and Data Management (Chapter Four)

The consumer has never before had the ability to "see" in near real-time how electricity is delivered and priced. This is a significant shift, and consumer education and outreach is critical to understanding, acceptance, and interest in this new relationship with electricity. Consumers will want to know that data that could potentially be used to determine their habits and actions is being protected, and utilities will want to know that they can access the data necessary for billing and operational purposes.

Recommendations

- ✓ Consumers should be educated concerning the benefits and costs of Smart Grid.
- ✓ The Governor's Energy Office (GEO) should serve as an independent third party offering consumer education so consumers may learn about their energy usage options.
- ✓ Privacy of consumer information should be guarded in such a manner that personally identifiable information is not accessible. Utilities must have access to applicable information and data necessary to conduct billing, operations, and services.
- ✓ Customers must sign informed consent to release information to third parties (signed consent may be electronically obtained), except in those instances where access is compelled by law enforcement.
- ✓ Metering protocols should include open[1] communication standards and, to the extent practical, allow for and enable timely data at reasonable costs.
- ✓ Consumers should have access to their own energy usage, production, cost, pricing, and time-of-use data.
- ✓ Control and ownership of data is complex, and there is no consensus on the appropriate balance of data ownership, individual privacy rights, and data access

[1]Open standards, according to NIST are (1) openly documented, (2) published without restriction, and (3) freely available for adoption and able to evolve collaboratively through standards organizations.

among the stakeholders of the emerging Smart Grid value chain. The state should monitor and, where appropriate, engage in the ongoing national and global debate around this topic.

- ✓ Promote open Smart Grid technology standards that encourage competition, innovation, market development, and broad participation.
- ✓ Utilities should not be mandated to provide information to third parties without due consideration of consumer interests or the reimbursement of reasonable costs associated with the collection of that data.

Distributed Energy Resources and Grid Management (Chapter Five)

A Smart Grid could enable and optimize greater use of distributed energy resources (DER). Reduced emissions and greater use of renewable energy are two of the significant benefits that DER technologies and demand-response (DR) offer.

Recommendations

- ✓ The state should be encouraged to utilize demonstration projects with public and private partners. These demonstration projects may facilitate cross-sector education and leadership development. Best ideas could then be recognized, fostered, and commercialized.
- ✓ The PUC and other appropriate governing bodies should explore consistent inclusion of demand response (DR) into energy efficiency and demand-side management (DSM) programs.
- ✓ The PUC and other relevant governing bodies should continue to explore time-based pricing that is attractive to large numbers of consumers while being aware of consumers on lower and fixed incomes.
- ✓ Within the context of Smart Grid, the PUC and other appropriate governing bodies should encourage the beneficial management and aggregation of DER in ways that benefit the consumer and utility.
- ✓ Within the existing Renewable Energy Standard, the General Assembly should consider a full range of policy options, such as additional incentives or requirements that could be provided to encourage greater investment in distributed renewable generation technologies.
- ✓ To increase internal cohesion and develop leadership around Smart Grid governance in Colorado, leaders — including but not limited to the Governor's Energy Office (GEO), the Colorado Public Utilities Commission (PUC), the Colorado Department of Public Health and the Environment (CDPHE), and the Colorado Department of Transportation (CDOT) — should participate in plug-in hybrid electric vehicle (PHEV) stakeholder groups to recommend appropriate infrastructure decisions[3]. Initial issues of concern include:
    - Who owns, maintains, and manages public plug-in stations?

[2] Variable pricing and peak-load reduction programs are examples of DR programs. These can help reduce energy consumption and associated emissions by providing consumers an opportunity to manage and reduce their energy usage in response to price signals.
[3] For example, the U.S. National Electric Vehicle Safety Standards Summit.

- What standards need to be adopted?
- How will fast charging stations be accommodated within the utility grid?

  and

- What pricing mechanisms, if any, need to be considered in the future?

✓ The PUC and appropriate governing bodies should explore, and pilot test, innovative financial investment models that appropriately consider the interests of consumers and the benefits of evolving DER technologies.

Technical Specifications (Chapter Six)

It is critical to Smart Grid development and deployment in Colorado that the technology "platform," or base operating system of protocols and communications, is standardized such that all new software systems, hardware devices and new products can be "plugged in" to the network and immediately recognize and be recognized on the network. Lack of technical standards for Smart Grid communications and devices will continue to slow deployment and innovation, as there will be continued confusion over best practices and what is the "standard" operating procedure for new products and services for the industry.

Recommendations

✓ Support a flexible, open, secure, and technical standards–compliant architecture to allow consumers and power providers to exchange information to support the provision of further services to/from the grid. A vendor- and platform-independent structure.

✓ The PUC and GEO should initiate a stakeholder group to be educated about the NIST Smart Grid Interoperability Panel (SGIP) process and associated recommendations. The group should consist of Colorado industries, the PUC and other regulatory bodies, the GEO, utilities, and other stakeholder groups.

✓ Energy management has the potential to positively impact the grid. However, this could be managed in multiple ways, including but not limited to appropriate pricing structures and other technologies.

✓ Manage the use of electric vehicles, through appropriate pricing structures and other technologies, to optimize performance and minimize impact.

✓ Foster the development of the technical specifications or guidelines to support stable adoption of electric vehicle initiatives.

✓ The future communications architecture should consider a model that incorporates the entire infrastructure span from consumer-end equipment to substations and the associated IT infrastructure.

✓ Smart Grid technical specifications in the State of Colorado[4] should be consistent with prevailing national standards. In order to achieve this, leaders in Colorado should coordinate with the appropriate bodies, such as NIST.

[4]These technical specifications include, but may not be limited to, grid architecture, reliability, and cyber security.

✓ The PUC and other utility-governing bodies should consider a balanced economic approach for the adoption of technical specifications and guidance to include but not be limited to:

- Implementation timing
- Customer cost impacts
- System benefits
- Incentivizing innovations
- Environmental impact

and

- Equity/socioeconomic impacts

✓ The PUC and other utility-governing bodies should consider mechanisms for utilities to include in their infrastructure design accommodation of distributed generation, transportation electrification, and associated billing processes.

Grid Operations (Chapter Seven)

Increased penetration of renewable-energy resources, both distributed and utility scale, will increase the level of variable power on the system. To maintain reliability and to smooth out base-load, intermittent, and variable resources in a new configuration, Colorado will need an increase in system monitoring, automation, load-shifting ability, and increased participation from consumers with self-generation (e.g., solar energy).

Recommendations

✓ Encourage research and appropriate use of storage technologies to better integrate intermittent resources.

✓ Initiate research and appropriate use of storage technologies to better integrate intermittent resources.

✓ Smart Grid efficiency planning may include the following: identification and reduction of transmission/distribution line losses, power factor management, voltage management, phase balancing, and demand response.

✓ Encourage the statewide dissemination of applicable system and reliability metrics to support transparency of electric system performance.

✓ Encourage the development of infrastructure and standards designed to support self-healing networks.

✓ Explore the ability to dynamically isolate systems that are able to self-start and seamlessly reconnect, as allowed within NERC reliability standards.

✓ Maximize the efficiency of workforce by incorporating equipment designed to quickly pinpoint and respond to outages.

✓ Encourage the development of infrastructure and standards designed to support the integration of utility-scale renewable energy and demand-response measures into grid operations.

- ✓ Encourage the consolidation of Balancing Authorities[5] to better diversify the available pool of utility-scale renewables.
- ✓ Encourage the appropriate governing bodies to explore options that would provide incentives for efficiency from innovation that does not penalize or harm utilities within the grid.
- ✓ Include distributed generation in capacity planning as an intermittent generation resource instead of being treated as masked load[6].
- ✓ Explore alternative business and regulatory models to address cost recovery/rate mechanisms related to utility losses associated with demand-side management.
- ✓ Identify specific incentives for utilities to innovate where value is produced for the consumer but may not fit with the standard utility business model.
- ✓ Explore other relevant standards to consider in a secure energy system (for example from defense and other critical installations).
- ✓ Identify and adopt an industry-standard definition of grid efficiency.

Scenarios to Transition to a Flexible, Secure, and Reliable Smart Grid (Chapter Eight)

That Smart Grid is evolving in Colorado, and elsewhere, is clear. What is not yet clear is which pathway will best serve the transition to a flexible, secure, and reliable future Smart Grid. This chapter presents three distinct scenarios policy makers could pursue to implement that transition: incremental, moderate, and transformational. In contrast to the consensus-based recommendations, these represent a range of options for interpreting the suite of recommendations proposed.

An **Incremental Approach** to Smart Grid development and deployment would proceed stepwise, with each step monitored for effectiveness, as well as its effects on consumers, utilities, and related industries. This would ensure that each new Smart Grid investment was built effectively upon lessons learned from previous investments.

Benefits

- Ensure infrastructure build-out is commensurate with consumer attitudes and interests.
- Collect information about how to better build the grid through the implementation, monitoring, and evaluation of projects.
- Enable the technology to evolve appropriately before large-scale public and private investment.

Risks

- Lose out on potential economic development and job creation opportunities.
- Could invest in overbuilding generation relative to future demand in an effectively managed Smart Grid system.
- Late implementation of Smart Grid technology that would have benefited consumers.

[5]A balancing authority is the responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a balancing authority area, and supports interconnection frequency in real time.
[6]Masked load occurs as distributed generation reduces the demand on the grid experienced by the utilities but does not decrease the number of users on the grid who rely on the grid for backup power. This mismatch between visible demand and potential capacity need is masked load and makes utility capacity planning more difficult.

A **Moderate Approach** to Smart Grid development and deployment would ensure that build-out of the grid is monitored and evaluated, while identifying places on the grid where increased investment can help drive or speed up the transition.

Benefits

- Reduced energy use and intensity.
- Increased environmental responsiveness.
- Grid reliability, affordability, and flexibility leading to higher acceptance and penetration of distributed generation.

Risks

- Degradation and financial viability of the utility business model, leading to adverse customer impacts.
- Increased grid disturbances and diminished reliability.
- Unfair or inequitable distribution of infrastructure costs among consumers.

A **Transformational Approach** to Smart Grid development and deployment would proceed quickly with increased public and private investment up front to build out a technologically advanced grid that enables increased uses, services, and applications on the grid.

Benefits

- Colorado emerges as an economic leader and positions itself as a design and manufacturing center that develops and sells technologies to the national and global community, spurring job and wealth creation.
- Increased use of clean-energy technologies leading to energy cost savings, environmental benefits, and a more stable and reliable electric grid.
- Intellectual and thought leadership leading to increased educational and research opportunities at universities, tech centers, and research parks, creating further economic opportunities for the state.

Risks

- Confusion, misunderstanding or rejection by consumers.
- Investment in technologies that later become obsolete could lead to stranded costs.
- Loss of investor confidence if Smart Grid value proposition does not materialize.

Managed appropriately, a transition to Smart Grid that seeks innovative and creative solutions to the many challenges posed could position Colorado to become a regional, national and global leader on this subject. Colorado stands at the cusp of this fundamental change to the modern electricity grid. How Colorado prepares the foundation for its construction and development will determine how quickly, efficiently, and effectively the state will benefit from its promise.

Chairman's Cover Note

In 2010, the General Assembly passed SB 10-180, establishing a Smart Grid Task Force to report recommendations for the Legislature and regulators to prepare for successful integration and deployment of Smart Grid technology in Colorado. As an entrepreneurial leader in technology related to Smart Grid information management, Colorado is poised to benefit from significant economic-development potential; yet, it is incumbent upon the state to put in place the regulatory and policy framework to support such an infrastructure if we expect to attract the associated investment.

This report presents the recommendations of the Smart Grid Task Force, which met monthly throughout the summer and into December of 2010.

The Task Force consisted of utility stakeholders, educators, researchers, consumer and environmental advocates, and private sector and public sector representatives — all of whom share a recognition that today's utility grid is shifting from a traditional centralized system of delivery of power upon demand to one that will fully utilize the opportunities of interactive control, data management, and advanced communication technology. There is also universal agreement that this increased capability of the grid presents many opportunities and also many challenges.

This report attempts to identify critical areas to be addressed through regulation from the appropriate regulatory bodies or policy from the Legislature. It should be noted that the recommendations consist of areas in which there was consensus among all stakeholders. Issues are also identified where there was not universal consensus, but where there is a need for policy makers and regulators to establish guidelines.

The extent to which policy makers wish to establish Colorado's leadership in implementation of Smart Grid technology will inform the level to which they will tackle some of these critical issues. It should be noted that many of these areas of disagreement remain outside of consensus precisely because an ongoing debate continues both nationally and internationally between regulators, public advocates, utilities, and others on how to resolve these issues.

It is clear that the mechanisms for managing generation and demand of electricity are changing as utilities respond to the digital world and incorporate Smart Grid technologies. It is also clear that consumer acceptance and involvement in this process is greatly enhanced by the information and communication capabilities of Smart Grid. Understandably, this creates opportunities for new models of energy delivery and demand management as well as a new level of involvement from nontraditional stakeholders in the energy system, including consumers and non-utility private sector entities.

Creating the policy and regulatory structure to support this new environment, which holds numerous potential opportunities and pitfalls, is the challenge this report attempts to address. It is the sincere desire of the Task Force members that you find these discussions helpful as you attempt to navigate a course toward a regulatory system and public policy to advance Smart Grid deployment for the State of Colorado.

Sincerely,

Tom Plant
Director, Colorado Governor's Energy Office

Task Force Vision

Colorado is well positioned to become an intellectual, commercial, and consumer leader in Smart Grid technology, both in the United States and internationally. The state's well-educated and innovative workforce has particular expertise in the three building blocks of Smart Grid — telecommunications, information technology (IT), and energy systems.

Colorado is home to leading educational and research institutions — including the University of Colorado (CU), Colorado State University (CSU), and Colorado School of Mines (CSM) — which have modest, but growing, Smart Grid–related courses and programs — as well as a Collaboratory, described in chapter two. Both the National Institute of Standards and Technology (NIST) and the National Renewable Energy Laboratory (NREL), organizations that will play critical roles in guiding the path forward for effective deployment of Smart Grid, are both located in Colorado. On the private sector side, several innovative Smart Grid demonstration projects are already under way in Colorado (listed in Appendix C), and several Smart Grid–related start-up companies are located in Colorado.

A sophisticated and flexible electricity system that provides low-cost, reliable, and clean electricity for Colorado would accommodate:

- Large amounts of renewable electricity generation, including large utility-sized and smaller household-sized renewable systems;
- Demand response, which allows electricity consumers to better observe and control their electricity use, and allowing utilities to influence demand through price and direct control; and
- Widespread use of electric vehicles — including, for example, plug-in hybrids and "pure" electric vehicles that would run on electricity generated in Colorado rather than on imported oil.

Implementing and maintaining our Smart Grid, as well as developing Smart Grid–related products and services, could stimulate significant job creation and economic-development opportunities. A vibrant Smart Grid industry in Colorado could employ large numbers of people at all skill and education levels, enabling the state to export Smart Grid–related products and services to other states and countries. Further, highly reliable and low-cost electricity, as well as flexibility in electricity services, could further bolster the state's economic competitiveness.

A strong Smart Grid sector could help build a nationally recognized suite of Smart Grid educational offerings and facilities in Colorado, ranging from short courses for technicians to graduate programs for future industry leaders. Graduates of Colorado's Smart Grid programs could lead industry and public sector Smart Grid efforts across the country.

A Smart Grid also could bring environmental benefits of reduced emissions from traditional fossil-fuel power sources, which would improve the health of Colorado and preserve the state's stunning natural environment, while ensuring that fewer of our funds are sent out of state to purchase fossil fuels. For instance, the electrification of the transportation sector could lead to the state importing less oil.

Finally, a Smart Grid, as well as increased opportunities to generate and access energy usage data, could provide consumers the opportunity to get more involved in the management and control of their energy use, thereby lowering their overall utility bills.

The remainder of this report focuses on how Colorado can make this vision a reality.

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[7]See Appendix I.

Chapter One: Introduction

The current electrical grid system is a centralized, unidirectional system, with power flowing out to the consumer from a central utility and distribution station. A future Smart Grid will enable a better distributed system, with power flowing among central power stations, large renewable-energy centers, small distributed energy generation centers, electric vehicles, smart homes, and smart buildings. Energy flow and use will be markedly more varied than it is today. Smart Grid can both enable as well as help monitor and regulate these varied future uses of the grid. The build-out of this grid is not a linear process. Rather, it will be an evolution in which each new addition will enable more uses, create more challenges, and offer a concomitant suite of risks and rewards.

Colorado SB 10-180 directed the Task Force to develop recommendations on the "feasibility, cost and timing of transitioning to a secure, resilient, and technologically advanced electric grid," also referred to in this report as the "Smart Grid." The legislation called for the Task Force to consist of a representative group of stakeholders in the state including utility representatives, educators, researchers, consumer and environmental advocates, and private sector and public sector representatives (for the full list of Task Force Members and their affiliations, please see Appendix B). Over the course of deliberations, the Task Force developed consensus recommendations for the Governor, the General Assembly, and the Colorado Public Utilities Commission (PUC). The report describes the context and background of each of these recommendations, articulates three pathways Colorado policy makers could use to guide the transition to Smart Grid in Colorado, and describes a number of complicated issues that must be addressed, but for which the Task Force was not able to reach consensus on a recommendation.

Principles

A number of broad principles guided the Task Force in developing and finalizing recommendations, including:

- This report contains high-level recommendations for policy-makers to support Smart Grid development in the State of Colorado.
- Among policy makers, the General Assembly should focus on defining overall goals, while the PUC and self-governing boards, county commissions or city councils should focus on mechanisms for achieving those goals.
- As a rule, incentives are preferred over mandates; however, policy-makers should examine all options available to them when developing Smart Grid policy.
- To spur economic development and keep consumer rates affordable, policymakers should seek to create an open market place, encourage competition, innovation, market development, product development, and broad participation.
- The advent of Smart Grid technology has the potential to provide significant value for both consumers and utilities. For consumer implementation to be successful, consumer education about the benefits and risks, especially that borne by early adopters, is critical.

- Significant economic value could be derived from technologies and applications developed for the Smart Grid. Market and regulatory structures should foster an environment that supports and encourages innovation. Further, state policies should seek to recognize, foster and commercialize new technologies.

- Policies should be adopted in such a way that the system can adapt to and support a rapidly changing marketplace.

- Pilot, demonstration and proof-of-concept projects offer the ability to test out new technologies, ideas, grid architecture and market structures and in the process provide valuable data for business leaders, policy-makers and regulators to help guide and refine the transition to Smart Grid.

- Generally speaking, Colorado's electric grid should conform to existing national and regional specifications and standards, as is already required in many instances by FERC and NERC. Technical specifications for Smart Grid and Smart Grid components, tools and applications should adhere to prevailing regional and national standards. Technical specifications and standards should not be put in statute.

- The costs as well as benefits of Smart Grid need to be analyzed. Initially, it will be easy to analyze the costs of building out the infrastructure to enable Smart Grid, while it will be difficult to quantify potential benefits. Policy-makers should recognize this fact when making decisions about a transition to Smart Grid.

- A number of outstanding issues surround the deployment of Smart Grid that need to be resolved. In some cases, there is an ongoing national and global debate. In other cases, further debate is needed before a decision can be made.

Definition

For the purposes of Task Force deliberations and this report, and in accordance with SB 10-180, Smart Grid is defined as "a system for electric transmission or distribution within the certificated service territory of an electric utility that incorporates one or more of the following functionalities:

a) "Enabling consumers to participate actively in managing their electric consumption by using information, control, and options for energy efficiency not previously available to consumers;

b) "Integrating electrical systems using universal interoperability standards;

c) "Monitoring, diagnosing, and responding to power quality deficiencies;

d) "Optimizing the use of system assets and enhancing overall efficiency through improved load factors and better management of outages;

e) "Anticipating and automatically responding to system deficiencies;

f) "Operating resiliently when confronted with a cyber attack or natural disaster; and/or

g) "Optimizing efficiency and demand response."

Structure of this Report

The full body of consensus recommendations conveyed in the executive summary and in chapters two through seven of this report cover the topics delineated in SB 10-180. These include: Challenges and Opportunities in Colorado, Workforce and Economic Development, Consumer Issues and Data Management, Distributed Energy Resources and Grid Management, Technical Specifications, and Grid Operations.

Chapters two through seven offer greater contextual detail for the set of recommendations. Chapter eight elaborates three different pathways towards the implementation of Smart Grid – incremental, moderate and transformational. Finally, the report concludes with an articulation of some of the key areas that task force members believe are critical for decision makers to address. However, no agreement was reached on how best to address these issues.

Chapter Two: Challenges and Opportunities in Colorado

The challenges and opportunities for Smart Grid development and deployment in Colorado clearly set the stage for the body of recommendations and other considerations set forth in this report. Colorado is home to a strong and burgeoning high-tech sector, a utility sector with a history of experimenting with Smart Grid, and leading research universities and critical organizations such as NIST and NREL, which together comprise a significant competitive advantage. Because of this, Colorado is positioned to garner a premier role in the global development of Smart Grid and become an intellectual and economic leader worldwide.

Utilities throughout the state are experimenting with different scales and levels of investment in Smart Grid technology, including Xcel's comprehensive pilot project SmartGridCity™ in Boulder; Black Hills Energy's advanced metering infrastructure (AMI) deployment at scale in Pueblo, with expansion to Cañon City, Rocky Ford, Cripple Creek, and other rural communities; metering infrastructure in Poudre Valley REA territory; Fort Collins' AMI investment grant project; and Fort Collins' FortZED, a demonstration project targeting distributed renewable resource integration to supply power during peak load periods. In addition to these projects, other electric utilities are investing in smaller scale projects that benefit customers and utility distribution networks throughout the state.

NIST and NREL are both located in the state and are the critical institutions responsible for developing national standards and conducting technology research to enable transformation of the electric power system to a full Smart Grid deployment. Both are involved at the federal level and are assigned by the Energy Independence and Security Act of 2007 to facilitate standards and R&D in this market space.

The Colorado Renewable Energy Collaboratory is a research partnership among NREL and the state's premier research universities (CSU, CU and CSM). The Collaboratory is home to engineers and scientists engaged in theoretical and applied research on renewable and clean-energy technologies and Smart Grid. Consequently, there is an exceptionally high concentration of Smart Grid experts in the State of Colorado, a group that is limited in number on both a national and global scale.

These advantageous circumstances open up an opportunity for Colorado to develop a well-thought-out, comprehensive system that could drive economic development in the state, provide a model for the region, and profit from exporting ancillary goods and services relating to Smart Grid deployment. With sustained public and private sector support, Colorado could easily be positioned as an economic and thought leader in Smart Grid.

✓ **Recommendation:** Leverage Colorado's unique workforce and institutional advantages to create innovative products and services that lead to additional jobs and economic value for the state.

In order to make better decisions about investments and planning — and to identify significant opportunities for economic development within the state — legislators, regulators, investors, and consumers need a tool to better understand the range of potential costs and benefits, as well as risks and opportunities associated with Smart Grid. This tool or analysis should: (a) be sufficiently broad; (b) focus on the multiple interactions that occur among stakeholders along the Smart Grid value chain (including consumers, third-party service, and application providers and utilities); (c) be completed quickly enough to be useful and inform development and deployment; and (d) delineate and describe the economic-development opportunities that stem from creating an ecosystem of products and services in this new industry. Finally, since Smart Grid is relatively new and there is little consensus or understanding about its benefits, the exercise should acknowledge the limitations of available data.

✓ **Recommendation:** To the extent practical, pursue a strategic market analysis from a statewide perspective of the impacts and benefits of Smart Grid on all stakeholders in the value chain.

Another significant challenge is that the current energy market is not designed to optimize Smart Grid investments. While utilities clearly see the potential benefits of Smart Grid, such as remote meter reading and outage identification, many benefits of Smart Grid — such as greater ways to drive energy efficiency, distributed generation and increased penetration of renewable energies, and new services on the grid that optimize energy usage — will result in reduced energy delivered to the consumer and, therefore, potentially reduced revenue for the utilities. The current energy market rewards utilities for delivering more energy to the consumer. In order to drive widespread investment in Smart Grid, the economic incentives for utilities will need to be modified to promote Smart Grid investments.

✓ **Recommendation:** The appropriate governing bodies should explore options and market structures that would provide incentives for Smart Grid development.

Regulatory structures are as important as market structures in governing the electric grid. As the Smart Grid is built out, the interactions between the markets and regulatory environments, such as the ability for utilities to recover costs from energy efficiency and renewable-energy gains that are mandated by legislation, will need to be examined further.

Chapter Three: Workforce and Economic Development

Evolution of the Smart Grid will eventually result in an amalgamation of the internet and communications industries with the electric-power industry. The electric-power industry is one of the largest and most capital intensive industries in the country. As a result of the scale and scope of changes needed, greater numbers of both existing and emerging work classes will be required to effectuate this transition. Colorado's existing workforce is skilled in each of the three distinct aspects of Smart Grid: distribution/transmission and grid network; communication network, and IT infrastructure[8]. What Colorado needs is more coordination and commitments from the universities, labs, and power sector to facilitate the development and deployment of a workforce with this combination of skills.

Through the effective use of incentive and regulatory structures to promote Smart Grid development and deployment, the state has an immediate opportunity to facilitate and promote economic-development opportunities. It is anticipated that small businesses, creating new tools and applications for the grid, may drive much of the innovation around the ancillary services and products for enabling stepwise changes to the power system. The universe of opportunities and innovations associated with Smart Grid is yet to be fully conceived and designed. Knowledge gained through discovery and interaction with the grid will lead to these innovations as firms, workers, and utilities explore, implement, and come to understand Smart Grid technologies. Incentive and regulatory structures can promote the development of innovations. A state fund could also help promote start-up Smart Grid businesses and entrepreneurial ventures.

✓ **Recommendation:** The PUC and other governing bodies should examine and develop regulatory structures that will provide utilities with incentives to innovate and foster small-business development (for example, helping with curriculum development, pilot programs, and/or technology demonstrations).

✓ **Recommendation:** The state should investigate incentives to promote the entrepreneurial creation of new Smart Grid businesses, existing businesses, and business relocations with proof-of-concept seed grants, technology transfer programs, and other entrepreneurial initiatives.

Smart Grid effects on job growth, loss, and transition are more complex than is commonly acknowledged. Innovation and economic development could lead to job growth; however, traditional electric-grid jobs with utilities may be lost or transitioned. A paucity of data on Smart Grid jobs makes it difficult to understand job loss, job creation, and workforce transition. Further research could help identify the scope, magnitude, and

[8]A sampling of these work classes include engineers, software architects, billing agents, government, battery and car manufacturing jobs, parts and services related to grid automation and equipment, etc.

impact of Smart Grid on jobs in Colorado. For this purpose, it could be most beneficial to frame job gains, losses, and transition in terms of the net impact on the workforce.

✓ **Recommendation:** The Colorado Department of Labor and Employment (CDLE) should conduct a study to identify and define the scope, magnitude, and impact of Smart Grid on jobs within Colorado. The study should examine the net impact on jobs and workforce transition issues and attempt to validate and expand on recent studies that have been conducted that rely on utility and utility supply chain job creation.

Smart Grid jobs will require a different set of skills than those required for working in the electric industry today. The Smart Grid combines electric distribution/transmission technology, IT infrastructure, and telecommunications technology. Workers in all sectors — from service providers to technicians to marketing and communications specialists — will need to understand the interdisciplinary components of Smart Grid. As the system is built out and becomes increasingly specialized (from grid maintenance to in-home networks), the variety and types of knowledge required to maintain and operate the systems will expand in equal proportion. A skilled and educated workforce is needed not only to help build the system, but also to provide the workforce for utilities and third-party companies to function, innovate, and grow.

✓ **Recommendation:** Institutions of higher education should pursue funding opportunities to further develop professional training and degrees that support the necessary integration of professional economic, engineering, and technical skills necessary to support the progression of Smart Grid deployment within Colorado.

Chapter Four: Consumer Issues and Data Management

The transition toward the Smart Grid is based not only around a step change in the configuration of the electric power system, but also around a fundamental relationship between consumers and the energy they use. That shift is from a one-way relationship of power delivery to the consumer to a multidirectional relationship where control and choice are shared between the utility and the consumer. Smart Grid will provide this capability by providing near real time generation and pricing directly to the consumer so they can start to make informed decisions about when and how they want to consume or conserve energy.

The consumer has never before had the ability to "see" in near real-time how energy is delivered and priced. This is a considerable shift. Consumer education and outreach is critical to understanding, acceptance, and interest in this new relationship with energy.

To this end, new uses, services, and applications developed for a Smart Grid platform may provide significant value to consumers, as well as dramatically alter the way consumers understand and interact with their energy usage. Consumers will be presented with access to more and different types of information about their energy usage and a plethora of options for using that information. Different consumers will require and ask for different services and applications, and the system should be designed to allow services to be customized and tailored to consumer choices.

One of the challenges of building out a system that would enable such a diversity of choices is the question of cost allocation for grid improvements. From an investment perspective, system-wide improvements are generally the most economical; under the current scheme, costs would be passed on to the entire consumer base. The concern with this approach is whether it is fair to ask consumers who would not "opt in" to the Smart Grid to bear the costs of implementation.

It will be important to educate consumers about the benefits, risks, implications, and changes they will experience with new opportunities and uses of the electric grid. Education should help consumers understand both the choices they have and the potential value available through Smart Grid, in order to increase understanding and support for Smart Grid investments. Careful and balanced communication regarding the benefits, changes, and risks associated with Smart Grid usage will be critical for the adoption of the technology on a widespread scale. Lessons can be drawn from implementation experiences in other states, such as California, where strong consumer push-back against Smart Grid technology resulted from consumer response to what was a temporary increase in energy prices, as a result of increased accuracy from AMI implementation. Furthermore, it should be acknowledged that just as an inefficient utility system has costs to the entire consumer base, an increase in efficient operations through Smart Grid technologies will provide benefits across the entire consumer base.

✓ **Recommendation:** Consumers should be educated concerning the benefits and costs of Smart Grid.

In order to ensure that consumers can access the services they desire and maintain control of their data, their personal data should be accessible to them for their own uses. Currently, the GEO offers consumer education around energy and utilities, but it does not provide education specific to the Smart Grid. As the system develops, the GEO should design and offer Smart Grid–specific consumer education.

✓ **Recommendation:** The Governor's Energy Office (GEO) should serve as an independent third party offering consumer education so consumers may learn about their energy usage options.

The increased data generation associated with Smart Grid deployment will include more data about consumer usage and activity. Consumers will want to know that the data that could potentially be used to determine their habits and actions is being protected.

✓ **Recommendation:** Privacy of consumer information should be guarded in such a manner that personally identifiable information is not accessible. Utilities must have access to applicable information and data necessary to conduct billing, operations, and services.

Utilities have a strong track record, as well as an obligation and interest, in protecting consumer information. However, as new industries and entities start to develop products for this space, appropriate safeguards must be put in place to protect consumer information. Consumers should sign and understand informed-consent agreements prior to the release of their individual usage information beyond the utility.

✓ **Recommendation:** Customers must sign informed consent to release information to third parties (signed consent may be electronically obtained), except in those instances where access is compelled by law enforcement.

While protection of consumer privacy is paramount to effective deployment of the Smart Grid, it is also the case that increased data generation will drive development of critical new services designed precisely for this area. In fact, much of the value proposition of Smart Grid lies in business opportunities related to the management and use of these data. In order to ensure that consumers can access the services they desire and maintain control of their data, it should be accessible to them for their own uses.

✓ **Recommendation:** Consumers should have access to their own energy usage, production, cost, pricing, and time-of-use data.

✓ **Recommendation:** Utilities should not be mandated to provide information to third parties without due consideration of consumer interests or the reimbursement of reasonable costs associated with the collection of that data.

Consumers will benefit from a diversity of choices for services and technologies. Open technology standards can facilitate innovation and competition, which can in turn generate more services and technologies for consumers. Broad consumer uptake of Smart Grid services and technologies may help build the value of the market and the system.

✓ **Recommendation:** Promote open Smart Grid technology standards that encourage competition, innovation, market development, and broad participation.

Metering protocols can be used both to stimulate the marketplace and to ensure that proper information is available for consumers. Two important elements of such metering protocols include (1) open communication standards that would allow third-party service providers to develop innovative services and technologies using information derived from the meter, and (2) the provision of timely data in short enough time intervals to match the value proposition of the derived service or application.

✓ **Recommendation:** Metering protocols should include open[9] communication standards and, to the extent practical, allow for and enable timely data at reasonable costs.

Finally, it is important to note that there is a significant, ongoing discussion at the national and international levels regarding ownership of data and information. This debate recognizes multiple issues — such as the need to protect consumer information, the need for utilities to access data necessary for their operations, and the desire to understand and promote value from Smart Grid that is derived from information and data management. There are a number of paradigms under consideration to address these issues, including instances where all data generated by the consumer is owned by the consumer, or where data and information are owned by the party that developed the infrastructure to generate the data, and hybrid options between those two (please see Appendix H). No resolution has been reached on this topic nationally, or internationally.

✓ **Recommendation:** Control and ownership of data is complex, and there is no consensus on the appropriate balance of data ownership, individual privacy rights, and data access among the stakeholders of the emerging Smart Grid value chain. The state should monitor and, where appropriate, engage in the ongoing national and global debate around this topic.

[9]Open standards, according to NIST are (1) openly documented, (2) published without restriction, and (3) freely available for adoption and able to evolve collaboratively through standards organizations.

Chapter Five: Distributed Energy Resources and Grid Management

Under Colorado HB 10-1001, Colorado has mandated that at least three percent of regulated retail electricity sales be generated from distributed renewable sources such as solar photovoltaic, small hydroelectric and small wind power systems. There are several benefits of distributed generation. Distributed generation has the potential to save consumers money, provide environmental benefits and serve as an economic development opportunity. Although it can function to defer or reduce investments in central power stations, it cannot entirely replace this need over the near-term. Other parts of the world have moved aggressively on distributed generation and have shown how to operate the system in a “micro-grid” manner.

Denmark, for example, has successfully implemented the operation of a high penetration of renewable energy with distributed generation by pairing wind and combined heat and power (CHP)[10] over sustained periods[11]. In order to deal with the variable nature of distributed generation, an intelligent and transparent energy management system should be employed. Such a system can actively manage the variability of power supply and user demand, coupled with storage and other distributed infrastructure and Smart Grid technologies. When balancing existing centralized resources with significant distributed energy resources, the Smart Grid provides the intelligence to effectively manage the system.

A Smart Grid could enable and optimize greater use of distributed energy resources (DER). Reduced emissions and greater use of renewable energy are two of the significant environmental benefits that DER technologies and demand-response (DR)[12] offer. To facilitate DER optimization, Colorado has created a number of policies and measures, some of which have been recently implemented — such as the increase in the state renewable-energy standard (RES)[13] from 20 percent to 30 percent by 2020. An important change to this law is the “DG carve-out,” which requires that 3 percent of the total utility sales come from distributed generation resources[14]. While some believe that these measures require time to be implemented and evaluated for efficacy, others would advocate stronger policy approaches to catalyze Smart Grid development.

✓ **Recommendation:** Within the existing Renewable Energy Standard, the General Assembly should consider a full range of policy options, such as additional incentives or requirements that could be provided to encourage greater investment in distributed renewable generation technologies.

[10]CHP is the production of both heat and electricity from a single heat source.
[11]Presentation by Dr. Sunil Cherian, Spirae, Inc.
[12]Variable pricing and peak-load reduction programs are examples of DR programs. These can help reduce energy consumption and associated emissions by providing consumers an opportunity to manage and reduce their energy usage in response to price signals.
[13]Note that the RES is applicable only to the state’s investor-owned utilities.
[14]Colorado HB 10-1001.

Some of these changes pose high risk for low- and fixed-income Coloradoans. This group may be less likely to use or benefit directly from new and emerging technologies but may benefit from the improvements in energy management on the system.

✓ **Recommendation:** The PUC and appropriate governing bodies should explore, and pilot test, innovative financial investment models that appropriately consider the interests of consumers and the benefits of evolving DER technologies.

DER can be managed and aggregated in ways that benefit consumers and the utilities. Although aggregators have struggled in the Colorado market to date, a recognized potential exists for DER aggregation companies[15] to play a significant role in expanding distributed energy resources.

✓ **Recommendation:** Within the context of Smart Grid, the PUC and other appropriate governing bodies should encourage the beneficial management and aggregation of DER in ways that benefit the consumer and utility.

DR programs can be helpful in achieving both energy-efficiency and demand-side management (DSM) goals. DR programs have been inconsistently included in many programs to date. As the Smart Grid is built out, it will offer more options for DR programs, such as variable pricing tied to the time of use for energy resources. Consumer needs should be considered in building out these programs so as not to disproportionately burden those on low or fixed incomes.

✓ **Recommendation:** The PUC and other appropriate governing bodies should explore consistent inclusion of demand response (DR) into energy efficiency and demand-side management (DSM) programs.

✓ **Recommendation:** The PUC and other relevant governing bodies should continue to explore time-based pricing attractive to large numbers of consumers while being aware of consumers on lower and fixed incomes.

Innovation will be critical to optimizing DER and developing a robust Smart Grid economy in the state of Colorado. In order to maximize innovation, the state should provide incentives and structures so that good ideas can be recognized, fostered, and quickly commercialized to grow the Smart Grid economy. Demonstration projects that are tied to research institutions, the state, and private companies could provide an efficient means for achieving this.

[15] Colorado HB 10-1001

✓ **Recommendation:** The state should be encouraged to utilize demonstration projects with public and private partners. These demonstration projects may facilitate cross-sector education and leadership development. Best ideas could then be recognized, fostered, and commercialized.

Broad use of electric vehicles and plug-in hybrid electric vehicles could prove to be a significant area of economic development for the state. Because there is still not a good national or international example of how this market can be created, Colorado should seek to capitalize on this opportunity by engaging in the appropriate forums to help make infrastructure decisions both within the state and nationally.

✓ **Recommendation:** To increase internal cohesion and develop leadership around Smart Grid governance in Colorado, leaders — including but not limited to the Governor's Energy Office (GEO), the Colorado Public Utilities Commission (PUC), the Colorado Department of Public Health and the Environment (CDPHE) and the Colorado Department of Transportation (CDOT) — should participate in plug-in hybrid electric vehicle (PHEV) stakeholder groups to recommend appropriate infrastructure decisions[16]. Initial issues of concern include:

- Who owns, maintains, and manages public plug-in stations?
- What standards need to be adopted?
- How will fast charging stations be accommodated within the utility grid?

  and

- What pricing mechanisms, if any, need to be considered in the future?

[16] For example, the U.S. National Electric Vehicle Safety Standards Summit.

Chapter Six: Technical Specifications

The consumer electronics experience of the “videotape wars” between BETA and VHS formats is a noteworthy and well-known example of the role markets play in the adoption of industry-wide technical standards. For Smart Grid development and deployment in Colorado, it is critical that the technology’s base operating system of protocols and communications are standardized in such a way that all new software systems, hardware devices, and new products can be “plugged into” the network for immediate recognition and operability. Lack of technical standards for Smart Grid communications and devices will continue to slow deployment and innovation, as confusion will persist over applicable best practices and “standard” operating protocols for new products and services within the industry.

The primary responsibility for developing these standards currently resides with NIST, and the final promulgation of these rules lies with FERC. In the state of Colorado, however, the regulatory process is not centralized. It is important that Colorado not have a balkanized system of operating protocols and standards for these technologies. The Smart Grid Task Force is in consensus that all industry, utility, and developer stakeholders are better served by adoption of a common set of technical specifications, which also will enable quicker and safer harmonization of Smart Grid technologies.

A significant potential value stream of the Smart Grid lies in the new uses, services, and applications that are developed on its platform. The technical standards that are developed to govern the grid will guide how these new uses, services, and applications are developed. A flexible, open[17], and secure architecture will provide a platform within which individuals and companies can develop new innovations. An electric power system that encourages new software and hardware devices to “plug and play” will allow market forces to ensure that quality innovations, technologies, and applications are successful. Further, the policies governing the grid should be explicitly technology agnostic.

✓ **Recommendation:** Support a flexible, open, secure, and technical standards–compliant architecture to allow consumers and power providers to exchange information to support the provision of further services to/from the grid. A vendor- and platform-independent structure.

The benefits of an open, secure, and flexible communication architecture could, and should, accrue across the span of interests and groups, including utilities, consumers, and third-party industries. A Smart Grid communication architecture that considers and incorporates this whole span will not only provide more value to a greater number of people but will also allow for future innovations to be developed for each level of the supply chain.

[17] Open standards, according to NIST are (1) openly documented, (2) published without restriction, and (3) freely available for adoption and able to evolve collaboratively through standards organizations.

✓ **Recommendation:** The future communications architecture should consider a model that incorporates the entire infrastructure span from consumer-end equipment to substations and the associated IT infrastructure.

There is significant ongoing activity at the federal level focused on developing technical specifications for Smart Grid. NIST's Smart Grid Interoperability Panel (SGIP) already has released an initial "NIST Framework and Roadmap for Interoperability Standards" (please see Appendix G) and is in the process of refining its recommendations. Other organizations, such as North American Electric Reliability Corporation (NERC), Federal Energy Regulatory Commission (FERC), and the Federal Communication Commission (FCC), are also running similar processes. Because of the ongoing national discussion and the cost associated with performing a full technical audit to develop specifications, Colorado should seek ways to work within the existing national structure. Representatives from Colorado should seek to leverage and shape existing processes to support the burgeoning Smart Grid market in Colorado.

✓ **Recommendation:** Smart Grid technical specifications in the State of Colorado[18] should be consistent with prevailing national standards. In order to achieve this, leaders in Colorado should coordinate with the appropriate bodies, such as NIST.

In an effort to stay informed about and shape national policy, the PUC and GEO could initiate a representative stakeholder group with the mission of staying educated about ongoing processes. The NIST SGIP process and its associated recommendations would be of particular importance for this purpose.

✓ **Recommendation:** The PUC and GEO should initiate a stakeholder group to be educated about the NIST Smart Grid Interoperability Panel (SGIP) process and associated recommendations. The group should consist of Colorado industries, the PUC and other regulatory bodies, the GEO, utilities, and other stakeholder groups.

Technical specifications should, to the extent possible, support and not hinder Smart Grid development. As the PUC and other regulatory bodies adopt technical standards for the state of Colorado, they should be aware of how the adoption process impacts many different arenas. For instance, the rate of adoption of new standards and technologies could affect the timing and speed of implementation. Large investments in new technologies could have adverse consumer-cost impacts, especially among lower-income customers. A technologically advanced grid would allow for greater variety of energy use and generation and enable the grid to act as a platform for service providers. This new platform, upon which it would be possible to offer services and applications, is the basis for innovation and economic value derived from the Smart Grid. The PUC and other governing bodies should strive for a balanced approach to adopting new standards that considers these issues and more.

[18] These technical specifications include, but may not be limited to, grid architecture, reliability, and cyber security.

✓ **Recommendation:** The PUC and other utility-governing bodies should consider a balanced economic approach for the adoption of technical specifications and guidance to include but not be limited to:

- Implementation timing
- Customer cost impacts
- System benefits
- Incentivizing innovations
- Environmental impact

and

- Equity/socioeconomic impacts

As the PUC and other regulatory bodies begin to oversee investments in Smart Grid in the state of Colorado, they should consider mechanisms to include distributed generation, transportation electrification, and other uses of the Smart Grid that could offer significant environmental and economic value in their updated infrastructure. Specifically, utilities run the risk of stranding investments if appropriate cost recovery mechanisms are not in place for beneficial grid improvements.

✓ **Recommendation:** The PUC and other utility-governing bodies should consider mechanisms for utilities to include in their infrastructure design accommodation of distributed generation, transportation electrification, and associated billing processes.

As new technologies are developed for the grid, they offer the possibility of both positive and negative impact on the grid as well as on grid functioning. Energy management will play an increasingly important role in managing the many new components of the Smart Grid.

✓ **Recommendation:** Energy management has the potential to positively impact the grid. However, this could be managed in multiple ways, including but not limited to appropriate pricing structures and other technologies.

Electric vehicles, especially, offer a number of potential challenges and benefits for the grid. Their widespread use could significantly reduce carbon dioxide emissions and the environmental impact from transportation, as the grid is powered by more renewable energies. However, an addition of a number of electric cars charging from the grid potentially will increase peak-charging loads. Further, if and when cars begin to return energy into the grid, the two-way flow of electricity poses potential safety hazards unless the grid architecture is designed and managed to support this type of use. Finally, consumers may wish to enhance their renewable-energy systems to accommodate future electric vehicle integration. However, the current 120 percent restriction on net metering may be a disincentive to build to that future capacity.

✓ **Recommendation:** Manage the use of electric vehicles, through appropriate pricing structures and other technologies, to optimize performance and minimize impact.

✓ **Recommendation:** Foster the development of technical specifications or guidelines to support stable adoption of electric vehicle initiatives.

Chapter Seven: Grid Operations

Increased penetration of renewable-energy resources, both distributed and utility scale, will tend to destabilize the grid absent commensurate increases in the capabilities of system-operational controls. Improvements in system monitoring and automation, the ability to shift load and increased participation of smaller consumer-level distributed resources (e.g. solar energy and EVs) should be employed to maintain reliability and to optimize the matching of base-load, firm and intermittent resources in new configurations. It is possible that Colorado's entire electric power system will need to consider the merits of other electric grid-operational models with more centralized management of energy supply and demand across large geographic areas to take advantage of both resource and load diversity.[19]

As with many other aspects of the electricity-distribution system, the Smart Grid raises the potential for both challenges and opportunities for electric grid operations manifested in grid reliability, energy efficiency, outage restoration and recovery, grid and cyber security, and utility-wide integration of renewable resources and demand response.

Traditionally, grid reliability has been very high. Adherence to NERC standards and state and other regulations has historically ensured both reliability and efficiency. They are expected to play an ongoing role in this manner. New investments in the grid should seek to maintain this strong reliability, but may not be able to promise further improvement. In accordance with the recommendation in this chapter to ensure that Colorado's technical standards are consistent with national and regional standards, there should be continued adherence to federal and state reliability standards for any Smart Grid policy implementation.

It is worth noting, however, that reliability has typically referred to supply and reserve; however, as a new system is built out, energy resources are more distributed, and services are more varied, so the definition of reliability could evolve. Under this scenario, reliability may come to mean the ability for the grid to match the appropriate type, quality, and quantity of energy to a diverse set of users. As the definition and understanding of reliability evolves, demonstration and pilot projects should be connected to feedback loops that allow regulators to understand and learn from the changing system.

As a new understanding of reliability is developed, it may be helpful to track key metrics and data about reliability. As reliability data are not currently shared among utilities, a central database that tracks a number of key reliability metrics would increase transparency and foster development of a baseline understanding of whether and how Smart Grid implementation is leading to improvements.

✓ **Recommendation:** Encourage the statewide dissemination of applicable system and reliability metrics to support transparency of electric-system performance.

Smart Grid technologies implemented at a grid-wide scale could offer energy-efficiency gains from the grid. A technologically advanced grid could allow utilities to better monitor and predict energy use from the

[19] Such grid operational models are known as regional transmission organizations (RTOs). Several exist currently in the United States, including the California Independent System Operator (CAISO), Electric Reliability Council of Texas (ERCOT), Midwest Independent System Operator (MISO), and the Pennsylvania-New Jersey-Maryland (PJM) Interconnection, to name a few.

individual level to the system level. Better targeting energy resources to match these demands could increase efficiency throughout the system. Energy efficiency, which could be quantified by a number of metrics, should be clearly outlined and defined by regulatory bodies. Implementing certain technologies across the grid today may assist future efficiency innovations. Strong and consistent grid architecture would support innovation and reduce transaction costs for future innovations. This would also help utilities and third-party providers maximize value from the grid. While building out the grid, it will be important to be aware of consumer-cost impacts. In addition, it will be critical to recognize that while a Smart Grid could enable significant savings, such as energy-efficiency optimization, consumers may or may not be willing to pay for the infrastructure needed to enable certain actions.

✓ **Recommendation:** Identify and adopt an industry-standard definition of grid efficiency.

✓ **Recommendation:** Smart Grid efficiency planning may include the following: identification and reduction of transmission/distribution line losses, power factor management, voltage management, phase balancing, and demand response.

Traditionally, gaining efficiency from the grid has been hampered by a number of challenges. Rigid adherence to strict technology standards can stifle innovations at the margins. This may have slowed improvements to the grid, such as a move to solid-state architecture. The system should be balanced between (1) the need to maintain a reliable system, (2) the possibility to create and test innovations to increase energy efficiency and (3) the interests of consumers to keep costs down. An innovation or pilot-testing waiver from NERC could help provide the incentive for innovation. Perverse incentives for utilities need to be addressed, such as the fact that many benefits of Smart Grid — including greater ways to drive energy efficiency, distributed generation and an increase in penetration of renewable energies, and new services on the grid optimizing energy usage — will result in reduced energy delivered to the consumer and, therefore, reduced revenue for the utilities.

✓ **Recommendation:** Encourage the appropriate governing bodies to explore options that would provide incentives for efficiency from innovation that does not penalize or harm utilities within the grid.

✓ **Recommendation:** Include distributed generation in capacity planning as an intermittent generation resource instead of being treated as masked load[20].

[20] Masked load occurs as distributed generation reduces the demand on the grid experienced by the utilities, but does not decrease the number of users on the grid who rely on the grid for backup power. This mismatch between visible demand and potential capacity need is masked load and makes utility capacity planning more difficult.

✓ **Recommendation:** Explore alternative business and regulatory models to address cost recovery/rate mechanisms related to utility losses associated with demand-side management.

✓ **Recommendation:** Identify specific incentives for utilities to innovate where value is produced for the consumer but may not fit with the standard utility business model.

As the Smart Grid enables a more distributed system with greater use of intermittent resources (such as solar and wind), outages and impacts in the system may increasingly be felt at the individual household level. Yet increases in integration of fast-response storage for frequency regulation and improved load forecasting from data-rich smart meters could help utilities, industry, and regulators better understand, and therefore integrate and utilize, distributed resources. Current data can serve as a proxy but, as the system becomes more complex, it will be necessary to have more detailed and individual information with which to understand impacts. Smart Grid can provide data to facilitate a better understanding of load behavior, particularly in the residential class.

✓ **Recommendation:** Encourage research and use of improved load and intermittent resource forecasting for better integration and utilization of intermittent resources.

✓ **Recommendation:** Encourage research and appropriate use of storage technologies to better integrate intermittent resources.

In addition to distributed renewable resources, the grid should also support utility-scale integration of renewable resources and demand response. This could be critical to helping with emissions reduction, fulfilling policy objectives (e.g., climate plan goals), and regulatory compliance (e.g., Renewable Energy Standard). DR technology and more intelligent networks will be necessary to connect utility-scale renewable resources, which are intermittent and pose potential challenges for traditional networks.

✓ **Recommendation:** Encourage the development of infrastructure and standards designed to support the integration of utility-scale renewable energy and demand-response measures into grid operations.

✓ **Recommendation:** Encourage the consolidation of Balancing Authorities[21] to better diversify the available pool of utility-scale renewables.

[21] A balancing authority is the responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a balancing authority area, and supports interconnection frequency in real time.

The Smart Grid could greatly enhance procedures and capacity for dealing with service disruptions and outages. IT-enabled networks could be self-healing, reducing the resources necessary to identify and repair breaks in the system. Moreover, these networks could help utilities accurately target and respond to issues that are not self-healing, which could maximize resource and workforce deployment to solve problems. Systems that can isolate, or "island," themselves could help minimize the number of consumers affected by outages. These benefits should be recognized and included in the build-out of the system.

✓ **Recommendation:** Encourage the development of infrastructure and standards designed to support self-healing networks.

✓ **Recommendation:** Explore the ability to dynamically isolate systems that are able to self-start and seamlessly reconnect, as allowed within NERC reliability standards.

✓ **Recommendation:** Maximize workforce efficiency by incorporating equipment designed to quickly pinpoint and respond to outages.

As the electric grid is enhanced with internet technology, many of the cyber security issues that are common to the internet will become relevant to the electric grid. NIST is in the process of developing standards for grid and cyber security. In order to ensure that the grid is interoperable, and that new uses of the grid adhere to technical and security standards, it will be important to continue to adhere to NIST standards, as indicated in this chapter. However, in Colorado many different communities and utilities may develop Smart Grid. Some, such as military installations, may be required to meet additional standards. In order to ensure that grids in different communities can communicate with each other and to support citizens who work and live across these different systems, the build-out of the system should factor for relevant standards across different communities and installations.

✓ **Recommendation:** Explore other relevant standards to consider in a secure energy system (for example from defense and other critical installations).

Chapter Eight: Scenarios to Transition to a Flexible, Secure, and Reliable Smart Grid

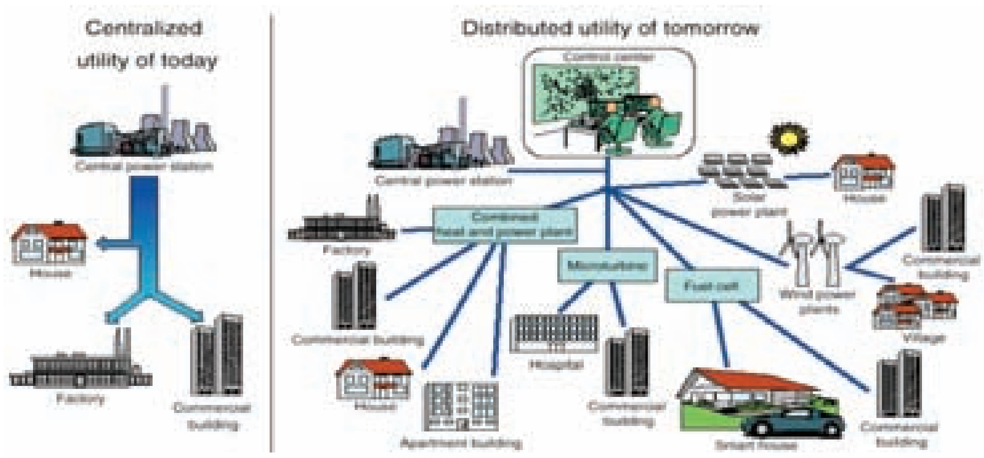


Image from U.S. Department of Energy

The consensus recommendations elaborated thus far in this report are those directions and actions agreed to by the Task Force as a whole. The extent to which policy makers establish a framework for transitioning to Smart Grid depends on their overall vision for Colorado. Naturally, these visions varied among and between the diversity of stakeholder views represented on the Task Force. This chapter outlines three distinct scenarios policy makers could pursue to implement the transition to a future Smart Grid that is flexible, reliable, and secure. The scenarios are presented along a range from incremental to moderate and transformational. The Task Force neither judges nor advises which option is best. Instead, the objective is to inform.

Incremental

An **Incremental Approach** to Smart Grid development and deployment would proceed stepwise, with each step monitored for effectiveness, as well as its effects on consumers, utilities, and related industries. This would ensure that each new Smart Grid investment was built effectively upon lesons learned from previous investments.

Benefits

- Ensure infrastructure build-out is commensurate with consumer attitudes and interests.
- Collect information about how to better build the grid through the implementation, monitoring, and evaluation of projects.
- Enable the technology to evolve appropriately before making large-scale public and private investment.

Risks

- Lose out on potential economic development and job creation opportunities.
- Could invest in overbuilding generation relative to future demand in an effectively managed Smart Grid system.
- Late implementation of Smart Grid technology that would have benefited consumers.

"I think there is a world market for maybe five computers."

— Thomas Watson, chairman of IBM, 1943

"The Internet? We are not interested in it."

— Bill Gates, Microsoft founder, 1993

The quotations above are instructional when discussing what may become a transformational technology. Computers initially were few in number, huge in size and complicated to use. Only when their size and cost shrank exponentially and their functionality increased did the computer become a transformational technology that helped expand the internet, break up the Bell System, develop smart phones, and create the promise of a smarter electrical grid.

The term "Smart Grid" implies that the current electrical grid is less than "smart." To refer to it only as "Smart Grid" gives the impression that the current electrical grid is "dumb" or "stupid," which it is not. In actuality, many utilities have been installing Smart Grid components on their side of the meter long before the term was in vogue. However, what has been missing to date is the creation of a two-way information exchange that gives consumers tools with which to manage the usage on *their* side of the meter. As a result, "smarter grid" is a more accurate term for what the Task Force is examining.

While the technologies referenced above have provided a basis for a number of transformational changes, consumers adopt them incrementally. The government did not mandate their acceptance. Instead, consumers came to accept them (and later to demand them) over time. A good example is the cell phone, which has morphed into the mobile smart phone. From fewer than 100,000 "brick" phones in 1985, the numbers exploded to 28 million ten years later to over 200 million in 2005 and nearly 300 million this year.

Even when the initial technology has some success, the version that many consumers ultimately adopt may come from a totally unexpected source. An example is the Flip video recorder profiled in an August 24, 2009, *Wired* magazine article titled "The Good Enough Revolution: When Cheap and Simple Is Just Fine." The point of the article is that consumers do not always need or want all the bells and whistles. They want something that is simple, easy to use and does not cost more than it is worth to them. These cases demonstrate that consumers took their own incremental steps to decide what technology met their needs and when to adopt it. In an era of an economic recession — the tightening of personal, business, and government budgets, along with a growing distrust of government, it may be difficult to impose the adoption of a Smart Grid on consumers when they are suspicious of government mandates and are already financially strapped.

Smart Grid deployment examples in Colorado and around the country highlight the value of an incremental approach. As an example, an electric cooperative in northeast Colorado has, in an incremental way, utilized a Demand Response program (DR) for its irrigation members since 2004. Smart Grid also allows utilities to better maintain their networks and isolate problems earlier and more specifically, resulting in decreased outages and reduced dispatching of field technicians. Smart meters also eliminate the need for meter readers and allow the utility to remotely disconnect service for nonpayment (as allowed by PUC regulations). On the other hand, consumers have responded that remote shutoffs are impersonal and can happen more quickly and without notice, which is especially problematic during the coldest months in Colorado and when many people are out of work.

Experiences in other states provide valuable lessons for Colorado on how to plan and bring consumers into the process. Pacific Gas and Electric has installed 7.4 million smart electric and gas meters in California and has received numerous consumer complaints of high bills — later shown to be attributable to a heat wave and an electric rate increase occurring simultaneously during the installation. Although a study in Texas has refuted the allegations, consumers have complained that after smart-meter installation their billed usage has gone up for no apparent reason. Complaints also have been raised that smart meters have caught fire after being installed incorrectly, that the radio-frequency emissions are a health hazard and that the information generated through a Smart Grid invades the privacy of consumers.

Whether these allegations are true or not, the perception to some is that smart meters and the Smart Grid do not directly benefit consumers and may not be worth the cost. Some of the same or similar allegations were made, especially concerning the privacy of information, when the Bell System was broken up in the mid-1980s, and multiple carriers were allowed to offer competing long-distance service. The information issue was resolved for telecommunication services through government, industry, and consumers working together to find a solution — and the same can be true for Smart Grid, as well.

The bottom line is that consumer acceptance is critical to the success of Smart Grid. The best way to achieve that is to encourage customers to be early adopters of this technology and to recognize that we will likely not get the Smart Grid correct in its initial deployment to customers. To facilitate adoption, electric customers in the state of Colorado will require comprehensive outreach education that will provide answers to customer questions and highlight the benefits they can expect to achieve. Assuming that Smart Grid products and services developed are easy to use and provide value to consumers, this will likely motivate more consumers to participate in the Smart Grid.

Our history of technology advances shows us that consumer and industry adoption rates accelerate as the functionality and benefits of the technology in question become clearer to consumers. This will also encourage nonparticipating, unregulated utilities to deploy a Smart Grid for their customers. Although waiting for the market to mature to before customers adopt new technologies may appear initially slower, such an approach has shown to be more efficient, effective, and consumer friendly than a government-mandated approach.

As Bill Gates has written, "we always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten." An incremental approach allows technology to move and be accepted at its own pace.

Moderate

A **Moderate Approach** to Smart Grid development and deployment would ensure that build-out of the grid is monitored and evaluated, while identifying places on the grid where increased investment can help drive or speed up the transition.

Benefits

- Reduced energy use and intensity.
- Increased environmental responsiveness.
- Grid reliability, affordability, and flexibility leading to higher acceptance and penetration of distributed generation.

Risks

- Degradation and financial viability of the utility business model leading to adverse customer impacts.
- Increased grid disturbances and diminished reliability.
- Unfair or inequitable distribution of infrastructure costs among consumers.

The future Smart Grid will include the seamless and dynamic integration of an increasingly broad variety of supply resources, demand resources, and information technology–enabled appliances optimized by digital information and intelligent-controls technologies. The resultant flexibility enabled by this system will facilitate resource adequacy, energy efficiency, cost effectiveness, and renewable-resource planning through an evolving landscape of regulatory and policy standards.

Benefits of this system could include reduced energy use and intensity, increased environmental responsiveness, grid reliability, and affordability. Grid flexibility could lead to higher acceptance and penetration of distributed generation. This transition will require the utility business model to evolve to be supportive. A combination of public and private investment is expected to drive this new system.

Meanwhile, risks might include the degradation and financial viability of the utility business model. Further risks transitioning to this scenario include the potential for increased grid disturbances, diminished reliability, and an unfair or inequitable distribution of infrastructure costs among consumers. This new system will require retraining the workforce with skills needed to meet the workforce demands of a Smart Grid infrastructure.

This vision embraces the concept of Smart Grid that is built to ensure that customers have viable choices in managing their energy profiles. Additionally, there is an emerging consensus that a consumer-based market will evolve on the customer side of the meter to enhance the ability of consumers to manage their energy usage. The market must be developed with security, reliability, privacy, and interoperability in mind.

Concerns, issues and benefits for the consumer and utility may differ. Consumer benefits, concerns, and issues could include:

- Affordable energy costs
- Renewable-energy choices
- Actionable information to manage their energy profile
- In-home area networks systems
- Ease of use
- Reliable infrastructure for backup and delivery
- Fair compensation for energy produced
- Flexible tariffs to support choice
- Plug-and-play interoperable appliances, thermostats, etc.

Meanwhile, utility benefits, concerns, and issues could include:

- Fair compensation for services rendered
- Recovery of lost margins for prudently incurred stranded investments
- Reliable, safe, resilient, secure grid
- Evolving business model with fair return
- Optimization of grid components
- Price elasticity of demand
- Rewards for innovative economic development
- Standards in place to support grid development
- Innovation cycles that are valued and encouraged
- Appropriate accommodation of legacy systems and stranded costs.

In this instance a market would develop that drives innovation and creativity; enables plug-and-play devices with standard, open protocols; and allows consumers to directly manage their energy portfolio. Societal benefits accrued would include renewable generation integration; reduced environmental impacts; market development and job creation; better consumer understanding of energy usage; research and development for future applications; and reliable, safe, efficient, secure, and affordable energy.

Colorado must effectively favor incentives over mandates in the development of innovative business models, which will align the varied interests of utilities, third-party vendors, regulators, policy makers, and consumers in order to become an epicenter of Smart Grid development and deployment. In order to avoid scenarios that saddle utilities with stranded costs associated with prudently incurred investments, Colorado must explore effective cost-recovery mechanisms, rate structures, and tariffs.

Transformational

A **Transformational Approach** to Smart Grid development and deployment would proceed quickly with increased public and private investment up front to build out a technologically advanced grid that enables increased uses, services, and applications on the grid.

Benefits

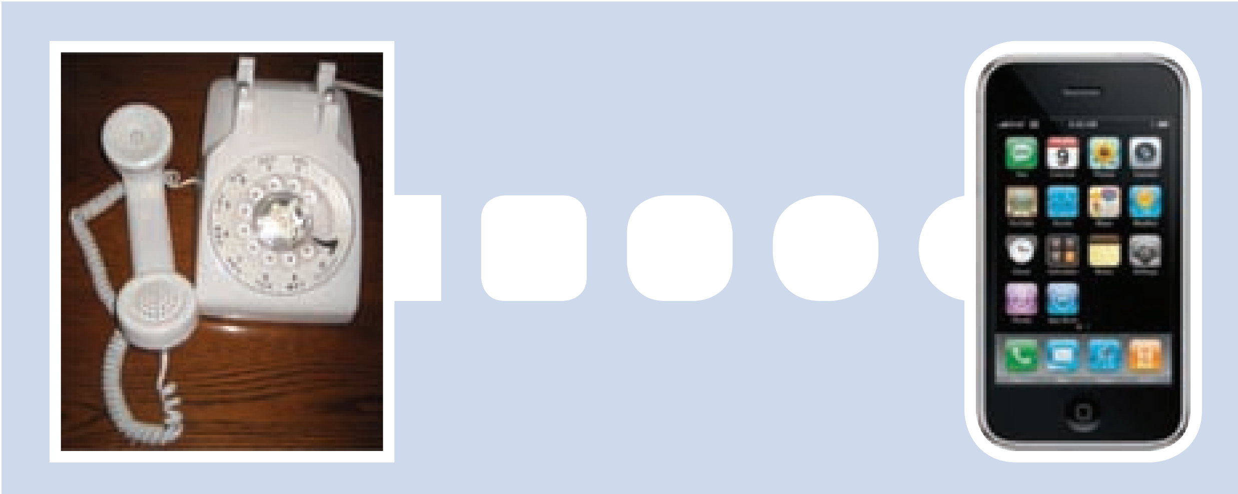
- Colorado emerges as an economic leader and positions itself as a design and manufacturing center that develops and sells technologies to the national and global community, spurring job and wealth creation.
- Increased use of clean-energy technologies leading to energy cost savings, environmental benefits, and a more stable and reliable electric grid.
- Intellectual and thought leadership leading to increased educational and research opportunities at universities, tech centers and research parks creating further economic opportunities for the state.

Risks

- Confusion, misunderstanding, or rejection by consumers.
- Investment in technologies that later become obsolete could lead to stranded costs.
- Loss of investor confidence if Smart Grid value proposition does not materialize.

Our current electricity system is similar to the telephone system prior to the breakup of AT&T. Service is provided by a regulated monopoly, and there is very limited opportunity for other individuals and organizations to enter the electricity market. The regulated monopoly is heavily incentivized to provide reliable service, maintain the status quo, avoid fundamental technological innovation, and keep costs relatively low while maintaining shareholder value. As a result, we have reliable service, stagnant technologies, and prices that may or may not be low — we don't really know, as we haven't seriously investigated technological alternatives to the 19th-century steam power plant.

Smart Grid presents a seminal opportunity to inject new technologies, new incentives, and new products and services into the electricity system. Just as it would be hard to imagine that the standard rotary phone would morph into the iPhone (see image on the following page), perhaps the most exciting aspect of the transformational portfolio is what we can't yet imagine.



Nevertheless, there are clearly some underutilized technologies that an aggressive implementation of Smart Grid might enable, including:

- Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs)
- Implementation of privately funded EV charging stations
- Demand response (DR), including community-funded DR
- Distributed generation, such as rooftop PV, localized wind power, and small co-generation systems
- Grid-efficiency systems that reduce waste and inefficiency in the distribution grid (IVVC: integrated volt/var controls)
- Distributed storage, such as building pre-cooling and community energy storage
- Microgrids and islanding

The Smart Grid, however, is not just about technological change: the key to Smart Grid success is a transformation of existing business models. Whereas today's regulated monopoly encourages large investments in central-site power plants; tomorrow's energy systems as they as starting to play out around the world encourage smaller, non–utility driven investments in "edge generation," i.e., localized, community-owned power. Customers move from "rate payers" in a one-size-fits-all model to "prosumers," i.e., producer-consumers who provide both power and reliability back into the grid. In these models, utilities migrate into regulated network operators of the distribution grid and are no longer incentivized to focus on maintaining the status quo of large central-site generation and transmission systems. Fundamental transformation takes place, creating deep and widespread opportunities for local investments, job growth, and community ownership of increasing components of the previous utility monopoly.

As a result, a vibrant Smart Grid could encourage or lead to:

- Decentralization of the electricity system
- Decomposition of the traditional regulated, vertically integrated, monopoly electricity provider
- A viable market for new electricity generation and electricity-related products and services
- Aggregation of demand response
- Community energy projects
- Jobs creation

- Smart cities, which efficiently address their infrastructure (water, transportation, electricity, gas, communications, etc.) and the identity of their community, e.g., Malaga, Spain; Amsterdam, Netherlands; Malta, etc.
- Removal of traditionally sanctioned inefficiencies in the grid and implementation of increasingly rigorous and transparent performance standards for utilities and lower costs for consumers (e.g., power factor improvements, conservation voltage reduction, etc.)

How might Colorado start on the path toward such a system? Several policy options would encourage an entrepreneurial, innovative Smart Grid system:

- Nonproprietary standards that allow new players and technologies to plug into the electricity system while mitigating against technological obsolescence
- Reexamination and expansion of the 120 percent net metering limitation to incent community investment and aggregation
- Innovative financing, providing capital for consumers and businesses to finance distributed electricity-generation systems
- Injection of transparency into Colorado electricity providers' Smart Grid plans by requiring an annual Integrated Resource Plan (IRP) process; this process would explicitly address utility business cases for costs and benefits of a "high Smart Grid implementation" scenario and subjects these analyses to public scrutiny
- Establishment of a Smart Grid technology transfer/commercialization/incubator program, involving CSU, CU and NREL, which attracts emerging businesses that are associated with SG technology and investors
- Creation of a Smart Grid oversight office as an extension of the Colorado Office of Economic Development that would encourage relocation of existing businesses to Colorado
- Creation of a PUC-supported mechanism not simply to provide utilities with cost recovery for their approved SG investments, but rather to add basis points that fundamentally incentivize utilities to invest in innovation
- Creation of a new state investment fund in coordination with the Colorado Cleantech Industry Association to support Colorado-based Smart Grid companies with working capital and loan guarantees

This transformational portfolio will take place, sooner or later, and it is starting to happen around the world. The critical question is whether Colorado wants to be a leader or a laggard in the transition to a modern — clean, efficient, reliable, and low-cost — electricity system.

Chapter Nine: Conclusion

Colorado has a significant opportunity to invest in Smart Grid and emerge both nationally and internationally as a leader in the field. The Colorado Smart Grid Task Force *Deploying Smart Grid in Colorado* report has been a first step to highlight and offer recommendations to advance this leadership position. Policy makers and leaders will face a number of complex decisions, trade-offs, and other interrelated challenges as they build the foundation for modernizing the electric power system and the associated Smart Grid deployment in Colorado. Many of these decisions are, not surprisingly, areas where the Task Force failed to reach consensus and, as such, are not listed among the issues with clear recommendations.

Although the Task Force did not reach consensus in these areas, they are critical areas in which legislators and regulators will need to determine a clear policy path for the state. For example, the opportunity for maximization of efficiency in electricity delivery is greatly increased with advanced data delivery and management, both from supply and demand. However, the numerous utility authorities and fractured system ownership may restrict realization of potential advancement of efficiency across the state. Colorado is home to 57 different electric utilities with some utilities rapidly deploying Smart Grid infrastructure and others moving at a different pace; with varying degrees of advancement, it's difficult for the state to take a uniform approach. The benefits of Smart Grid accrue directly to the customer base of the utility, but some utilities lack the population base to justify the significant investment in these infrastructure improvements. Since the indirect benefits accrue to the population at large, there may be a role for state policy to assist a statewide effort at infrastructure improvements.

Similarly, with large volumes of data generation and ever increasing computing power, opportunities abound for improving customer services in energy delivery and demand; however, the same data may be used by third-party entities to bring harm to both the electric network and the customers themselves. From a legal perspective, clarification is needed surrounding the ownership of data. Does ownership reside with consumers because they generate the data through their energy use? Or does it reside with the utilities because they have invested in the infrastructure to transmit and manage the data for the benefit of the consumer? As third-party developers begin to target data-intensive services to consumers that help them manage their energy use, permission needs to be granted by the entity that owns the data. Should that permission be legally transmitted by the consumer or by the utility? If the consumer owns the data, how can it be ensured that the utility has access to the data to enable it to effectively deliver essential services? If law enforcement requests data, is it the consumer or the utility that is legally compelled to respond to the request?

These are issues that have yet to be resolved either at the local or national level. Fundamentally, the Task Force and industry stakeholders recognize that the traditional mechanisms of utility-power management in the digital age offer substantial opportunities for transformation; however, the nature and direction of those transformations are not currently known or agreed upon. Nevertheless, much as we have witnessed a generational change in telecommunications, we will similarly see a change in power management and delivery. Colorado should develop the foundation for those changes not only to occur but to flourish, while protecting the consumer from the potentially negative consequences of those changes and maximizing the potential benefits.

Smart Grids take on different forms, such as Fort Collins' "FortZED," which is focused on peak-load reduction, and Boulder's SmartGridCity™, which is focused on grid intelligence, utility management, and consumer use. Precisely because Smart Grid addresses so many different aspects of the energy infrastructure, many stakeholder interests must be balanced as policy is formed. The Task Force identified a number of outstanding issues, observations, and questions deemed relevant for decision makers considering how best to deploy Smart Grid in Colorado.

- Demonstration projects could be knitted together in order to establish best practices, optimize across projects, and learn from multiple and varied testing environments. There are many issues that this may help address — such as the multitude of cross-jurisdictional issues (trans-grid), fair compensation, regulatory barriers, standards, plugs, interoperability, interaction with defense infrastructure (physical islanding), increased integration of renewable, and technology obsolescence.
- The system needs to be technologically agnostic, as well as open and interoperable. How can the Smart Grid enable further uses and integration? Can we build smart cities? How can Smart Grid and smart meters integrate with other measurements and processes, such as gas, thermal, and water meters, transportation, heating, and so on?
- Colorado could become a national research, innovation, and economic center for Smart Grid (like Research Triangle Park in North Carolina). How can Colorado create a strong market for Smart Grid and attract investment to the state? What is the economic value and value proposition of Smart Grid and its associated economic development?
- There is already global competition for industries in the state. How can Colorado build and expand global partnerships? What are the legislative incentives for investment? Do we develop a Smart Grid corridor?
- This is a move toward a different, more distributed system, which is leading to a blurring of the edge of the utility space. The Smart Grid transition is an evolution. It is the first step toward an alternative industry structure for delivering electricity. What are the feasibility, cost, and timing of transitioning to a Smart Grid? What are the levels of risk that are enhanced through the introduction of new technologies to the system?
- As we view the potential for transportation to move from a distributed fossil-fuel system for vehicles to a distributed electrical charging system, how do we prepare for the increase in power demand, optimize the potential storage capabilities of such a system, and still meet the need for flexibility and range of travel demanded of the modern citizen? In short, how do we make an integrated charging system fit within the lifestyle expectations of the consumer while protecting the infrastructure and reliability of the utility?

Managed appropriately, a transition to Smart Grid that seeks innovative and creative solutions to the many challenges posed could help Colorado become a regional, national, and global leader on this subject. The changes in the modern grid could be substantial and fundamental.

Colorado is currently standing at the cusp of this change. How the state prepares the foundation for its construction and development will determine how quickly, efficiently, and effectively consumers, utilities, and new, innovative industry players benefit from its promise.

Appendix A: Enabling Legislation

SENATE BILL 10-180

BY SENATOR(S) Williams, Penry, Schwartz, Kester, Boyd, Carroll M., Hudak, Johnston, Morse, Romer, Bacon, Heath, Hodge, Keller, Newell, Shaffer B., Tapia;

also REPRESENTATIVE(S) Kerr A., Casso, Court, Curry, Fischer, Hullinghorst, Miklosi, Solano, Frangas, Labuda, Pace, Pommer, Todd, Tyler.

CONCERNING THE DEVELOPMENT OF A SMART GRID FOR COLORADO, AND, IN CONNECTION THEREWITH, CONVENING A TASK FORCE TO RECOMMEND LEGISLATIVE AND ADMINISTRATIVE MEASURES TO ENCOURAGE THE ORDERLY IMPLEMENTATION OF SMART GRID TECHNOLOGY IN COLORADO[22].

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. Article 4 of title 40, Colorado Revised Statutes, is amended BY THE ADDITION OF A NEW SECTION to read:

40-4-118. Colorado Smart Grid Task Force — fund — definition — reports — repeal.

(1) Task Force. (a) THERE IS HEREBY CREATED THE COLORADO SMART GRID TASK FORCE, ALSO REFERRED TO IN THIS SECTION AS THE "TASK FORCE." THE TASK FORCE SHALL PROVIDE TECHNICAL EXPERTISE AND STRATEGIC POLICY RECOMMENDATIONS, FROM A STATEWIDE PERSPECTIVE, TO THE COMMISSION AND THE GENERAL ASSEMBLY. THE TASK FORCE'S PRIMARY TASK IS TO PRODUCE A REPORT CONTAINING RECOMMENDATIONS AND ANALYSIS ON THE FEASIBILITY, COST, AND TIMING OF TRANSITIONING TO A SECURE, RESILIENT, AND TECHNOLOGICALLY ADVANCED ELECTRIC GRID, ALSO REFERRED TO IN THIS SECTION AS THE "SMART GRID," IN COLORADO FOR USE BY COLORADO RESIDENTS, BUSINESS, AND GOVERNMENTAL AGENCIES.

(b) THE TASK FORCE SHALL ELECT A CHAIR AND A VICE-CHAIR FROM ITS MEMBERS AT ITS FIRST MEETING.

(c) IN COLLECTING INFORMATION FOR ITS REPORT, THE TASK FORCE SHALL:

(I) HOLD AT LEAST FOUR MEETINGS, WHICH SHALL BE OPEN TO THE PUBLIC. THE TASK FORCE SHALL SOLICIT AND RECEIVE COMMENTS, INCLUDING WRITTEN COMMENTS, FROM MEMBERS OF THE PUBLIC. THE TASK FORCE MAY DETERMINE THE MANNER IN WHICH SUCH COMMENTS ARE RECEIVED;

(II) CONSIDER AND GIVE WEIGHT TO ANY COMMENTS RECEIVED FROM THE GENERAL PUBLIC, AS WELL AS WRITTEN COMMENTS FROM AFFECTED COUNTIES, CITIES, STATE AGENCIES, ELECTRIC UTILITIES AND THEIR CUSTOMERS, ENVIRONMENTAL GROUPS, AND OTHER INTERESTED STAKEHOLDERS;

[22] Capital letters indicate new material added to existing statutes; dashes through words indicate deletions from existing statutes and such material not part of the act.

(III) CONSIDER AND GIVE WEIGHT TO RESEARCH PAPERS AND TECHNICAL INFORMATION MADE AVAILABLE THROUGH CURRENT RESEARCH PROJECTS AT THE COMMISSION AND ACADEMIC INSTITUTIONS AND FROM PRIVATE CITIZENS; AND

(IV) TAKE NOTICE OF PROCEEDINGS BEFORE THE COMMISSION ADDRESSING SMART GRID DEVELOPMENT; CONFER WITH COMMISSIONERS AND COMMISSION STAFF; AND CONSIDER AND GIVE WEIGHT TO THE RECORDS, FINDINGS, AND DECISIONS IN THOSE PROCEEDINGS.

(2) Membership.

(a) THE TASK FORCE CONSISTS OF ELEVEN MEMBERS AS FOLLOWS:

(I) THE DIRECTOR OF THE GOVERNOR'S ENERGY OFFICE, CREATED IN SECTION 24-38.5-101, C.R.S., OR HIS OR HER DESIGNEE, WHO SHALL CONVENE THE TASK FORCE AND WHO IS AUTHORIZED TO CONTRACT WITH A MEDIATOR OR OTHER THIRD PARTY TO FACILITATE ACCOMPLISHMENT OF THE TASK FORCE'S DUTIES;

(II) SIX MEMBERS APPOINTED BY THE GOVERNOR AS FOLLOWS:

(A) TWO MEMBERS REPRESENTING INVESTOR-OWNED ELECTRIC UTILITIES;

(B) ONE MEMBER REPRESENTING MUNICIPAL UTILITIES;

(C) ONE MEMBER REPRESENTING COOPERATIVE ELECTRIC ASSOCIATIONS;

(D) ONE MEMBER WITH EXPERTISE IN ENERGY POLICY AND REGULATION AT THE STATE AND FEDERAL LEVEL; AND

(E) ONE MEMBER WITH EXPERTISE IN ENVIRONMENTAL ISSUES.

(III) FOUR MEMBERS REPRESENTING THE FOLLOWING CONSTITUENCIES AND WITH THE FOLLOWING AREAS OF EXPERTISE, OF WHOM ONE SHALL BE APPOINTED BY THE PRESIDENT OF THE SENATE, ONE SHALL BE APPOINTED BY THE MINORITY LEADER OF THE SENATE, ONE SHALL BE APPOINTED BY THE SPEAKER OF THE HOUSE, AND ONE SHALL BE APPOINTED BY THE MINORITY LEADER OF THE HOUSE:

(A) ONE MEMBER REPRESENTING COMMERCIAL DEVELOPERS OF SMART GRID SOFTWARE, HARDWARE, OR SERVICES, AND WITH A BACKGROUND IN CAPITAL AND BUSINESS DEVELOPMENT;

(B) ONE MEMBER REPRESENTING CONSUMER PROTECTION;

(C) ONE MEMBER REPRESENTING ACADEMIC RESEARCH AND DEVELOPMENT OF SMART GRID TECHNOLOGY; AND

(D) ONE MEMBER WITH EXPERTISE IN ENGINEERING STANDARDS, PROTOCOLS, AND TECHNICAL REQUIREMENTS FOR SMART GRID DEPLOYMENT.

(b) MEMBERS OF THE TASK FORCE SHALL BE APPOINTED WITHIN 30 DAYS AFTER THE EFFECTIVE DATE OF THIS SECTION.

(c) VACANCIES SHALL BE FILLED BY APPOINTMENT BY THE OFFICIAL WHO APPOINTED THE MEMBER WHOSE ABSENCE RESULTED IN THE VACANCY.

(3) Duties — initial report — updates — issues.

(a) THE TASK FORCE SHALL DEVELOP AN INITIAL REPORT, DESIGNATED THE 2011 COLORADO SMART GRID REPORT, IN WHICH THE TASK FORCE ADDRESSES AND MAKES RECOMMENDATIONS FOR THE FOLLOWING:

(I) ISSUES RELATED TO THE UTILITY SIDE OF THE METER IN THE DEVELOPMENT OF A SMART GRID, INCLUDING:

(A) GRID RELIABILITY;

(B) GRID EFFICIENCY;

(C) OUTAGE RESTORATION AND RECOVERY;

(D) DISTRIBUTED GENERATION INTEGRATION;

(E) TRANSPORTATION ELECTRIFICATION; AND

(F) SYSTEM INTEGRATION OF RENEWABLE AND CONVENTIONAL SOURCES OF ELECTRIC POWER GENERATION.

(II) ISSUES RELATED TO THE CUSTOMER SIDE OF THE METER IN THE DEVELOPMENT OF A SMART GRID, INCLUDING:

(A) CONSUMER METERING PROTOCOLS;

(B) DRIVING INCREASES IN CONSUMER EFFICIENCY;

(C) PROVIDING EFFECTIVE CONSUMER INFORMATION;

(D) INTEGRATION OF DEMAND RESPONSE PROGRAMS; AND

(E) INTEGRATION OF VARIABLE PRICING MECHANISMS; AND

(III) POTENTIAL IMPACTS FROM THE DEVELOPMENT OF A SMART GRID, INCLUDING:

(A) CONSUMER PROTECTION AND PRIVACY;

(B) CYBER SECURITY;

(C) COMMUNICATION AND TECHNICAL STANDARDS;

(D) WORKFORCE AND ECONOMIC-DEVELOPMENT ISSUES;

(E) ENERGY EFFICIENCY AND DEMAND RESPONSE; AND

(F) EMISSIONS FROM ELECTRIC GENERATION.

(b) THE TASK FORCE SHALL PERIODICALLY REVISIT THE ISSUES SET FORTH IN PARAGRAPH (a) OF THIS SUBSECTION (3) AND UPDATE THE REPORT WITH NEW INFORMATION OR RECOMMENDATIONS AS THE TASK FORCE DEEMS ADVISABLE.

(4) Timeline. THE TASK FORCE SHALL PRODUCE AND DELIVER ITS INITIAL REPORT UNDER SUBSECTION (3) OF THIS SECTION TO THE GOVERNOR, THE COMMISSION, AND THE GENERAL ASSEMBLY ON OR BEFORE JANUARY 20, 2011, AND SHALL MEET AT LEAST ANNUALLY THEREAFTER TO REVIEW THE REPORT, RECEIVE ADDITIONAL INFORMATION, AND CONSIDER UPDATES TO THE REPORT.

(5) Funding. (a) THE GOVERNOR'S ENERGY OFFICE MAY ACCEPT PRIVATE GIFTS, GRANTS, AND DONATIONS FOR THE PURPOSE OF PROVIDING SUPPORT TO THE TASK FORCE TO PERFORM ITS RESPONSIBILITIES SPECIFIED IN THIS SECTION. ANY SUCH GIFTS, GRANTS, AND DONATIONS SHALL BE HELD IN A SEPARATE ACCOUNT WITHIN THE CLEAN-ENERGY FUND CREATED IN SECTION 24-75-1201, C.R.S., AND SHALL BE AVAILABLE TO THE OFFICE AND THE TASK FORCE ONLY FOR THE PURPOSE OF CARRYING OUT THE TASK FORCE'S DUTIES UNDER THIS SECTION. THE ACCOUNT SHALL ALSO CONSIST OF MONEYS APPROPRIATED AND TRANSFERRED TO THE ACCOUNT. ANY UNEXPENDED OR UNENCUMBERED MONEYS REMAINING IN THE ACCOUNT AS OF JANUARY 1, 2015, SHALL REVERT TO THE CLEAN-ENERGY FUND TO BE USED BY THE GOVERNOR'S ENERGY OFFICE.

(b) IT IS THE INTENT OF THE GENERAL ASSEMBLY THAT THE GOVERNOR'S ENERGY OFFICE NOT BE REQUIRED TO SOLICIT GIFTS, GRANTS, OR DONATIONS FROM ANY SOURCE FOR THE PURPOSES OF THIS SECTION AND THAT NO GENERAL-FUND MONEYS BE USED TO PAY FOR GRANTS AWARDED PURSUANT TO THIS SECTION OR FOR ANY EXPENSES OF THE TASK FORCE.

(c) IF, BY JUNE 1, 2010, MONEYS IN THE FUND CREATED PURSUANT TO PARAGRAPH (a) OF THIS SUBSECTION (5) HAVE NOT REACHED AN AMOUNT SUFFICIENT TO PAY THE EXPENSES OF THE TASK FORCE, THE TASK FORCE SHALL NOT MEET NOR UNDERTAKE ANY OTHER DUTIES PURSUANT TO THIS SECTION, AND THE GOVERNOR'S ENERGY OFFICE SHALL RETURN TO EACH GRANTOR OR DONOR AN AMOUNT EQUAL TO SUCH GRANTOR'S OR DONOR'S CONTRIBUTION. THE INTEREST, IF ANY, EARNED FROM THE INVESTMENT OF MONEYS IN THE ACCOUNT SHALL BE TRANSFERRED TO THE GENERAL FUND.

(6) Definition. AS USED IN THIS SECTION, "SMART GRID" MEANS A SYSTEM FOR ELECTRIC TRANSMISSION OR DISTRIBUTION WITHIN THE CERTIFICATED SERVICE TERRITORY OF AN ELECTRIC UTILITY THAT INCORPORATES ONE OR MORE OF THE FOLLOWING FUNCTIONALITIES:

(a) ENABLING CONSUMERS TO PARTICIPATE ACTIVELY IN MANAGING THEIR ELECTRIC CONSUMPTION USING INFORMATION, CONTROL, AND OPTIONS FOR ENERGY EFFICIENCY NOT PREVIOUSLY AVAILABLE TO CONSUMERS;

(b) INTEGRATING ELECTRICAL SYSTEMS USING UNIVERSAL INTEROPERABILITY STANDARDS;

(c) MONITORING, DIAGNOSING, AND RESPONDING TO POWER QUALITY DEFICIENCIES;

(d) OPTIMIZING THE USE OF SYSTEM ASSETS AND ENHANCING OVERALL EFFICIENCY THROUGH IMPROVED LOAD FACTORS AND BETTER MANAGEMENT OF OUTAGES;

(e) ANTICIPATING AND AUTOMATICALLY RESPONDING TO SYSTEM DEFICIENCIES;

(f) OPERATING RESILIENTLY WHEN CONFRONTED WITH A CYBER ATTACK OR NATURAL DISASTER; AND

(g) OPTIMIZING EFFICIENCY AND DEMAND RESPONSE.

(7) Repeal. THIS SECTION IS REPEALED, EFFECTIVE JULY 1, 2015.

SECTION 2. Federal funds. The general assembly anticipates that for the fiscal year beginning July 1, 2010, the department of governor-lieutenant governor-state planning and budgeting, office of the governor, governor's energy office, will receive the sum of twenty thousand dollars ($20,000) in federal funds and 0.4 FTE for the implementation of this act. Said sum shall be from federal State Energy Planning funds received through the American Recovery and Reinvestment Act of 2009. Although these funds are not appropriated in this act, they are noted for the purpose of indicating the assumptions used relative to these funds.

SECTION 3. Safety clause. The general assembly hereby finds, determines, and declares that this act is necessary for the immediate preservation of the public peace, health, and safety.

Brandon C. Shaffer PRESIDENT OF THE SENATE	Terrance D. Carroll SPEAKER OF THE HOUSE OF REPRESENTATIVES
Karen Goldman SECRETARY OF THE SENATE	Marilyn Eddins CHIEF CLERK OF THE HOUSE OF REPRESENTATIVES

APPROVED

Bill Ritter, Jr.
GOVERNOR OF THE STATE OF COLORADO

Appendix B: Task Force Members

Tom Plant, Chair

Tom Plant is the director of the Colorado Governor's Energy Office (GEO) and was appointed by Governor Bill Ritter in 2007. Prior to GEO, Plant was executive director of the nonprofit Center for Resource Conservation and served in the Colorado House of Representatives from 1998 through 2006, including two years as chairman of the House Appropriations Committee and one year as chairman of the Joint Budget Committee.

During his tenure in the general assembly, Plant was named "legislator of the year" by such organizations as the University of Colorado and the Sierra Club of Colorado, was the recipient of Colorado Conservation Voters' "Green Sense Award for Environmental Leadership," and received the "Champion of the Family Farmer" award from the Rocky Mountain Farmers' Union. In the late 1980s, Plant worked in the Climate Change Department of the Union of Concerned Scientists in Washington, D.C., exploring the causes of global climate change and policy options to address the threats of climate change.

Prior to his work at the Union of Concerned Scientists, and after graduating from Colorado State University, Plant worked in Oklahoma as an exploration geologist. Plant has traveled around the world and taught school in Central America. In 1994, he and his wife, Dawn Dennison, established The Acoustic Coffeehouse in Nederland, which became known nationally as a community gathering place, as well as a living-room setting for many famous musicians who played there. Tom and Dawn ran the coffeehouse for seven years before selling the business in 2001. The couple still lives in Nederland with their dog, Fergus, and a horse named Chester.

Paul Komor, Vice-Chair

Paul Komor is a lecturer in the Environmental Studies Program at the University of Colorado–Boulder and a senior advisor at E SOURCE, a Boulder-based energy-research firm. His current research is on renewable-energy technologies and policies, and their relationship to electric-utility restructuring. He currently teaches undergraduate and graduate courses in energy policy and technology at CU–Boulder. In 2001, he was awarded the Diebold Foundation for European Policy Studies and spent 2001 as a visiting academic in the Environmental Policy Group at Imperial College, London.

Prior to joining the University of Colorado faculty, he was a project director at the U.S. Congress's Office of Technology Assessment (OTA), where he worked with both House and Senate Congressional Committees in preparing and evaluating energy legislation. His 1992 report, "Building Energy Efficiency," played a major role in the debates that culminated in the Energy Policy Act of 1992. Prior to joining OTA, he taught at the Woodrow Wilson School at Princeton University. He holds a B.S. from Cornell University, and an M.S. and Ph.D. from Stanford University. He has published numerous refereed articles, reports, and other papers, and in 2004 published a book, *Renewable Energy Policy,* that compares United States and European Union experiences with regard to renewable-energy policies.

In 2005, Komor was selected 2006 MAP/Ming Visiting Professor of Energy and the Environment at Stanford University, where he spent six months at Stanford researching and teaching renewable-energy policy and technology. *Renewable Energy Policy* is now a required text for ESM 207, "Renewable Energy Law and

Policy," at the University of California–Santa Barbara (UCSB), as well as required or recommended reading for courses at University of Denver (DU), University of Utah, Robert Gordon University (UK), and elsewhere.

In 2007, Komor shared in the Nobel Peace Prize. The prize was awarded to Al Gore and the Intergovernmental Panel on Climate Change (IPCC) "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change." The IPCC consists of a large number of scientists and researchers — including Komor, who coauthored a chapter on "Mitigation Options for Human Settlements" in the IPCC's Second Assessment Report. For his work with the IPCC, Komor was named a contributor to the Nobel Peace Prize.

Also in 2007, Komor was appointed CU–Boulder's energy-education director, charged with the responsibility of enhancing CU–Boulder's energy-education efforts. He is currently working to institute undergraduate and graduate energy certificate programs, increase CU–Boulder's energy course offerings, and establish that institution as a leader in energy education.

Christopher Burke

Christopher Burke is vice president of operations at Black Hills Energy — Colorado Electric. In that role, he focuses on operational performance, strategy development, and execution and partnering with Black Hills Energy's many stakeholders to continue to support the growth of the southern Colorado communities where it operates.

Burke comes to Black Hills Energy from Alliant Energy, Inc., where he spent six-plus years in management positions, including director of energy market operations, director of business and financial performance, and plant manager at Alliant Energy's 730 MW coal-fired electric-power-generating station. Burke has held increasingly senior leadership positions in management consulting, e-procurement, consumer packaged goods, and internet-services industries over his nearly 25-year career, including his service as a nuclear engineer and commissioned officer in the U.S. Navy.

Burke holds an engineering degree from the U.S. Naval Academy, an MBA from the Darden Graduate School of Business, and a Juris Doctorate from the University of Virginia School of Law.

Mark Farnsworth

Mark Farnsworth is general manager of Highline Electric Association located in Holyoke, Colorado. He has been involved in rural distribution systems for 31 years starting at Wheat Belt Public Power District in Sidney, Nebraska. He became the general manager of Chimney Rock Public Power District, Bayard, Nebraska, in 1994. While at Chimney Rock, they participated with the testing of a microturbine on a distribution system. He has been at Highline as general manager for the last eight years. Highline participated in a study commissioned by NREL, DOE, and OEMC titled Distributed Wind Study for Northeast Colorado. The purpose of the study was to determine the ability to interconnect large wind turbines to a typical distribution system. Highline also has worked with Ormat Technologies to develop a 3.5 MW waste heat-recovery generation project near Crook, Colorado.

Highline has had AMR in place on a small portion of its meters since 2000 and is actively investigating Smart Grid options for the future. They started a 450 MHz pilot project for irrigation meters in 2010. The association's goal is to begin a Smart Grid build-out in 2012.

Mary Fisher

As Xcel Energy's vice president of strategic technologies, Mary Fisher oversees projects that identify and explore state-of-the-art technologies that help meet corporate goals, reduce emissions and improve environmental performance. She has assumed leadership for the nation's first fully integrated Smart Grid community at SmartGridCity™ in Boulder, Colorado. The initiative is a real-life demonstration of Smart Grid strategies designed to engage customers in energy management and allow the utility to better manage overall grid operations.

Prior to her current role, Fisher previously served as vice president of Colorado Resource Development, where she was responsible for evaluations of integrated gasification combined-cycle technology, carbon capture and sequestration, carbon-reduction plans, and financial impacts of plant retirements. She played an integral role in the permitting process for Comanche Unit 3, a new 750 MW coal-fired electric generating unit that will become the utility's newest plant in Colorado.

She also has served as Xcel Energy's vice president of transmission and planning, during which time she was accountable for operations, capital improvements, and project management of the utility's 10-state transmission system.

Fisher has been employed by Xcel Energy and its predecessor companies for 28 years in various management positions. She has an extensive background in energy delivery, business development, divestiture and plant decommissioning, nuclear management, and operations.

Fisher earned a bachelor of science in metallurgical engineering from the Colorado School of Mines. She currently serves on the board of directors for Warren Village, a Denver-based nonprofit that helps low-income and previously homeless single parents achieve personal and economic self-sustainability. She is also a past director of the Public Education and Business Coalition and a former committee member of the Mid-Continent Area Power Pool.

Ray Gogel

Ray Gogel serves as president and chief operating officer of Current Group, LLC, with responsibility for all areas of operations, including sales, marketing, product development and management, and information technology. Current provides real-time distribution grid visibility through intelligent sensing and analytics to enable utilities to maximize the value of existing assets while incorporating renewable sources of generation. Current's scalable solution combines advanced sensing technology with low latency IP based communications and enterprise analysis software and related services to provide location-specific, real-time actionable data that is easily integrated into a utility's existing IT infrastructure.

Prior to joining Current, Gogel worked for Xcel Energy, a major Midwest utility, where he was directly responsible for creating the nation's first SmartGridCity™ in Boulder, Colorado. Gogel joined Xcel Energy as chief information officer in 2002, and in 2005 became chief administrative officer and vice president of customer and enterprise services, where he was responsible for information technology, customer care and revenue cycle, human resources, and utility innovations. From 1999 to 2002, he was vice president and senior client services principal for the utilities practice at IBM Global Services and also held consulting positions at IBM, where he helped start its business process management practice.

Prior to joining IBM in 1996, Gogel spent 20 years in increasingly senior executive positions at Public Service Electric & Gas, the electric utility serving New Jersey. He received his doctorate and master's degrees from Drew University.

Dan Gregory

Dan Gregory is cofounder and president of Plymouth Systems, Inc., and chairman of the board of Green Energy Corp. Gregory has 25 years of experience as a power-system engineer, entrepreneur, and employer. He has worked on electric utility automation projects for several major electric utilities worldwide. Gregory has conceived and led the development effort of multiple monitoring, control, and systems products. He is chairman of the industrial advisory board of the FREEDM Systems Center, a National Science Foundation Gen-III Engineering Research Center hosted at North Carolina State University. Gregory founded GS4, a new division of Green Energy Corp, focused on open standards and open-source code to support the Smart Grid. He has filed two U.S. patents and is a member of the IEEE Power Engineering Society Standards Association and CIGRE.

Gregory is recognized internationally by the United Nations as a power expert and has been called upon to present on power generation and transmission issues.

Bill Levis

Bill Levis is the consumer counsel and the director of the Office of Consumer Counsel (OCC) in the Colorado Department of Regulatory Agencies. He has been in the position since March 2009.

Previously, he was the general counsel of CAP Logistics, a freight-forwarding company that the Denver Metro Chamber of Commerce named as small business of the year in 2008. Prior to that, Levis represented both large and small telecommunications companies before the Colorado Public Utilities Commission (PUC). He was the director of public policy for MCI in Denver and appeared on behalf of the company before PUCs and state legislatures in 20 states. Along with the OCC, Levis served on the task force that drafted the rules for local telecommunications competition. He also has appeared as a witness in telecom proceedings in several states, including Colorado.

Prior to joining MCI, where he worked for 19 years, Levis was as an assistant attorney general in the Colorado Department of Law. There for six years, he represented numerous departments, including the Department of Regulatory Agencies. He also has served as a special counsel to Colorado Legislative Council on personnel matters, as regional attorney for the U.S. Commission on Civil Rights, and as an attorney-investigator for the Colorado Civil Rights Commission.

Levis received his B.A. in political science from the University of Michigan and his J.D. from the University of Illinois. He is licensed to practice law in Colorado and Illinois. Levis is the president of the Brain Injury Association of Colorado and serves on the Colorado Traumatic Brain Injury Trust Fund Board. He also is on the board of the Silicon Flatirons telecommunications program at the University of Colorado and of Rocky Mountain Health Care Services in Colorado Springs.

John Nielsen

John Nielsen directs the energy program at Western Resource Advocates, an environmental law and policy center working to protect the environment of the interior Western United States. He is a leader in the Western environmental community on the relationship between energy policy and air quality, and has served as an expert witness in regulatory proceedings around the region involving utility resource planning, electric industry restructuring, renewable energy, energy efficiency, and green marketing. Nielsen holds a B.A. in mathematics and economics from the University of Colorado at Boulder and a M. Philosophy degree in economics from Yale University.

John Romero

John Romero is the general manager of acquisition, engineering and planning at Colorado Springs Utilities. In this role, he is responsible for developing and implementing the long-term strategic gas and electric plans. Romero directs all gas and electric integrated resource planning, renewable-energy/demand-side management, transmission/distribution planning, gas planning, field engineering, and associated engineering functions at Springs Utilities.

Romero has nearly 20 years of utility-industry experience and has served in various management capacities throughout his career. He has led in such areas as distribution and system operations, field operations, and EMS/SCADA. Romero has B.S. in electrical engineering and an MBA from the University of Colorado at Colorado Springs.

Wade Troxell

Wade Troxell received his B.S., M.S. and Ph.D. in engineering from Colorado State University and has been on the mechanical engineering faculty since 1985. He currently serves as the associate dean for research and economic development in the College of Engineering at CSU.

Troxell is a fellow of the American Society of Mechanical Engineers. He was recently appointed to the State of Colorado's Smart Grid Task Force. He is a founding member of the U.S. Department of Energy's GridWise Architectural Council and now serves as an emeritus member.

He founded the RamLab (Robotic and Autonomous Machines Laboratory), which has conducted educational, research, and outreach activities with more than $12 million in funding from industrial and federal sources. He is an internationally recognized expert in the areas of intelligent robotics and intelligent control of distributed energy systems. His Smart Grid research has focused on intelligent systems and the integration of the distributed energy resources (DER) including renewable energy into the electric power grid.

Dr. Troxell has formed the Smart Grid Innovation Center that is dedicated to the transformation of the U.S. electric power infrastructure. We have a vision of being a world leader and making a global impact in Smart Grid innovations and technologies. The Smart Grid Innovation Center takes a systems approach towards innovative research with the aim of furthering a secure U.S. Smart Grid infrastructure. A key facility of the Smart Grid Innovation Center is the InteGrid Laboratory developed in partnership with Spirae, Inc. With the City of Fort Collins, Spirae, and other partners, we have been awarded a DOE Renewable and Distributed Systems Integration (RDSI) Smart Grid demonstration project called FortZED. The Smart Grid Innovation Center works closely with our partners including the Northern Colorado Clean Energy Cluster and the Colorado Renewable Energy Collaboratory.

Dr. Troxell cofounded Sixth Dimension, Inc., a provider of network communications and real-time control technology for the electric power industry integrating in distributed energy resources. As President/COO, he led this early-staged company through three rounds of venture financing totaling over $18 million involving some of the top energy venture firms.

From 1988 to 1997, he cofounded and directed the Manufacturing Excellence Center (MEC) at CSU. MEC was a consortium of 41 laboratories and centers focused on improving the competitiveness and profitability of small- to medium-sized manufacturers in Colorado. He established Colorado's NIST-funded Manufacturing Extension Partnership (MEP) center and served as its executive director from 1992 to 1997.

Troxell serves on the Fort Collins City Council as an elected official representing District 4.

Appendix C: Deliberative Process

The Task Force was appointed in June 2010 and held seven public meetings between July and December of 2010 to craft a range of administrative and legislative recommendations to offer to the Governor of Colorado, the State Legislature and the Colorado Public Utilities Commission (PUC). The enabling legislation (SB 10-180) stipulated that the "Task Force:

- "Solicit and receive comments from the public;
- "Determine the manner in which those will be received;
- "Consider and give weight to any such comments from the general public, as well as written comments from affected counties, cities, state agencies, electric utilities, environmental groups, and other interested stakeholders;
- "Consider and give weight to research papers and technical information made available through current research projects at the commission, academic institutions, and from private citizens; and
- "Take notice of proceedings before the commission addressing Smart Grid development, confer with commissioners and commission staff, and consider and give weight to the records, findings, and decisions in those proceedings."

To aid the Task Force in understanding and developing recommendations around this subject, researchers from CU prepared a white paper titled "Smart Grid Deployment in Colorado: Challenges and Opportunities." Recommendations from this paper were utilized as a point of departure for the development of Task Force recommendations.

The Task Force deliberated on the issues stipulated in SB 10-180 and developed recommendations over the course of seven monthly meetings. Between meetings, facilitated group and individual calls were held to allow Task Force members to voice their interests and concerns related to each subject area. Following these calls, and taking into consideration the suite of interests and issues articulated by the Task Force and members of the public, teams of Task Force Members (termed "Subject Matter Experts") generated recommendations for each topic area. These recommendations became the starting point of deliberations for the Task Force in each public meeting.

Consensus recommendations are summarized in the executive summary and are highlighted throughout the report. In cases where consensus was not reached, the range of views is documented in the report.

Appendix D: Overview of Smart Grid Projects in Colorado

There are currently a number of Smart Grid projects of varying size and degree throughout the state of Colorado, including those listed here. A list of Smart Grid projects in Colorado and around the country is included in chapter one of the CU white paper, “Smart Grid Deployment in Colorado: Challenges and Opportunities.”

Smart Grid Projects

Black Hills/Colorado Electric Utility Company — Smart meters have been installed to 100 percent of the Colorado customer base, as well as the associated communications infrastructure. This project has established the foundation for future benefits to customers, including time-based pricing mechanisms and enhanced demand-response programs.

City of Fort Collins Utility — Installing 79,000 smart meters and in-home demand-response systems.

City of Fountain Utility — Installing 14,600 smart meters, extending fiber-optic network, and deploying outage-management system (in partnership with Loveland, Longmont, and Fort Collins).

City of Longmont — Installing smart meters.

City if Loveland — Installing smart meters.

Colorado Springs Utility — Installing AMI system.

Denver and Xcel DOE Grant — A demonstration project on Xcel Energy’s distribution system in Denver that will research, develop, and demonstrate a real-time monitoring, control, and health-management system to improve grid reliability and efficiency using digital data from sensors and substation intelligent electronic devices to continuously monitor system performance.

FortZED — U.S. Department of Energy renewable distributed systems integration demonstration project with a primary objective to substantially increase the use of distributive energy resources for supplying power during peak-load periods and services that support efficient management of electric-distribution systems.

Xcel Energy SmartGridCity™ — Comprehensive Smart Grid project in Boulder piloting a fully integrated Smart Grid community. It is a comprehensive system that includes a digital, high-speed broadband communication system; upgraded substations, feeders, and transformers; smart meters; and Web-based tools for consumers.

Rural Electric Associations

It is important to note that due to unique requirements and needs, rural electric cooperatives and associations (REAs) throughout Colorado have been investing for some time in technologies that would fall under many definitions of Smart Grid, including the definition utilized in this report. Examples of REAs using Smart Grid technologies include:

La Plata Electric Association has deployed SCADA and a 24-hour system-control system since 1996, as well as a 24-hour system-control center. They have utilized time-of-use programs for residential and commercial since 1990, been able to give industrial and large commercial customers the Tri-State load signal, and have been able to control their peak loads during Tri-State's peak period. They have been performing power-quality studies for the customer as well as on their distribution lines with technologies well before 1990. They have also implemented a high-quality outage management system (OMS), which gives their system controllers instant analysis of total outage information that is tied directly to their GPS, mapping system, and customer information systems. La Plata Electric Association's mapping and customer information data bases tied together in the last 10 years or so have enabled them to find potential overloaded transformers, fuses, and line OCRs before an outage occurs.

Poudre Valley Rural Electric Association, Inc. (PVREA) is installing an Automated Metering Infrastructure (AMI) system that will help achieve several goals, including energy efficiency and cost reduction, by using energy efficiently, reducing meter-reading costs, improving system efficiency, and reducing outage response time.

Morgan County Rural Electric Association launched a SCADA/AMI system in 2001, with 100 percent utilization completed in 2004 that allows them read each meter every day plus monitor and control many aspects of electric distribution, including improving load factor, thus reducing line loss.

The Colorado Rural Electric systems that purchase their wholesale power from Tri-State G&T also have access to the Cooperative Research Network to test all aspects of "smarter grid" deployment from meter-data management and associated data transfer, communications, metering and home area networks/devices for transferability to all cooperatives, and the Electric Power Research Institute, where they are research testing four smarter grid models, from grid optimization and customer participation, pricing, and behavior to grid automation, such as HAN, monitoring, detection, restoration to power plant driven, such as DR, LM, and DG/DER integration to retail/wholesale interface, particularly for disaggregated approaches and pricing approaches.

Highline Electric Association has implemented a demand-response (DR) program for irrigation consumers since 2004. In that time period, more than $5 million have been returned to Highline and its members who participated in the load-control program. The irrigation load control has an effective participation rate of 50 percent. Highline is also working with Tracciare, a wireless AMI technology company for three-phase and single-phase meters headquartered in Fort Worth, Texas, to integrate with their existing Cannon Yukon system. The pilot project will identify utilizing wireless technology to control irrigation loads, reduce communications costs and build out a wireless AMI system.

Delta Montrose REA — Installed 31,000 smart meters.

Appendix E: Overview of Relevant Legislation and PUC Activities

Smart Grid–Related Legislation to Date

Colorado Senate Bill 10-180, the enabling legislation for the Task Force, is the only piece of state legislation pertaining to Smart Grid that has been passed.

Smart Grid–Related Colorado PUC Activities to Date:

In its 2009 rate case (Docket No. 09AL-299E), Public Service Company of Colorado (Public Service) sought to recover costs related to its SmartGridCity project in Boulder, Colorado. In December 2009, through Decision No. C09-1446, the commission required Public Service to file an application for a Certificate of Public Convenience and Necessity (CPCN) for SmartGridCity™, finding that the project was neither in the ordinary course of business nor a simple distribution project. The commission permitted Public Service to begin recovering costs associated with SmartGridCity™ pending the CPCN proceeding, subject to refund if the CPCN was not granted. A final decision in the CPCN proceeding (Docket No. 10A-124E) is forthcoming.

The commission, on May 19, 2010, in a separate docket (No. 09A-796E), approved of Public Service's application to implement a pilot program testing three time-variable rate options for residential customers using the SmartGridCity™ platform. The rates, which took effect on October 1, 2010, include a time-of-use (TOU) rate, a critical peak pricing (CPP) rate, and a peak time rebate (PTR). The goal of the pilot program is to provide feedback on the effect of time-variable rates on reductions in peak demand, energy consumption, carbon footprint, and whether the rates defer capital spending for transmission and distribution. The pilot program is projected to conclude by September 30, 2013, at the latest.

On March 3, 2010, the PUC opened an investigatory docket (10I-099EG) with the goal of creating a knowledge resource to help inform future Smart Grid deliberations and rule makings. This investigatory docket exists to explore key regulatory issues related to the Smart Grid concept and bring into the record relevant Smart Grid analyses, secondary research, and public comments. Some of the issues being explored in the docket include new rate designs, impacts on low-income customers, methodologies for evaluating utility investments in Smart Grid technologies, the required components of a utility Smart Grid CPCN application, and PHEV rate design.

In order to examine the legal and regulatory issues concerning consumer privacy as the quality and quantity of data resulting from installing smart-meter technology increases, the commission opened a separate investigatory docket (09I-593EG) in August 2009 devoted to this issue. After two rounds of public comment, proposed rules relating to Smart Grid data and privacy issues were drafted and released in a Notice of Proposed Rulemaking on November 4, 2010 (Decision No. C10-1192, Docket No. 10R-799E).

The Colorado PUC is also researching a number of wide-ranging federal regulatory standards for cyber security. Currently NIST has drafted standards that are being considered by FERC. They include, for example, 189 rules that help mitigate risk in a number of areas within the Smart Grid architecture. Based on the outcome of federal deliberations, the PUC will likely deliberate, through a rule-making procedure, on adoption of the federal standards as "recommended practices" by the electric utilities within Colorado for

Smart Grid cyber security risk mitigation. In addition, with respect to Smart Grid interoperability, there are 25 NIST standards ready for immediate applicability, along with another 50 that are currently under EPRI review.

The commission acknowledges the potential benefits and complexities of the Smart Grid concept and, through the efforts mentioned above, is aiming to remove regulatory uncertainty regarding Smart Grid implementation in the state of Colorado while serving the public interest by balancing concerns that relate to utilities, consumers, the environment, and economic development.

Appendix F: Presenters

These speakers presented to the Task Force on their specific areas of Smart Grid expertise.

Frank Barnes
Distinguished Professor of Electrical and Computer Engineering
University of Colorado

Ron Binz
Chairman
Colorado Public Utilities Commission

Steve Catanach
Fort Collins Power and Light Manager
Fort Collins Utility

Sunil Cherian
Chief Executive Officer
Spirae, Inc.

Lynn DeForest Hunt
Chief Solution Architect
Energy Division
Alcatel-Lucent

Kevin Doran
Senior Research Fellow
Center for Energy & Environmental Security (CEES)
University of Colorado

Karen Ehrhardt-Martinez
Research Associate
Renewable and Sustainable Energy Institute (RASEI)
University of Colorado

Jennifer Shipley
Policy Advisor for Western U.S.
Federal Energy Regulatory Commission

Julie Simon
Director of Public Policy
Federal Energy Regulatory Commission

Dennis Sumner
Senior Electrical Engineer
City of Fort Collins

Appendix G: Additional Resources for Technical Understanding

This report and the recommendations of the Colorado Smart Grid Task Force focus on the policy and regulatory environment in Colorado and how they influence Smart Grid. For those interested, these resources may provide more technical background on Smart Grid.

AARP, National Consumer Law Center, National Association of State Utility, Consumer Advocates, Consumers Union, and Public Citizen (2010). *The Need For Essential Consumer Protections Smart Metering Proposals and the Move to Time-Based Pricing.*
http://www.nclc.org/images/pdf/energy_utility_telecom/additional_resources/adv_meter_protection_report.pdf

Darby, Sarah (2006). *The Effectiveness of Feedback on Energy Consumption — A Review for DEFRA of the Literature on Metering, Billing and Direct Displays.*
http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf

Ehrhardt-Martinez, K., Donnelly, K., and Laitner, J. (2010). *Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities.*
http://www.aceee.org/research-report/e105

EPRI. (2010). *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects.*
http://www.smartgridnews.com/artman/uploads/1/1020342EstimateBCSmartGridDemo2010_1_.pdf

Franklin Energy (2009). *Residential Energy Use Behavior Change Pilot.*
http://www.opower.com/LinkClick.aspx?fileticket=cLLj7p8LwGU%3d&tabid=76

KEMA for the Gridwise Alliance (2009). *The U.S. Smart Grid Revolution — KEMA's Perspectives for Job Creation.*
http://www.kema.com/Images/KEMA_SmartGrid%20Jobs%20Creation_01-13-09.pdf

Lichtenberg, S. National Regulatory Research Institute (2010). *Smart Grid Data: Must There Be Conflict between Energy Management and Consumer Privacy?*
http://www.nrri.org/pubs/telecommunications/NRRI_smart_grid_privacy_dec10-17.pdf

National Institute of Standards and Technology (2010). *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0.*
http://www.nist.gov/public_affairs/releases/upload/smartgrid_interoperability_final.pdf

North American Electric Reliability Corporation (2010). *Reliability Considerations from the Integration of Smart Grid.*
http://www.nerc.com/files/SGTF_Report_Final_posted.pdf

Quinn, E.L. (2009). *Smart Metering & Privacy: Existing Law and Competing Policies.*
http://www.dora.state.co.us/puc/DocketsDecisions/DocketFilings/09I-593EG/09I-593EG_Spring2009Report-SmartGridPrivacy.pdf

Appendix H: Data and Information Ownership

Smart Grid deployment will produce a significant amount of new data about users and uses on the grid. This data could prove valuable to a number of entities. Consumers have an interest in protecting the integrity of data and information that could be used to determine their actions or habits. Utilities need access to the data and information for billing and operations purposes. Utilities and third parties also see an opportunity to use this data to provide additional services to consumers.

Currently, there is no national or global consensus on who owns or should own the data. The Task Force recommended in this report that the state should monitor this debate. In Colorado, the PUC opened an investigatory docket (09I-593EG) in August 2009 to examine the legal and regulatory issues concerning consumer privacy. After two rounds of public comment, proposed rules relating to Smart Grid data and privacy issues were drafted and released in a Notice of Proposed Rulemaking on November 4, 2010 (Decision No. C10-1192, Docket No. 10R-799E).

The National Regulatory Research Institute is also studying the issue and released its report on Smart Grid privacy in December 2010 titled *Smart Grid Data: Must There Be Conflict between Energy Management and Consumer Privacy.* The report is available at **http://www.nrri.org/pubs/telecommunications/NRRI_smart_grid_privacy_dec10-17.pdf.**

Throughout the debate, two models have been proposed for regulating data ownership:

(1) **Ownership derived from infrastructure development —** The party that builds the infrastructure owns all data generated, recorded, stored, or transmitted by its infrastructure.

(2) **Consumer owns all data —** Metering and energy-usage data should be considered the property of the customer, regardless of whether this data is kept by the customer, utility, or a third-party service provider.

Many organizations, including the Electronic Privacy Information Center (EPIC) and a number of utilities, are working together to find a hybrid model between these two models that adequately supports the interests of all vested parties.

Appendix I: Definitions

Unless otherwise indicated, definitions are from the U.S. Energy Information Administration (EIA) glossary.

Advanced Metering Infrastructure (AMI) — Advanced Metering Infrastructure is a term denoting electricity meters that measure and record usage data at a minimum, in hourly intervals, and provide usage data to both consumers and energy companies at least once daily.

Balancing Authority — The responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a balancing authority area, and supports interconnection frequency in real time.

Combined Heat and Power (CHP) — Production of both heat and electricity from a single heat source.

Demand Response (DR) — In which the demand for electricity is modified to reflect the needs of the overall electricity system. An example is a system in which customers reduce their electricity demand in response to a price signal when electricity supplies are tight.

Demand-Side Management (DSM) — The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. DSM refers only to energy and load-shape-modifying activities undertaken in response to utility-administered programs. It does not refer to energy and load-shaped changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. Demand-Side Management covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.

Distributed Energy Resources (DER) — A different type of electricity system in which large quantities of electricity are produced and managed at the distribution-system level.

Distributed Generation (DG) — Electricity generation that is located close to the particular load that it is intended to serve.

Distribution System — The portion of the transmission and facilities of an electric system that is dedicated to delivering electric energy to an end user.

Masked Load (from Task Force) — Occurs as distributed generation reduces the demand on the grid experienced by the utilities but does not decrease the number of users on the grid who rely on the grid for backup power. This mismatch between visible demand and potential-capacity need is masked load and makes utility capacity planning more difficult. This concept is also known as behind-the-meter-generation (BTMG).

Prosumer (from Task Force) — A producer-consumer who provides both power and reliability back into the grid.

Reliability — A measure of the ability of the system to continue operation while some lines or generators are out of service. Reliability deals with the performance of the system under stress.

Reserve — That portion of the demonstrated reserve base that is estimated to be recoverable at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the demonstrated reserve base.

Supervisory Control and Data Acquisition (SCADA) — A system of remote control and telemetry used to monitor and control the transmission system.

Smart Grid (from CO SB 10-180) — A system for electric transmission or distribution within the certificated service territory of an electric utility that incorporates one or more of the following functionalities:

(a) Enabling consumers to participate actively in managing their electric consumption using information, control, and options for energy efficiency not previously available to consumers

(b) Integrating electrical systems using universal interoperability standards

(c) Monitoring, diagnosing, and responding to power-quality deficiencies

(d) Optimizing the use of system assets and enhancing overall efficiency through improved load factors and better management of outages

(e) Anticipating and automatically responding to system deficiencies

(f) Operating resiliently when confronted with a cyber attack or natural disaster

(g) Optimizing efficiency and demand response

Supply — Energy made available for future disposition. Supply can be considered and measured from the point of view of the energy provider or the receiver.

Timely Data — Data available in short enough time intervals to match the value proposition of the derived service or application.

Transmission — (1) n. An interconnected group of lines and associated equipment for the movement or transfer of electric energy between points of supply and points at which it is transformed for delivery to customers or is delivered to other electric systems. (2) v. The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

Acknowledgment and Disclaimer

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Governor's Energy Office

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