Illinois Statewide Smart Grid Collaborative

# Smart Grid Applications and Technologies

DRAFT

August 13, 2010

# Table of Contents

[Smart Grid Applications and Technologies 1](#_Toc264891637)

[Table of Contents 2](#_Toc264891638)

[1. Introduction 4](#_Toc264891639)

[1.1. Objectives and Purpose 4](#_Toc264891640)

[1.2. Scope 5](#_Toc264891641)

[1.3. Definitions and Context 6](#_Toc264891642)

[1.3.1. Potential Benefits 6](#_Toc264891643)

[1.3.2. Customer Benefits 7](#_Toc264891644)

[1.3.3. Utility Benefits 8](#_Toc264891645)

[1.3.4. Regional Electricity Market Benefits 8](#_Toc264891646)

[1.3.5. Competitive Supplier and Third Party Benefits 9](#_Toc264891647)

[1.3.6. RTO/ISO Benefits 9](#_Toc264891648)

[1.3.7. Societal Benefits 9](#_Toc264891649)

[1.3.8. Beneficiaries 10](#_Toc264891650)

[1.3.9. Potential Negative Impacts 12](#_Toc264891651)

[2. Smart Grid Applications 13](#_Toc264891652)

[2.1. AMI Applications 13](#_Toc264891653)

[2.1.1. Core AMI Functionality 13](#_Toc264891654)

[2.1.2. Remote Connect/Disconnect 17](#_Toc264891655)

[2.1.3. Outage Management Support 19](#_Toc264891656)

[2.1.4. Power Quality/Voltage Monitoring at Meter 22](#_Toc264891657)

[2.1.5. Customer Prepayment Utilizing AMI 24](#_Toc264891658)

[2.2. Customer-Oriented Applications 27](#_Toc264891659)

[2.2.1. In-Premises Devices for Energy Usage Data 27](#_Toc264891660)

[2.2.2. Customer Web Portal for Energy and Cost Data 30](#_Toc264891661)

[2.2.3. Outage Notification to Customer 33](#_Toc264891662)

[2.2.4. Government and Third Party Use of Customer Data 35](#_Toc264891663)

[2.3. Demand Response Applications 38](#_Toc264891664)

[2.3.1. Pricing Information to In-Premises Devices 38](#_Toc264891665)

[2.3.2. Direct Load Control 41](#_Toc264891666)

[2.3.3. System Frequency Signal to Customer Load Control Devices 44](#_Toc264891667)

[2.3.4. System Renewables Output to Customers 46](#_Toc264891668)

[2.4. Distribution Automation Applications 49](#_Toc264891669)

[2.4.1. Automatic Circuit Reconfiguration 49](#_Toc264891670)

[2.4.2. Improved Fault Location 51](#_Toc264891671)

[2.4.3. Dynamic System Protection for Two-Way Power Flows and Distributed Resources 54](#_Toc264891672)

[2.4.4. Dynamic Volt-VAR Management 56](#_Toc264891673)

[2.4.5. Conservation Voltage Optimization 59](#_Toc264891674)

[2.5. System and Asset Monitoring and Modeling 61](#_Toc264891675)

[2.5.1. Asset Sizing Optimization 62](#_Toc264891676)

[2.5.2. Asset Condition Monitoring 64](#_Toc264891677)

[2.5.3. Enhanced System Modeling and Planning 66](#_Toc264891678)

[2.6. Distributed Resource Applications 69](#_Toc264891679)

[2.6.1. Customer Distributed Resource Interconnection 69](#_Toc264891680)

[2.6.2. Coordinated Management of Distributed Resources 71](#_Toc264891681)

[2.6.3. Electric Vehicles: Optimized Charging 74](#_Toc264891682)

[2.6.4. Dispatch of Electric Vehicle Storage 77](#_Toc264891683)

[2.7. Transmission Applications 79](#_Toc264891684)

[2.7.1. Wide Area (Phasor) Measurement 80](#_Toc264891685)

[2.7.2. Wide Scale Outage Recovery 81](#_Toc264891686)

[2.7.3. Enhanced Physical Security 84](#_Toc264891687)

[3. Smart Grid Technologies 86](#_Toc264891688)

[3.1. End Point Technologies 86](#_Toc264891689)

[3.1.1. AMI Meters 86](#_Toc264891690)

[3.1.2. Electric Vehicle Charging Portal 90](#_Toc264891691)

[3.1.3. In-Premises Device 91](#_Toc264891692)

[3.2. Line Technologies 93](#_Toc264891693)

[3.2.1. Capacitor Bank Controllers 93](#_Toc264891694)

[3.2.2. Dynamic Line Rating Sensors 95](#_Toc264891695)

[3.2.3. Fault Indication Devices 98](#_Toc264891696)

[3.2.4. Fault Location Devices 99](#_Toc264891697)

[3.2.5. Feeder Switch Controllers 100](#_Toc264891698)

[3.2.6. Recloser Controllers 101](#_Toc264891699)

[3.3. Substation Technologies 102](#_Toc264891700)

[3.3.1. Asset Condition Monitoring Sensors 102](#_Toc264891701)

[3.3.2. Data Concentrators 104](#_Toc264891702)

[3.3.3. Fault and Disturbance Recorders 105](#_Toc264891703)

[3.3.4. Flexible AC Transmission System Devices 107](#_Toc264891704)

[3.3.5. Substation Computer 110](#_Toc264891705)

[3.3.6. Substation Controllers and Remote Terminal Units (RTUs) 111](#_Toc264891706)

[3.3.7. Substation IEDs 113](#_Toc264891707)

[3.3.8. Substation Gateway or Data Manager 116](#_Toc264891708)

[3.3.9. Phasor Measurement Units and Applications 119](#_Toc264891709)

[3.3.12. Protective Relays 121](#_Toc264891710)

[3.3.13. Power Quality Monitors 123](#_Toc264891711)

[3.3.15. Transformer Monitoring and Dynamic Rating 124](#_Toc264891712)

[3.4. Telecommunications Network Technologies 128](#_Toc264891713)

[3.4.1. Premises Networks 128](#_Toc264891714)

[3.4.2. AMI Network 130](#_Toc264891715)

[3.4.3. Wide Area Network 134](#_Toc264891716)

[3.5. Enterprise Systems Technologies 136](#_Toc264891717)

[3.5.1. AMI Management System 137](#_Toc264891718)

[3.5.2. Meter Data Management System 139](#_Toc264891719)

[3.5.3. Asset Management/Monitoring System 142](#_Toc264891720)

[3.5.4. Distributed Resource Management System 143](#_Toc264891721)

[3.5.5. Distribution Management System 144](#_Toc264891722)

[3.5.6. Planning and Modeling System 145](#_Toc264891723)

[3.5.7. SCADA System 147](#_Toc264891724)

[3.6. Appendices 149](#_Toc264891725)

[3.6.1. Appendix A – Reactive Power 149](#_Toc264891726)

# 

## Introduction

This section introduces the Smart Grid Applications and Technologies chapter of the report.

### Objectives and Purpose

One of the key Collaborative tasks identified by stakeholders was to develop a comprehensive list of potential smart grid investments. This task is consistent with the first foundational policy identified in the ICC Order authorizing the Collaborative – a definition of a smart grid and its functionalities.

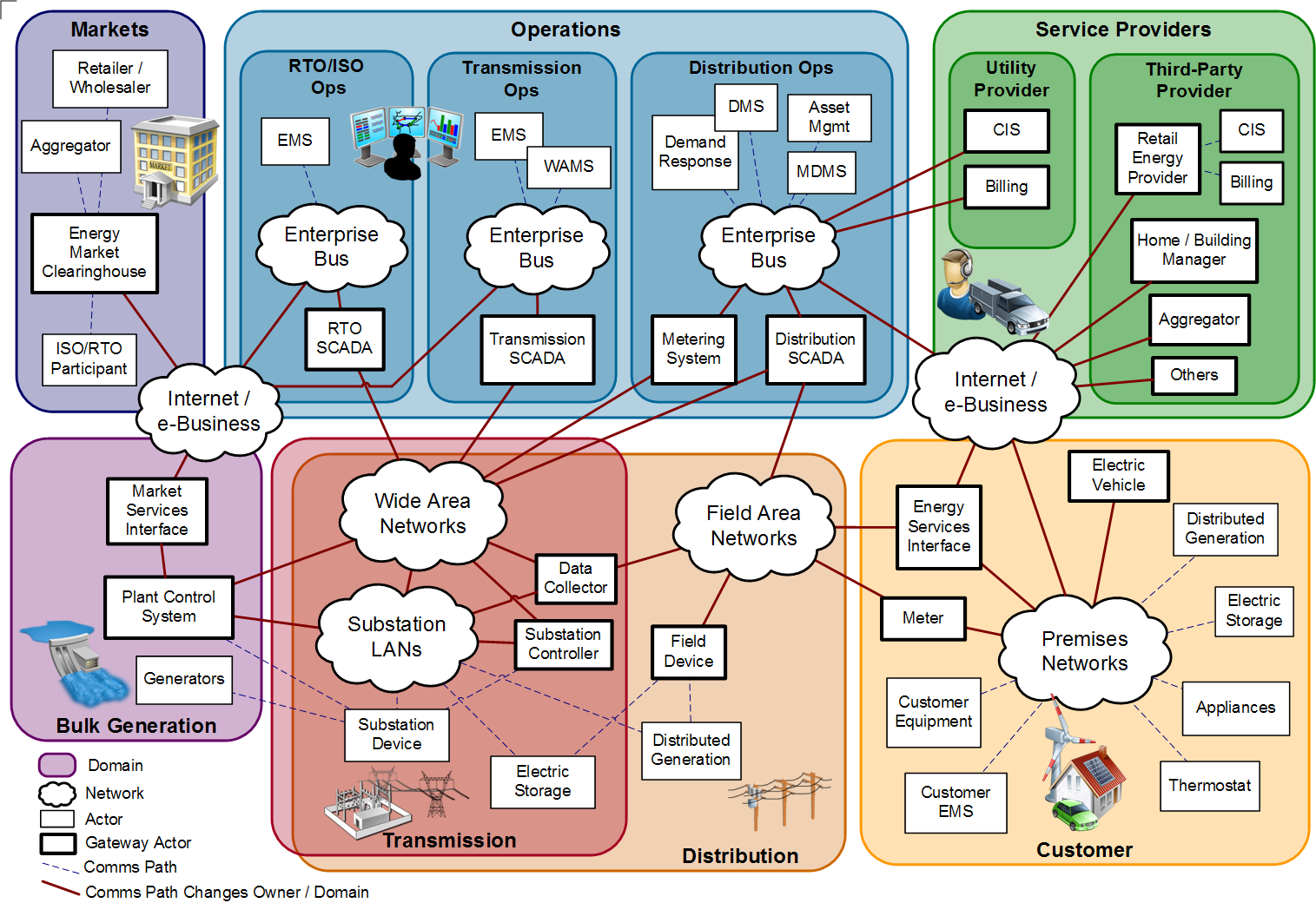
This chapter of the report provides a catalog of the smart grid investments that could be considered by the electric utilities in Illinois. The chapter is divided into two sections: Smart Grid Applications and Smart Grid Technologies. Smart grid *applications* integrate hardware, software, and/or infrastructure (technologies) to deliver defined smart grid functionality and value. Smart grid *technologies* are the hardware, software, and infrastructure building blocks needed for the applications to deliver smart grid functionality/value.

The objectives of this chapter in the report include the following:

* Provide the Commission with a comprehensive list of smart grid investments that could be considered by the electric utilities in Illinois
* Identify the specific functionalities that could be provided by these investments and the potential sources of benefits to customers, utilities, other electricity market participants (RTO/ISO, competitive electric suppliers, and third parties), and society that could result from these investments
* Provide a mapping between the potential benefits of smart grid applications and beneficiaries
* Identify the potential sources of cost associated with these investments as well as any potential negative impacts
* Provide an informational resource for the Commission on the potential applications and technologies associated with smart grid
* Provide an informational resource and organizational framework for the work of the Collaborative, including the identification of:
  + Primary smart grid applications (input for the development of technical requirements for smart grid (see Chapter 4.0))
  + Potential sources of cost and benefit for each application (input for the development of a smart grid cost-benefit framework (see Chapter 5.0))
  + Potential beneficiaries of application deployment (input for the development of a smart grid cost-benefit framework (see Chapter 5.0))
  + Potential negative impacts of application deployment (input for the development of recommended smart grid-related consumer policy (see Chapter 3.0) and utility filing requirements for smart grid investment (see Chapter 6.0)).

### Scope

Smart grid applications can have an impact on the entire electricity value chain – from sources of generation, the growth of other energy resources, energy markets, the transmission grid, the distribution network, to competitive energy suppliers and individual customers. Some applications are limited to a few elements in the value chain while others span many elements. Linking the smart grid elements together requires a robust, two-way communications network. NIST has developed a conceptual reference model for smart grid that depicts the various “domains” that can be impacted by smart grid.



At the direction of the Illinois Commerce Commission, this chapter on Smart Grid Applications takes a broad view of smart grid, identifying smart grid applications and mapping costs, benefits and potential beneficiaries without regard to the Commission's jurisdictional limitations. The inclusion of smart grid applications that would primarily impact elements of the value chain outside of the Commission’s jurisdiction carries with it no assumption that cost recovery for these investments would be limited to jurisdictional delivery service ratepayers. Rather, this broader perspective was adopted to provide the Commission with a comprehensive understanding of the potential of smart grid and the need for collaboration and cooperation among market participants and regulators across all of the smart grid domains.

It is important to recognize that smart grid is an evolving concept. Although every effort was made to identify a comprehensive set of smart grid applications and technologies in this chapter, it should be understood that new smart grid applications and technologies will be developed over time. Therefore, the list of applications and technologies identified and discussed herein should not be considered to be exhaustive or definitive.

Although an attempt is made in the chapter to identify the potential sources of cost and benefit for a set of smart grid applications, no effort was made to quantify these costs or benefits. An analysis of specific application costs and benefits was determined to be outside of the scope of the Collaborative. Therefore, no conclusions (pro or con) should be drawn about the ultimate cost-effectiveness or prudence associated with an implementation of the identified smart grid applications in Illinois.

### Definitions and Context

The focus of this chapter is on smart grid applications and smart grid technologies. Smart grid *applications* integrate hardware, software, and/or infrastructure (technologies) to deliver defined smart grid functionality and value. Smart grid *technologies* are the hardware, software, and infrastructure building blocks needed for the applications to deliver smart grid functionality/value. A separate section of the chapter is dedicated to each.

To facilitate understanding of the following sections, some additional definitions and clarifications are provided.

### Potential Benefits

Potential benefits are identified as those plausibly expected outcomes of an application deployment that would be value-creating to a customer, utility (in its transmission and distribution functions), RTO/ISO, competitive supplier, third party (including government), and/or society.

* For customers, the potential benefits realized by individual electricity consumers in Illinois, include reductions in customer costs for electric delivery service and energy supply service, and decreases in outages and improved power quality.
* For distribution and transmission utilities, value is recognized in benefits that would work to reduce costs, improve system reliability, increase levels of customer satisfaction, optimize assets, and/or mitigate risk
* For regional electricity markets, value is recognized through the reduction in regional energy and/or capacity prices
* For competitive suppliers, third parties, and government, value is recognized through enabling the creation of new value-adding products/services for customers or residents
* For RTO/ISO, value is recognized through increased grid stability, improved system awareness, improved forecasting, and more competitive markets for ancillary services
* Societal value is realized by society as a whole, not necessarily Illinois electricity consumers (e.g., environmental benefits, improvements to public health and safety, economic development, and improvements to or the expansion of broadband communications networks)

Potential benefits described in this chapter are those that are plausibly expected; however, the realization of particular benefits may be contingent on a number of factors, including:

* Participation by the customer or other market entities
* Existence of supporting and effective business and regulatory models
* Establishment of supportive legislative and regulatory polices
* Sufficient deployment/coverage in a utility’s service territory
* Sufficient customer adoption rates
* Persistence of customer results over time

Although no effort was made to quantify potential benefits, an attempt was made to differentiate between *primary* and *secondary* benefits.

* A **primary benefit** would be one that would be plausibly expected to be a primary contributing factor to the positive, value-creating elements in a cost-benefit analysis of the application.  Primary benefits would represent the likely driving motivations behind a decision to evaluate an application for deployment.
* A **secondary benefit** would be a factor that would be expected to supplement the other positive factors/benefits in a cost-benefit analysis of the application or may be ancillary to or a byproduct of a major or primary benefit.  As a standalone factor, a minor benefit would not likely be sufficient to justify application deployment.

### Customer Benefits

* **Reduce energy usage – efficiency** -- This benefit is achieved indirectly by making the customer aware of the energy usage and energy costs of various appliances or devices at their premises and encouraging the customer to improve efficiency.
* **Reduce energy usage – conservation** -- Conservation is achieved when the customer reduces their energy consumption and does not shift the saved energy usage to another time. This benefit is achieved by making the customer more aware of their energy usage and costs and incentivizing them to change their energy consumption patterns.
* **Improve information availability to the customer** -- This generic benefit can apply to any scenario where the customer is provided with information that is useful to the customer. Examples are: notifying the customer about power outages, feedback on a price based demand response event and provide customers with information about current generation sources.
* **Increase ability to manage energy cost** -- This benefit assumes that providing more detailed information about energy usage and costs to the customer will allow them to make better decisions about how and when they use energy.
* **Enhance services to the customer** -- This benefit is achieved by enhancing existing or providing new services to the customer. The service may be provided by the utility, a competitive supplier, private sector third party or a governmental entity.
* **Facilitate integration of customer generation** – This benefit is achieved by facilitating the integration and operation of customer owned generation devices.
* **Improve system availability** -- This benefit applies to any scenario where outages affecting the customer are reduced in frequency or duration of occurrence.
* **Improve power quality** -- This benefit occurs when the utility is able to detect and correct power quality problems or by decreasing the number of distribution fault current events to which a customer is exposed.

### Utility Benefits

* **Increase field labor productivity** -- This benefit occurs when automation, communications or efficiency improvements reduce utility field labor costs
* **Reduce back office support costs** -- This benefit occurs when automation, communications or efficiency improvements reduce utility back office costs
* **Improve system reliability** -- This benefit occurs for reductions in frequency or duration of outages
* **Improve forecasting and modeling** -- This benefit is achieved by improving the accuracy of the utility’s load predictions and electric system modeling. This benefit can represent both long and short term forecasts
* **Improve situational awareness** -- This is an improvement in the utility’s real time visibility for the electric system’s status allowing for quicker identification and resolution of system performance issues
* **Extend asset life** -- This benefit occurs for extending the useful life of any utility electrical system assets by reducing stress on those assets and improving maintenance
* **Reduce failure rates** -- This benefit occurs for reducing asset failures, especially of electric system components
* **Improve asset performance** -- This benefit occurs if system assets can be made to perform more efficiently.
* **Improve employee safety** -- This benefit typically occurs by reducing the amount of time employees spend in the field.
* **Reduce non-energy procurement cost** -- Procurement costs can be reduced by having better data to correctly size a new or replacement asset and improving the ability to plan for new or replacement assets.
* **Reduce line losses** -- Line losses can be improved by correcting power factor, lowering voltage, and correctly sizing and siteing utility equipment
* **Reduce lost revenues (theft)** -- This benefit is achieved by stopping, deterring or detecting theft.
* **Reduce lost revenues (unbilled)** -- This benefit is achieved by reducing unbilled energy delivered.
* **Improve collections or cash flow** -- This benefit is achieved by increasing the collection rate of late payments and no payments. This may not be a utility benefit due to a uncollectables rider that is or soon will be in place.

### Defer investments or enhancements -- This benefit occurs when the utility can extend current systems and assets to meet future needs. Regional Electricity Market Benefits

* **Reduce electricity price volatility** – This benefit is the moderation of electricity prices resulting from increased deployment and utilization of demand response and distributed energy resources
* **Reduce energy supply and capacity prices** – These benefits can result from changes in the magnitude or timing of electricity demand and deferrals or reductions in transmission and generation investment

### Competitive Supplier and Third Party Benefits

* **Improve or expand products and services** -- This benefit occurs when new services or products are accommodated by smart grid technology or when competitive suppliers and third parties receive more customer data, higher resolution data, or customer data that provides the competitive suppliers and third parties with opportunities to offer new or improved services.

### RTO/ISO Benefits

* **Increase grid stability** -- This benefit occurs by reducing the frequency and duration of transmission level outages that affect the RTO / ISO
* **Improve situational awareness** -- This is an improvement in the RTO / ISO’s real time visibility for the electric system’s status allowing for quicker identification and resolution of system performance issues
* **Improve forecasting and modeling** -- This benefit is achieved by improving the accuracy of the RTO / ISO’s load predictions and electric system modeling. This benefit can represent both long and short term forecasts
* **Improve settlement process --** This benefit occurs if there are efficiency and effectiveness improvements in the RTO/ISO’s settlement process
* **Increase market competitiveness (ancillary services)** – This benefit occurs through the expansion of participants in the market for ancillary services

### Societal Benefits

* **Increase use of renewables** -- With better information, load can be more readily shifted to occur when preferred renewable generation output is higher and new grid functionalities can facilitate incorporation of renewable resources into the supply portfolio
* **Reduce carbon footprint** -- Carbon emissions are assumed to slightly decrease by reducing utility vehicle miles or reducing system load that depends on carbon based generation
* **Improve air quality** -- This benefit primarily occurs if coal generation can be reduced
* **Improve public safety** -- This benefit is generally achieved by reducing the frequency and duration of outages
* **Improve economic productivity** -- This benefit is generally achieved by reducing the frequency and duration of outages
* **Improve system resiliency (disaster recovery)** -- This benefit is generally achieved by reducing the frequency, duration and scale of outages
* **Improve broadband/communications network** – This benefit is generally achieved through improvements to, or the expansion of, broadband/communications networks in connection with the development of the smart grid

### Beneficiaries

A beneficiary is the entity that would initially realize the benefit. Benefits initially realized by utilities are assumed to accrue to customers through the regulatory process.

For the purposes of mapping benefits to beneficiaries, six categories of beneficiaries were designated.

* Customers
* Utility
  + Distribution
  + Transmission
* Regional Electricity Markets
* Third-parties/competitive suppliers
* RTO/ISO
* Society

Since not all customers would stand to realize the same kind (and magnitude) of benefits, the following customer groups were identified.

* Residential / Small Business – Served through distribution system and IPA
  + Active Participants – Utilize AMI data and other smart grid technologies and applications to participate in new rate structures. Active participants also receive passive participant benefits.
  + Passive Participants – Benefit from utility SG efficiencies and market improvements.
* Medium Sized Businesses – Served through distribution system and RES. May or may not have AMI meter, but will not have service switches.
  + Active Participants – Utilize AMI data and other smart grid technologies and applications to participate in new rate structures. Active participants also receive passive participant benefits.
  + Passive Participants – Benefit from utility SG efficiencies and market improvements.
* Large Businesses – Served through transmission system and RES. Benefit from utility SG efficiencies and market improvements
  + Active Participants
  + Passive Participants

These customer groupings provide some additional insight into the relative benefit realized by specific customer groups. However, even within these segmentations, subgroups or individuals may realize specific benefits to greater or lesser degrees. For that reason, potential benefits may need to be mapped and understood in greater detail for cost allocation purposes.

Consistent with the above definitions, a graphical representation was prepared for each application depicting the potential source of primary and secondary benefits and a mapping of these benefits to beneficiaries. The following graphics are representative of those used in the following section of the report. Primary benefits are depicted with green-shaded boxes; secondary benefits are depicted with yellow-shaded boxes.

### Potential Negative Impacts

A “potential negative impact” would be a plausibly expected outcome of an application deployment that could be expected to reduce, or detract from, value to a customer, utility (in its distribution and transmission functions), RTO/ISO, competitive supplier/third party, and/or society. Categories of potential negative impacts include:

* Customer, including negative impacts on customer privacy, customer safety, customer equipment, or customer costs
* Technology, including risks and costs resulting from increased reliance and dependence on digital technologies
* Employee and Public Safety
* Utility Operations, including potential increases in undetected energy theft, legal costs, or customer care costs.

Potential negative impacts are application-specific and discussed in further detail, by application, in the following section. Additional discussion of potential negative impacts can be found in the Consumer Policy Issues chapter.

### *Smart Grid Applications*

The Collaborative identified 28 different smart grid applications. Smart grid applications integrate hardware, software, and/or infrastructure (technologies) to deliver defined smart grid functionality and value. The identified applications were organized into seven categories:

* AMI Applications
* Customer-Oriented Applications
* Demand Response Applications
* Distribution Automation Applications
* Asset/System Optimization Applications
* Distributed Resource Applications
* Transmission Applications.

This section provides a description of each identified smart grid application, a description of the potential sources of cost associated with deploying the application, a description of the potential benefits and beneficiaries of the application, and a description of any potential negative impacts that could be associated with application deployment.

### AMI Applications

The AMI applications group encompasses the major features that could be expected of a mature AMI metering system. Different functional options have been separated to facilitate discussion about policy, technical or cost issues that have significant impact on the specific application. It is not necessary or required to implement all application functions in an AMI metering system. Communications by an AMI meter to in-premises devices is typically identified as a major feature of AMI but for this analysis was kept separate in recognition that communications could be enabled by technologies other than AMI.

The AMI applications are:

* Core AMI Functionality
* Remote Connect/Disconnect
* Outage Management Support
* Power Quality/Voltage Monitoring at Meter
* Customer Prepayment Utilizing AMI.

### Core AMI Functionality

* + - 1. **Description:**

AMI metering allows the utility to collect usage data from customers more frequently and supports time differentiated interval measurement. These new measurement capabilities allow for new rate structures and can support increased customer awareness of their energy usage.

Data from AMI meters can be used by the utility to support other smart grid applications. AMI meters can optionally include a customer owned network interface to support demand response applications and increased customer awareness.

AMI Meters reduce some traditional theft and tamper opportunities that can be used against electro-mechanical meters. Additionally, AMI Meter data can be analyzed to discover potential occurrences of theft. The Core AMI application provides a direct benefit to utilities, but is a foundation for other smart grid applications that can provide a direct benefit to customers.

The Core AMI application is intended to embody the basic AMI functionalities that are at the core of any AMI system (i.e. metering) or functions that have few public policy, system cost or challenging technical issues. The determination of which functions have few issues is open to interpretation, but the Application Working Group defined the Core AMI application as including the following functions:

* A meter with two-way communications which records energy usage and supports interval usage measurements
* On demand meter reading
* A metering system that supports the utility’s efforts to detect and prevent meter tampering and energy theft

Additional functions that are often associated with AMI meters were separated into different applications so that potential policy, cost and technical issues could be discussed and evaluated in more discrete pieces.

Basic AMI functionality is a relatively mature application with tens of millions of meters installed worldwide. The AMI industry is currently in a period of rapid change as new functions and new technologies are incorporated in meters. The new functionalities allow AMI meters to support additional smart grid applications.

* + - 1. **Potential Sources of Costs:**

Under traditional regulatory processes, the utility bears the direct cost for installing an AMI system, which includes the following major components:

* AMI Meters – the actual meters
* AMI Network – the communications infrastructure to communicate with the AMI meters. The AMI network can include multiple networks to support different geographic conditions and customer meter densities found in the utility’s service territory. The AMI network may leverage existing utility or public communications networks.. The AMI network may also be used by other utility devices supporting new smart grid functions.
* AMI Management System – a system to manage the normal data collection communications with AMI meters, AMI system health, AMI meter firmware upgrades, and AMI meter configuration settings.
* Meter Data Management System (MDMS) – a system which stores the data recorded by the meter and provides it to other utility systems (i.e. billing). Many smart grid applications can be enhanced by the use of data that is provided by AMI meters and the MDMS serves as a clearinghouse for the AMI data.
  + - 1. **Potential Sources of Benefits and Beneficiaries:**

The following benefits of Core AMI Functionality are both likely and significant:

* Utilities
  + Increased field labor productivity – The Core AMI application removes the need for the utility to regularly send workers into the field to collect energy usage data from meters. Utility workers may still be required to manually read some meters in special circumstances.
  + Improve employee safety – Removing workers from regularly traveling in the field reduces the opportunity for vehicle accidents, accidental injuries, injuries by animals and incidents on private property.
  + Improve forecasting – The interval metering capability of the AMI system provides the utility with a significant improvement in system wide energy usage visibility. Energy usage can be more clearly understood both by time of use and by location.

Additional benefits of Core AMI Functionality could include:

* Utilities
  + Reduce back office support costs – Interval meter data can be provided to customers in a manner that helps the customer understand when they are using electricity. If customers have increased understanding about their bill and how they use energy, they are less likely to contact the utility to complain about high bills. Additionally, the utility’s ability to read meters daily dramatically reduces the need for bill estimating, off cycle billing reads, and other billing process exceptions that increase back office costs.
  + Reduce lost revenues (theft) – An AMI metering system can provide several methods to detect meter tampering and provide indications that energy theft may be occurring. Additionally, AMI meters are less vulnerable to some traditional theft techniques. AMI metering is not a magical panacea for theft; a comprehensive process is needed where the meter records and reports data to the utility, a system analyzes the data and provides an indication to utility personnel for the need to investigate.
  + Improve situational awareness – Related to the Improve Forecasting benefit, AMI meters with an on demand read capability provide the utility with the ability to understand when and where energy is being used. The ability of the meter to support situational awareness is more fully described in other applications.
* Competitive Suppliers or Third Parties
  + Improve/expand products and services – Interval energy usage data allows competitive suppliers or other third parties to offer new rate programs or other energy services that depend on more discrete data than is available today.
* Society
  + Reduce carbon footprint – This benefit attributable directly to meter installation is likely to be minor and for this specific application is obtained by the reduction in the utility’s use of vehicles for their meter reading workforce.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved as part of the AMI system solution
    - 1. **Potential Negative Impacts:**

The primary concern for this application relates to customer data privacy. AMI meters record customer usage in more discrete time intervals, typically 15 minutes to an hour. This data is very useful for utility operations and potential electric market operations. There is a concern that unsecured customer data could be abused by unauthorized persons to determine when customers are not at home or discover how customers use electric devices within their home. Utilities and meter vendors are aware of this privacy issue and are mitigating it through well understood network security and information technology practices.

In addition, by eliminating the need for manual reading of meters, it is possible that hazardous conditions currently noted by meter readers could go undetected.

### Remote Connect/Disconnect

* + - 1. **Description:**

AMI meters can be equipped with remotely operable service switches. The utility can open or close the switch by sending a signal to the meter. The utility operates the switch for purposes of customer requested service connection and disconnection or for disconnection for non-payment and reconnection after payment is received. The service switch may also be used by the utility to disconnect power as requested by official emergency personnel in the event of an emergency such as a house fire.

Not all AMI meters can be equipped with remote service switches, the Collaborative considered single phase meters at 240 volts or lower to be capable of being fitted with an integrated service switch.

This application is dependent on the presence of the Core AMI application. This application was considered separately from the Core AMI because it is an additional option provided by AMI vendors and there are public policy issues concerning how and when the service switch can be used.

Including a remote service switch in AMI meters is a well understood option with very high reliability, with switches typically rated for 10,000 or more lifetime operations. In the past, utilities were concerned with the cost-benefit consideration of installing service switches in all AMI meters, but their increased deployment has dramatically reduced the unit cost of switches and it is generally considered to be a smart investment.

* + - 1. **Potential Sources of Costs:**

In addition to the AMI metering system, this application requires the physical service switch which in the past added a significant cost to the AMI meter, but has been steadily decreasing in the past few years. There is also a potential for more stringent and costly security requirements for a metering system with automated service switches.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The following benefits of Remote Connect/Disconnect are both likely and significant:

* Utilities
  + Increase field labor productivity – The utility would no longer be required to dispatch a field crew to perform service connections and disconnections.
  + Improve employee safety – Utility personnel would spend less time in the field reducing opportunities for vehicle accidents, accidental injuries, injuries by animals and incidents on private property.
  + Improve collections or cash flow – Currently, utilities do not perform disconnections for non-payment in a consistent manner and may allow customers eligible for disconnect to remain on for extended periods of time. Automating the disconnect function provides the utility with the ability to disconnect customers in a consistent manner and prevent additional usage from accruing.

Additional Potential Sources of Benefits for Remote Connect/Disconnect:

* Utilities
  + Reduce lost revenues (unbilled) – Customer requested disconnections, as when moving out of their premises, may not occur with existing work processes. Energy usage that occurs before a new customer moves in may either be unbilled or billed to customers in a non-equitable manner.
* Society
  + Reduce carbon footprint – This benefit is likely to be minor and for this specific application is obtained by the reduction in the utility’s use of vehicles for their meter reading workforce.
* Customers
  + Enhances services to the customers – Customers requesting either a service connection or disconnection can expect that the automated process will occur in a few minutes as opposed to days with existing technology and work processes.
    - 1. **Potential Negative Impacts:**

There are several potential negative impacts when using remote service switches. The most significant concern for stakeholders has to do with the use of remote disconnect for non-payment, and the potential for negative customer safety and health impacts or increased public safety costs. Other concerns such as erroneous or unauthorized disconnections can be mitigated through well understood network security and information technology practices.

### Outage Management Support

* + - 1. **Description:**

AMI Meters can report power outage and power restoration messages to the utility allowing the utility to: improve its ability to determine the scope and location of an outage, improve outage response and verify that all affected customers are restored.

Utilities currently have outage management systems (OMS) that receive input from distribution or transmission system devices and customer phone calls and perform a predictive analysis to determine the location of the outage. AMI meters can report power outage conditions to the OMS which effectively replaces the role of customer reports and improve the OMS’s analysis. More significant than outage reporting is the ability of the utility to verify that customers have had their power restored.

This application is considered separately from the Core AMI application due to potential technical and system design requirements needed for implementation. Outage and restoration reporting is a mature application with low risk.

* + - 1. **Potential Sources of Costs:**

This application assumes the existence of an AMI metering system. Additional costs are expected for updating the outage management system and potential network design decisions required to increase the reliability of communications during outages.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Increase field labor productivity – Improved outage detection and location can better direct utility workers to the outage location and reduce the amount of time taken patrolling power lines. After repairs are made, using the AMI system to verify restoration to customers can efficiently direct utility workers to additional work sites.
  + Improve system reliability – Using the AMI meter system to support the outage management system does not reduce the number of outages, but it does reduce outage duration by allowing the utility to work more efficiently.
  + Improve employee safety – Reduces the amount of time that utility workers spend in the field
  + Improve situational awareness – AMI meters can report in near real time, power outage and power restoration messages to the outage management system.
* Customers
  + Improve system availability – Customers who rely on the distribution system can expect to benefit from reduced outage durations similar to the above Improve System Reliability benefit.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Reduce back office support costs – Increased automation and a reduced need for customer reports.
* Customers
  + Enhance services to the customer – Customers can expect that their power will be restored by the utility even if they do not call to report the outage.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Automated outage reporting at the individual customer level could enable new services.
* Society
  + Reduce carbon footprint – This benefit is likely to be minor and for this specific application is obtained by the reduction in the utility’s use of vehicles for their field workforce.
  + Improve public safety – Public safety is increased by reducing the duration of outages.
  + Improve economic productivity – Improved by reducing the duration of outages.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Power Quality/Voltage Monitoring at Meter

* + - 1. **Description:**

AMI Meter data can provide the utility with an extensive view of voltage levels throughout the distribution system. AMI Meters may also provide other measurements that allow the utility to evaluate system harmonics and power factor. The ability to achieve the benefits for this application largely depend on the capability of the meter to perform measurements that are not normally associated with traditional metering functionality and the network capacity to transport the additional data.

Measurement of voltage, power factor and harmonics are mature capabilities in high end devices. AMI meters typically incorporate voltage measurement and power factor measurement is increasingly available. Harmonic measurement capabilities may be not be cost effective to include in the near future for most AMI meters but may be a desired feature for higher end commercial and light industrial meters.

* + - 1. **Potential Sources of Costs:**

The primary costs for this application are for the additional measurement capabilities of the meter and the modifications to back office systems to store and use the data.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative determined that there were no benefits that are both likely and significant. Additional potential benefits are:

* Utilities
  + Improve system reliability – The utility can use the additional meter data to improve distribution operations. If the additional meter data is appropriate, the utility’s system reliability can be improved.
  + Improve situational awareness – The utility can use the additional meter data to improve distribution operations. If the additional meter data is provided in a timely manner, the utility’s situational awareness can be improved.
* Customers
  + Improve system availability – Any improvements in reliability made by the utility also benefit the customer as improved availability.
  + Improve power quality – AMI meters with improved measurement capabilities can provide the utility with data that can indicate locations where voltage or other power quality quantities are out of specification. If the utility is able to correct the system issues, then customers’ power quality can be improved.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Customer Prepayment Utilizing AMI

* + - 1. **Description:**

A prepayment program provides customers with an option to purchase electricity in advance of its use. Such programs typically include automatic disconnection of service when the customer’s usage exceeds the amount of electricity purchased. Prepayment can serve as an alternative to deposit requirements for utility service, and may reduce the utility’s credit and collection costs, as well as provide a structure to assist customers in reducing their electricity usage and manage a limited budget. The application group made the assumption that prepayment was a voluntary program that would utilize the AMI metering system to provide a communications link between the utility and the customer.

Prepayment systems are a mature application that have traditionally been implemented using specialized meters, but are increasingly being implemented as an option in AMI meters.

* + - 1. **Potential Sources of Costs:**

This application generally requires an in-premises display device for the customer to view remaining balance or other prepayment related information. The utility will require a modification to their billing system in order to support a prepayment program.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Improve collections or cash flow – Utilities can benefit from a prepayment program if significant numbers of users utilize the service, especially if the customers are more likely to be late payers.
* Customers
  + Enhances services to the customers – The Collaborative made the assumption that Customers choosing to participate in a prepayment program would do so because some aspect of the program such as no deposit requirement or budget management is appealing.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Reduce back office support costs – The assumption for this benefit is that prepayment will appeal to customers who are more likely to require the utility to spend more customer service and billing resources on them in a traditional payment program.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Prepayment programs may permit competitive suppliers new options to provide to customers.
* Customers
  + Reduce energy usage-conservation – Customers with in-premises display devices that show the customer how much money they are spending on electricity typically reduce usage by 5-10%.
  + Improve information availability – Customers with in-premises display devices will be provided with better information about their energy consumption and spending.
* Society
  + Reduce carbon footprint – If sufficient numbers of customers reduce their energy usage, a reduced carbon footprint can occur. For this application, the effect is likely to be very minor.
  + Improve air quality – If sufficient numbers of customers reduce their energy usage and the reduction comes from dirtier generation, air quality can be improved. For this application the effect is likely to be very minor.
    - 1. **Potential Negative Impacts:**

Prepayment service is considered to be a controversial application in the Collaborative with several potential negative impacts. Some of these potential negatives are: cost effectiveness and cost allocation, impact on low income customers, disconnection when a customer’s prepaid balance reaches zero and potential predatory marketing. These negative impacts can be addressed through the adoption of appropriate consumer-oriented policies.

## Customer-Oriented Applications

The customer-oriented applications group is focused on applications that communicate data either to the customer or about the customer. Other application groups are also heavily centered on interactions with the customer, but merited their own group. The first three applications represent three different communications channels between the customer and utility. These communications channels can be summarized as:

* Communications to an in-premises device
* Communications to a web based application
* Communications by email, text message or mobile device

These three applications present a reasonable and expected use of the different communications channels, but different types of data can also be expected to be sent using any of the three channels. The last two applications are for practical purposes the same, but were separated to isolate potential policy differences.

The Customer-Oriented Applications are:

* In-Premises Devices for Energy Usage Data
* Customer Web Portal for Energy and Cost Data
* Outage Notification to Customer
* Government and Third Party Use of Customer Data.

### In-Premises Devices for Energy Usage Data

* + - 1. **Description:**

Customers can install devices that can receive and display energy usage information. Various studies have shown that customers who receive better usage information decrease their energy consumption. AMI meters can be used to communicate energy usage data to in-premises devices using a home area network (HAN), but AMI meters are not explicitly necessary to perform this application. Communications to in-premises devices can also occur through pager networks, cellular networks, traditional wired phone services, or broadband internet connections. The AMI communications network may be preferred because it provides the utility with a ubiquitous and standardized way to communicate with customers.

This application is intended to cover not only simple display devices but also includes energy management systems, appliances, thermostats and pool pumps. The technology for this application is not mature, but is increasingly becoming more developed as vendors, utilities and standards organizations work to improve home networking technology and devices. Utilities currently have some risk that installed meters implement an in-premises communication solution that is not widely accepted or cannot be upgraded to an accepted standard.

* + - 1. **Potential Sources of Costs:**

The utility bears the direct costs of the AMI metering system and any inherent HAN communications capability. Costs for most customer devices will likely be the responsibility of the customer, but some devices could be provided by the utility or other third party as part of AMI or other suitable application program.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Competitive Suppliers and Third Parties
  + Improve/expand products and services – By improving communications to the customer, competitive suppliers and third parties can offer new products, rate offerings and energy management services.
* Customers
  + Reduce energy usage-conservation – Customers with displays can readily monitor their energy usage and receive feedback on efforts to conserve energy.
  + Improve information availability – Customers with in-premises devices can take advantage of energy usage data from the meter to improve their energy usage decision making capability.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Reduce back office support costs – Assuming that in-premises display technologies become widespread over time, customers may rely on their own displays to understand their consumption and be less likely to call the utility for high bill complaints or other complaints.
  + Extend asset life – This benefit assumes that widespread adoption by customers leads to significant system-wide conservation and less wear on electric system assets.
* Customers
  + Enhances services to the customers – Customers with displays or other devices will have new information provided to them that allow for manual or automated energy management.
  + Increase ability to manage energy cost – Customers who choose to install and use in-premises devices will be able to conserve energy and reduce their monthly bill.
  + Reduce energy-usage efficiency – Customers using in-premises devices to monitor their energy usage can analyze the usage of specific devices in their home or business to determine if newer, more energy efficient models are appropriate.
* Regional Electricity Market
  + Reduce market price of energy -- This benefit assumes that sufficient numbers of participating customers will provide system-wide conservation and shift the entire load curve down
  + Reduce market price of capacity -- This benefit assumes that sufficient customer participation leads to a reduction in peak energy demand and a reduction in peak energy prices.
* Competitive Suppliers and Third Parties
  + Obtain better customer load data – Potential new third party products, rates and services could include the customer providing more detailed information to the third party. Proper policy will include specific protections for customers.
* Society
  + Reduce carbon footprint – With sufficient participation and conservation, this benefit assumes that carbon based generation will be reduced.
  + Improve air quality – Similarly to Reduce Carbon Footprint, a reduction in carbon based generation will improve air quality.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved in order to support communications to customers
    - 1. **Potential Negative Impacts:**

Potential negative impacts for this application relate to policy. A policy issue for cost allocation exists that includes this application and other applications that implement in-premises communications to devices in the customer’s home or business. This application primarily benefits the customer but other applications using the same devices and technology can benefit both the utility and the customer. There are questions in determining who should provide and pay for these devices, which are discussed in further detail in the Consumer Policy chapter.

### Customer Web Portal for Energy and Cost Data

* + - 1. **Description:**

Customers can view historical energy usage and energy cost data provided by their electric supplier on the internet. Information viewed on the internet would not be real time, but would allow for more descriptive views and comparisons of a customer’s energy usage. This application includes customers viewing data on a computer by visiting a utility website, more advanced in-premises devices receiving information through the internet or information rich emails that the customer receives periodically from the utility or third party. The general expectation is that a customer will be able to view the previous day’s energy usage on the utility’s website along with additional historical data and an estimated month-to-date bill. The Application Working Group generally assumed that this application was deployed with an AMI metering system performing the daily data collection, but the application is possible in the absence of AMI.

Presenting data to customers through a web site is a mature application with low risk.

* + - 1. **Potential Sources of Costs:**

The most significant costs for this application are for upgrades to the utility’s web servers and customer information systems. The application assumes that customers will use existing general purpose devices or in-premises devices to access internet delivered data.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Competitive Suppliers and Third Parties
  + Improve/expand products and services – By improving communications to the customer, competitive suppliers and third parties can offer new products, rate offerings and energy management services.
* Customers
  + Reduce energy usage-conservation – Customers can use the provided energy usage data to modify their behavior and receive daily feedback on attempts to conserve energy.
  + Improve information availability – Customer will have access to historical usage data and energy cost information.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Reduce back office support costs – This benefit assumes that a significant number of customers will use automated, web based information services and reduce utility call center costs.
  + Extend asset life – This benefit assumes that widespread adoption by customers leads to significant system-wide conservation and less wear on electric system assets.
* Customers
  + Enhances services to the customers – Customers will have new options for monitoring energy usage and energy costs.
  + Increase ability to manage energy cost – Customers can monitor energy usage on a daily basis, providing more insight into their monthly bill.
  + Reduce energy-usage efficiency – Customers monitoring their energy usage may be able to analyze the usage of specific devices in their home or business to determine if newer, more energy efficient models are appropriate.
* Regional Electricity Market
  + Reduce market price of energy -- This benefit assumes that sufficient numbers of participating customers will provide system-wide conservation and shift the entire load curve down
  + Reduce market price of capacity -- This benefit assumes that sufficient customer participation leads to a reduction in peak energy demand and a reduction in peak energy prices.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Potential new third party products, rates and services could include the customer providing more detailed information to the third party. Proper policy will include specific protections for customers.
* Society
  + Reduce carbon footprint – With sufficient participation and conservation, this benefit assumes that carbon based generation will be reduced.
  + Improve air quality – Similarly to Reduce Carbon Footprint, a reduction in carbon based generation will improve air quality.
    - 1. **Potential Negative Impacts:**

There is some concern about potential confusion for customers viewing energy usage data in near-real time and potential discrepancies between viewing “raw” data and billing quality data. The web site should make clear that a customer’s bill includes elements other than the immediate usage information. Cybersecurity vulnerabilities must be adequately addressed or information could be inappropriately accessed through the web portal.

### Outage Notification to Customer

* + - 1. **Description:**

The utility can inform customers through automated emails, text messages and phone calls of existing outages and estimated restoration times. Customers receiving this information can make better decisions on how to respond to the outages. This application does not depend on AMI for communicating to the customer. An installed AMI system may provide the utility with better information about the scope and nature of the outage. It is assumed that customers can choose to participate in this program voluntarily.

Automated messaging is a mature application with low risk.

* + - 1. **Potential Sources of Costs:**

The costs for this application are utility system upgrades to the customer information system and potentially the outage management system. The utility may have additional costs related to transmitting large numbers of emails, text messages or phone calls. The Collaborative did not consider the cost for customers to receive messages to be significant.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Enhances services to the customers – Outage notification is a new service to customers. It is currently being piloted by Commonwealth Edison.
* Utilities
  + Reduce back office support costs – By proactively notifying customers of outages and restoration, the utility could see a reduction in call center costs.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Improve information availability – Customers can be made aware of outages that affect their property even when they are not present.
* Society
  + Improve economic productivity – If outage restoration times can be reported and are sufficiently accurate, businesses receiving outage notifications can improve their operational decisions. This is a benefit to businesses, employees and customers.
  + Improve public safety – Improved outage and restoration notification can improve services to members of society who are vulnerable to a disruption in electric service.
    - 1. **Potential Negative Impacts:**

A potential negative impact for this application is inaccurate reporting of outages. It is possible that the system could report an outage to a customer whose premises is not affected (false positive) or for the system to fail to determine that a customer’s premises is affected and report it to the customer (false negative).

### Government and Third Party Use of Customer Data

* + - 1. **Description:**

This application is a high level representation for numerous, more specific scenarios where customers could choose to share some portion of their energy usage data, outage status, appliance energy usage and settings or energy cost data with third parties. The Collaborative assumed that the customer would control access to their data and determine which third parties would be able to view specific types of information. The customers would also be informed of how third parties intended to use data. Most examples for sharing data focused on energy management services that could be provided to customers.

The maturity of this application varies based on the source of the data. Data that is shared by the utility to authorized third parties is mature and has low technical risk. More specific applications that involve in-premises devices communicating information to authorized third parties either through the utility’s AMI network or other communication channel are less mature. Home area network communications standards and in-premises devices are developing quickly.

* + - 1. **Cost:**

This application requires potential upgrades to utility systems to collect, manage and share customer data with third parties. Third parties require systems to receive and use the data. Customers could replace the role of the utility in this application and directly store and transmit data to desired third parties.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Energy management and other services can be provided to customers if third parties have access to appropriate data. Services with a data collection component could improve the third parties’ understanding of how customers use energy and allow the third party to improve their service offerings.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Enhance services to the customers – It was assumed that customers would generally only use services that the customer determined were beneficial.
* Utilities
  + Reduce back office support costs – This benefit assumed that standardized interfaces for sharing data would reduce utility costs.
    - 1. **Potential Negative Impacts:**

Similar to the Core AMI Metering application, the primary concern for this application relates to customer data privacy. There is a concern that unsecured customer data could be abused by unauthorized persons. Proper network security, information technology practices and privacy policies can be used to mitigate negative impacts.

## Demand Response Applications

The demand response applications group presents four scenarios that use different signals to the customer either directly or to a customer’s devices that are enabled to respond. The four signaling types are:

* Price signals
* Direct load control signals
* System measurements
* Environmental signals

The applications provide good representations of how these different signal types could be used by customers and utilities but do not cover every possibility. The Collaborative assumed that participation by customers in demand response activities was voluntary, but that a customer could voluntarily enroll in a program where participation in a specific event was mandatory.

The Demand Response Applications are:

* Pricing Information to In-Premises Devices
* Direct Load Control
* System Frequency Signal to Customer Load Control Devices
* System Renewables Output to Customers

### Pricing Information to In-Premises Devices

* + - 1. **Description:**

Demand response generated by price signals leaves the customer in control of how they wish to participate during periods when energy costs are higher. Price based demand response requires the customer to have more advanced devices if they wish to automate the response than demand response programs based on a simple utility control signal. This application assumes that price based demand response can be as simple as a fixed schedule, tiered, time of use rate or a more dynamic interval based real time price rate. It also includes critical peak pricing and critical peak rebates. The Collaborative assumed that more dynamic rate structures require additional automation of in-premises devices to achieve the application’s benefits.

This technology for this application is not mature but is increasingly becoming more developed as vendors, utilities and standards organizations work to improve home networking technology and devices. Utilities currently have some risk that installed meters implement an in-premises communication solution that is not widely accepted or can’t be upgraded to an accepted standard.

* + - 1. **Potential Sources of Costs:**

The utility may require a demand response management system for some forms of price based demand response. Additionally, the utility may require customer information system and billing system upgrades. Customers may be required to install in-premises devices for some types of demand response.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Reduce energy usage-conservation – With a price signal, customers can see a more immediate need to reduce energy usage.
  + Increase ability to manage energy cost – This assumes that pricing programs provide an incentive to the customer to reduce or shift usage to lower energy cost time periods.
  + Improve information availability – Customer with in-premises displays can receive more energy usage and cost information.
* Regional Electricity Market
  + Reduce market price of energy -- This benefit assumes that sufficient numbers of participating customers will provide system-wide conservation and shift the entire load curve down
  + Reduce market price of capacity -- This benefit assumes that sufficient numbers of participating customers will provide system-wide conservation and shift the entire load curve down, but with a more significant impact of reducing the system peaks
* For Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties and competitive suppliers may have more options for the types of products, rates and demand response programs they can offer.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Reduce energy-usage efficiency – Variable priced energy may incentivize customers to purchase more energy efficient devices and appliances.
  + Improve system availability – Assumes that sufficient customers are participating and reducing usage, leading to less wear on electric system components and fewer outages. Also envisions more dramatic, real time price signals during extreme energy shortages reducing the potential for brown outs.
* Utilities
  + Improve system availability – Assumes that sufficient customers are participating and reducing usage, leading to less wear on electric system components and fewer outages.
  + Extend asset life – Assumes that sufficient customers are participating and reducing usage, leading to less wear on electric system components.
  + Defer investment/enhancements – Assumes that sufficient customers are participating and reducing usage, leading to less wear on electric system components.
* RTO/ISO
  + Flatten load curve – This benefit assumes that sufficient numbers of participating customers will provide system-wide conservation and shift the entire load curve down, but with a more significant impact of reducing the system peaks.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Customers participating in price based demand response with third parties may generate higher resolution data than customers who are not participating.
* Society
  + Reduce carbon footprint – With sufficient participation and conservation, this benefit assumes that carbon based generation will be reduced.
  + Improve air quality – Similarly to Reduce Carbon Footprint, a reduction in carbon based generation will improve air quality.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved in order to support communications to customer devices needed for this application
    - 1. **Potential Negative Impacts:**

The primary potential negative impact for this application is the impact on customers who are participating in time based rates but cannot limit or shift their electric usage during periods of high energy cost. There is also concern that customers choosing to participate in programs based on time-variant rates may overreact to price signals, putting their health and/or safety at risk. Regulatory policy should address how and if time varying rates should be adopted.

### Direct Load Control

* + - 1. **Description:**

Demand response can be provided by installing load control devices that receive a signal from the utility to reduce load. Direct control by the utility causes concern for some users, which may be mitigated by allowing the customer to override a demand request.

This application has been widely used by utilities for many years; however newer technologies allow for more flexible implementation and provide better feedback to the utilities. The future vision of this application relies on network technologies and devices that are still in the early stages of deployment.

* + - 1. **Potential Sources of Costs:**

The utility may require a demand response management system to send signals to customers’ devices. Additionally, the utility may require customer information system and billing system upgrades. Customers will be required to install in-premises devices for direct load control demand response.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Improve system availability – The utility has increased control and can call for demand response reductions to improve system conditions.
* Regional Electricity Market
  + Reduce market price of energy -- This benefit assumes that a sufficient number of actively participating customers will reduce their energy usage enough to lower the market price of energy for all customers
  + Reduce market price of capacity -- Assumes that the utility will signal for demand response during system peaks
* RTO/ISO
  + Increase grid stability – Similar to Improve System Availability, the RTO benefits from the utility’s operation of direct load control in emergency situations.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties can provide direct load control demand response programs.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Reduce energy usage-conservation – Customers will use less electricity when under direct load control.
  + Increase ability to manage energy cost – This assumes financial benefits exist for participating in a direct load control program and the customer can choose to participate on a per event basis.
  + Improve system availability – Customers benefit from the utility’s direct control to improve system stability and prevent outages.
* Utilities
  + Extend asset life – Assumes that sufficient customers are participating and reducing usage, leading to less wear on electric system components.
  + Defer investment/enhancements – Assumes that sufficient customers are participating and reducing usage, leading to less wear on electric system components.
  + Improve forecasting – Assumes that with direct control and sufficient participation, the utilities can directly reduce usage to conform to forecasts. This application doesn’t directly improve forecasts; however, it allows the utility to reduce the impact of potential error in forecasts.
* Society
  + Reduce carbon footprint – With sufficient participation and conservation, this benefit assumes that carbon based generation will be reduced.
  + Improve air quality – Similarly to Reduce Carbon Footprint, a reduction in carbon based generation will improve air quality.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved in order to support communications to customer devices needed for this application
    - 1. **Potential Negative Impacts:**

Potential negative impacts that were discussed by the Collaborative include: safety or health concerns due to load control of critical customer service, potential damage to customer equipment from increased cycling and potential increases in customer complaints or liability for the utility. These potential negative impacts have been successfully addressed by utilities performing this application by proper program design and policy.

### System Frequency Signal to Customer Load Control Devices

* + - 1. **Description:**

Customer devices or appliances equipped with electric system frequency sensors can detect changes in the electric system frequency that indicate instability due to insufficient generation and drop load. Frequency sensing can be added to existing appliances or for very low cost be incorporated into future appliance designs. Customers could provide frequency response load reduction to utilities or third parties in exchange for a financial benefit. The Collaborative recognized that too much uncoordinated load shedding was problematic for this application.

The technology to implement this application is mature but has not been implemented due to cost-benefit limitations and difficulty in providing customers with an incentive to participate. The in-premises communications capabilities that may be developed in other applications could increase the appeal for this application.

* + - 1. **Potential Sources of Costs:**

Customers bear the costs for device and appliance sensors. Additionally, some communication capability may be required by the customer’s device or appliance to report participation in a frequency response event. The communication capability could be through the customer’s HAN and AMI network. The utility may need to upgrade customer information systems, demand response systems, AMI communications networks and AMI management systems to support this application.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* RTO/ISO
  + Increase grid stability – Customers’ devices and appliances will automatically decrease their load on the system during a low frequency event, increasing system stability.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Improve system availability – Assumes that sufficient customers are participating and reducing usage, improving system reliability.
  + Improve power quality –
* Utilities
  + Extend asset life – Assumes that sufficient customers are participating and reducing usage, improving wear on electric system components.
  + Improve system reliability – Assumes that sufficient customers are participating and reducing usage, improving system reliability.
* RTO/ISO
  + Increase market competitiveness (ancillary services) – This application provides additional sources for frequency based response
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties can aggregate customers for purposes of providing larger amounts of frequency response.
* Society
  + Improve public safety – Through reduced outages.
  + Improve economic productivity – Through reduced outages.
    - 1. **Potential Negative Impacts:**

Potential negative impacts for this application are potential damage to customer equipment from increased cycling and potential increases in customer complaints or liability for the utility. Proper technical design of the systems should mitigate these issues.

### System Renewables Output to Customers

* + - 1. **Description:**

Customer’s displays or devices can receive information about the current output of the electric system’s renewable generation. The customer can choose to lower their energy usage or program devices to use less energy when renewable output is low. Information about the system’s renewable output is provided by the Regional Transmission Operator.

As described this application is not mature, as it relies on still developing in-premises communications technologies and devices.

* + - 1. **Potential Sources of Costs:**

The RTO currently provides this data on their web site. Utility system updates may be required to deliver this data to customers’ in-premises devices. Customers may require devices which can respond to signals based on renewable output.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative discussed the following Potential Sources of Benefits and Beneficiaries:

* Customers
  + Reduce energy usage-conservation – Customers who respond to low renewable generation will conserve energy.
  + Enhance services to the customers – Customers have expressed a desire to have renewable generation output presented to them.
  + Improve information availability – Customers have expressed a desire to have renewable generation output presented to them.
  + Improve system availability – Assumes that sufficient customers are participating and reducing usage, improving system reliability.
* Utilities
  + Extend asset life – Assumes that sufficient customers are participating and reducing usage, improving electric system asset life.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties may be able to offer services related to low renewable generation signals.
* Society
  + Increase use of renewables – Assumes that all renewable generation will be used, but that this application may incentivize additional construction of renewable generation.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

## Distribution Automation Applications

The distribution automation applications group includes applications that are typically utility centric while still providing a benefit to the customer through increased reliability or improved system efficiency. Utilities are increasingly becoming interested in these applications because they can generally leverage a utility’s AMI metering system and its associated communications network.

The Distribution Automation Applications are:

* Automatic Circuit Reconfiguration
* Improved Fault Location
* Dynamic System Protection for Two-Way Power Flows and Distributed Resources
* Dynamic Volt-VAR Management
* Conservation Voltage Optimization

### Automatic Circuit Reconfiguration

* + - 1. **Description:**

A smart distribution system can use communicating switches and circuit reclosers to reconfigure the distribution system during an outage. Automatic reconfiguration allows for a portion of customers who would traditionally suffer a distribution level outage to have their power restored in a few seconds. An advanced system provides better information to the utility about the location of faults and the current configuration of the distribution system.

This is a mature application. ComEd is currently deploying some devices envisioned by this application. Additional devices and improved inter-device communications would provide all of the benefits envisioned by the Collaborative.

* + - 1. **Potential Sources of Costs:**

The utility will require new or upgraded distribution system switches and reclosers, a communications system suitable for this application which could be, in whole or in part, leased from existing communications providers or built as a new network, depending on what alternatives are most cost-effective, and a new or upgraded distribution management system. The communications network may be part of the AMI network.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Improve system availability – During outages, a significant percentage of customers will have a momentary outage and not a prolonged outage.
  + Improve power quality – Automated circuit reconfiguration will better coordinate reclosers attempting to clear system faults and decrease fault current exposure to customers’ equipment.
* Utilities
  + Increase field labor productivity – The system will improve the location of system faults and allow utility workers to begin repairs sooner.
  + Extend asset life – Automated circuit reconfiguration will better coordinate reclosers attempting to clear system faults and decrease fault current exposure to electric system assets.
  + Improve system reliability – During outages, a significant percentage of customers will have a momentary outage and not a prolonged outage.
  + Improve employee safety – Decrease field workers time in the field.
  + Improve situational awareness – The automated system provides better information to the utility’s distribution management system.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Reduce back office support costs – Improved information and distribution management reduces back office costs.
  + Reduce failure rates – Based on Extend Asset Life, future failures will be less likely.
  + Improve asset performance – Based on Extend Asset Life, asset performance will be improved.
* Society
  + Reduce carbon footprint – This benefit is likely to be minor and for this application is obtained by the reduction in the utility’s use of vehicles by their field workforce.
  + Improve public safety – Reduced area and duration of outages improves public safety.
  + Improve economic productivity – Reduced area and duration of outages.
  + Improve system resiliency (disaster recovery) – Reduced area and duration of outages.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved in order to support communications to utility devices needed for this application
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Improved Fault Location

* + - 1. **Description:**

Additional sensors with communications can be installed to improve the utility’s ability to detect the location of system faults. The fault sensors can report to the utility distribution management system and help pinpoint the location of system faults.

This is a mature technology which has historically not been implemented by utilities due to limited field communications. This application can benefit from AMI or other smart grid communications networks.

* + - 1. **Potential Sources of Costs:**

The utility will require fault sensors, a field network which may be part of the AMI network, and a new or upgraded distribution management system.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Improve system availability – The utility will be able to repair outages more quickly.
* Utilities
  + Increase field labor productivity – Field workers will spend much less time patrolling lines, searching for outages.
  + Extend asset life – By using fault location sensors, utilities can prevent some circuit recloser operations that expose system assets to fault current.
  + Improve system reliability – Reducing the duration of outages improves the system reliability and extending asset life improves system reliability.
  + Improve employee safety – Decrease field workers time in the field.
  + Improve situational awareness – Fault location sensors report back to the distribution management system.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Reduce back office support costs – Improved information and distribution management reduces back office costs.
  + Reduce failure rates – Based on Extend Asset Life, future failures will be less likely.
* Society
  + Reduce carbon footprint – This benefit is likely to be minor and for this application is obtained by the reduction in the utility’s use of vehicles by their field workforce.
  + Improve public safety – Reduced area and duration of outages improves public safety
  + Improve economic productivity – Reduced area and duration of outages.
  + Improve system resiliency (disaster recovery) – Reduced area and duration of outages.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved in order to support communications to utility devices needed for this application
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Dynamic System Protection for Two-Way Power Flows and Distributed Resources

* + - 1. **Description:**

The existing distribution system is designed and built with the assumption that electricity is supplied to customer end points. As distributed resources become more prevalent, the distribution system will require upgrades that provide sensing of local system conditions and systems and devices that send control signals and operational settings to devices to maintain safety and stability.

The underlying technologies for this application are mature, but no products exist for this application because there is no current need. Utilities and vendors recognize the potential need for this application, but it is considered to have lower priority until greater numbers of distributed resources are deployed.

* + - 1. **Potential Sources of Costs:**

The utility will need new or upgraded devices that perform system protection and circuit reconfiguration, new or upgraded devices that can sense or communicate with distributed resources and a new or upgraded distribution management system. Customers participating in net generation programs may be required to install communications and control systems for their distributed resources.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Facilitate customer generation – Customers can currently use distributed resources and participate in net generation programs. This benefit assumes that a more dynamic system can increase the value to customers for providing net generation.
  + Improve system availability – This benefit assumes that increased net generation can improve system availability for all customers.
* Utilities
  + Improve system reliability – Similar to Improve System Availability, this benefit assumes that increased net generation reduces the impact of system outages.
  + Improve employee safety – This benefit assumes that improved protection systems that accommodate distributed resources improve field worker safety.
  + Improve situational awareness – This application assumes the existence of additional sensing capability that is communicated to the utility’s distribution management system.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Improve power quality – Improved sensing capability can notify customers and the utility of power quality issues that may arise with wide spread distributed resources. This benefit assumes that customers or the utility will correct problems that are discovered.
* Utilities
  + Extend asset life – Monitoring and measuring system conditions with wide spread distributed resources allows the utility to operate the distribution system in a manner that reduces stress on system assets.
  + Reduce failure rates – Monitoring and measuring system conditions with wide spread distributed resources allows the utility to operate the distribution system in a manner that reduces stress on system assets.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties may have increased service opportunities if distributed resources are widely deployed.
* Society
  + Improve public safety – Assumes that this application improves system reliability.
  + Improve economic productivity – Assumes that this application improves system reliability.
  + Improve system resiliency (disaster recovery) – This benefit occurs if distributed resources can be used to recover more quickly from outages.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Dynamic Volt-VAR Management

* + - 1. **Description:**

The smart distribution system can monitor voltage and power quality at multiple points throughout the system and communicate control signals to capacitor banks to optimize system operation. This application would include the use of voltage and power quality monitoring devices along with capacitor bank and load tap changing transformer controls to control the voltage and reactive power on the system for reliability. The Collaborative assumed that AMI meters would likely be used to provide voltage measurements at points throughout the distribution system. An AMI system is not required for this application and voltage measurements can be provided by devices installed specifically for this application.

The fundamental capabilities of this application rely on mature technologies. The application as described is in the developmental stage as utilities implement AMI meters, field communications networks, capacitor and transformer controls -- and integrate them into a working system.

* + - 1. **Potential Sources of Costs:**

The utility will require new or upgraded capacitor bank controls, transformer controls, field communications (which may be provided by an AMI system), and a new or upgraded distribution management system.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Improve power quality – Customers can benefit from improved voltage and VAR control
* Utilities
  + Reduce line losses – Utilities can use this application to improve power factor, reducing line losses.
  + Improve asset performance – Utilities can manage voltage and power quality to improve asset performance.
  + Improve situational awareness – This application provides improved information to the utility’s distribution management system.
* Regional Electricity Market
  + Reduce market price of energy -- Reduced line losses and improved power factor can decrease the amount of energy purchased and result in a lower market price for all customers
  + Reduce market price of capacity -- Reduced line losses and improved power factor can decrease the amount of energy purchased and result in a lower market price for all customers.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Increase field labor productivity – This benefit occurs if existing manual capacitor bank operations are replaced with automation.
  + Extend asset life – Asset life can be extended by operating the distribution system with a finer degree of control.
* Society
  + Reduce carbon footprint – This benefit assumes that significantly reduced line losses will decrease the need for carbon based generation.
  + Improve air quality – This benefit assumes that significantly reduced line losses will decrease the need for carbon based generation.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Conservation Voltage Optimization

* + - 1. **Description:**

This application is an extension of *Dynamic Volt-VAR Management.* The smart distribution system can sense and control the voltage level more capably. Utilities can maintain a lower regulated voltage providing savings to the customer and increasing system efficiency. This application would include the use of voltage and power quality monitoring devices along with capacitor bank and Load Tap Changing transformer controls to control the voltage and reactive power on the system for conservation optimization. This application could be used in a near real time manner to reduce usage during periods of high energy costs or to alleviate system congestion.

As with *Dynamic Volt-VAR Management*, this application is based on mature technologies that have not been implemented in this fashion due to the lack of a wide set of sensor devices and a field network. This application envisions using AMI meters and the AMI or smart grid network to enable this application.

* + - 1. **Potential Sources of Costs:**

The utility will require new or upgraded capacitor bank controls, transformer controls, field communications (which may be provided by an AMI system), and a new or upgraded distribution management system.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Reduce energy usage-conservation – Customers operating at a lower voltage use less energy.
* Utilities
  + Reduce line losses – Decreased voltage can reduce the line losses.
  + Improve situational awareness – This application provides improved information to the utility’s distribution management system.
* Regional Electricity Market
  + Reduce market price of energy -- If a sufficient reduction occurs by lowering the voltage, energy market prices can be lowered, benefitting all customers
  + Reduce market price of capacity -- If a sufficient reduction occurs by lowering the voltage, energy market prices can be lowered, benefitting all customers

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Increase field labor productivity – This benefit assumes that the asset performance and asset life extension benefits reduce field labor for asset repairs and replacement.
  + Extend asset life – Asset life can be extended by operating the distribution system with a finer degree of control.
  + Improve system reliability – This benefit assumes that voltage reduction can be used to reduce the load on system components that may be overloaded and prevent outages.
  + Improve asset performance – Utilities can manage voltage to improve asset performance.
* Society
  + Reduce carbon footprint – This benefit assumes that energy savings from voltage reduction are sufficient to decrease output from carbon based generation.
  + Improve air quality – This benefit assumes that energy savings from voltage reduction are sufficient to decrease output from carbon based generation.
    - 1. **Potential Negative Impacts:**

The discussed potential negative impact for this application is a concern for potential customer equipment damage or poor performance due to voltage levels at the low end of the acceptable range. By definition, the acceptable range should be sufficient but some customer equipment may respond poorly at the lower voltage level.

## System and Asset Monitoring and Modeling

The system and asset monitoring and modeling applications group is related to the distribution automation group and is differentiated by the timing of the activities. The distribution automation applications occur in real time and the system and asset monitoring and modeling applications are performed in a more analytical manner. As with the distribution automation group, these applications can leverage AMI meter data and the AMI communications network.

The System and Asset Monitoring and Modeling Applications are:

* Asset Sizing Optimization
* Asset Condition Monitoring
* Enhanced System Modeling and Planning

### Asset Sizing Optimization

* + - 1. **Description:**

Data provided by AMI meters and new distribution system devices connected by the smart grid network provide the utility with the ability to accurately determine loading and view operational attributes of distribution system components. The increase in system visibility allows the utility to correctly size system components and replace them based on actual operating condition.

This application is mature and only depends on a sufficient quantity and quality of data to implement. Ameren has used data provided by their fixed network AMR system to perform this application.

* + - 1. **Potential Sources of Costs:**

The utility will require new or enhanced distribution management and asset management systems.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Extend asset life – Asset life can be extended if utility operators have improved information about system loading conditions and have installed correctly sized equipment.
  + Reduce failure rates – Correctly sized equipment will be less likely to fail.
  + Improve asset performance – Proper asset sizing allows for more efficient use of utility investment.
  + Reduce non-energy procurement cost – Procurement costs can be reduced by deploying correctly sized assets and not oversized equipment.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Improve system availability – Customers will experience improved system availability if the utility reduces asset failure rates.
* Utilities
  + Increase field labor productivity – Reduced equipment failure rates reduces unplanned field labor.
  + Improve system reliability – Reduced equipment failure rates improves system reliability.
  + Improve employee safety – Reduced equipment failures and asset replacements increases field employees’ safety.
  + Improve situational awareness – The utility benefits from improved device data.
* Society
  + Improve public safety – Reduced equipment failure rates results in fewer outages.
  + Improve economic productivity – Reduced equipment failure rates results in fewer outages.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Asset Condition Monitoring

* + - 1. **Description:**

Distribution and transmission system sensors allow the utility to monitor the real time performance and health of system components. The utility can take corrective action at the appropriate time, increasing system reliability and operational efficiency.

This is a mature application which has been typically deployed in limited instances due to a lack of field communications.

* + - 1. **Potential Sources of Costs:**

The utility will require new or enhanced distribution management and asset management systems. The utility will also require condition monitoring sensors to be added to existing utility equipment or for new equipment to be equipped with conditioning monitoring capabilities.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Improve system availability – Customers will experience improved system availability if the utility reduces asset failure rates.
* Utilities
  + Increase field labor productivity – Utilities can optimize maintenance and repair activities if they have greater data about asset condition.
  + Extend asset life – Asset life can be extended if utility operators have improved information about system loading conditions.
  + Reduce failure rates – Improved information about asset loading allows the utility to control the system in a manner that prevents asset failures.
  + Improve system reliability – Reduced asset failures improve system reliability.
  + Improve asset performance – Improved information allows for asset performance optimization.
  + Improve situational awareness – System sensors could provide near real time asset condition monitoring, improving situational awareness.
  + Reduce non-energy procurement cost – Procurement costs can be reduced by extending asset life and performing planned as opposed to emergency asset replacement.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Improve employee safety – Reduced equipment failures and asset replacements increases field employees’ safety.
* RTO/ISO
  + Increase grid stability – Improved condition monitoring of transmission level assets improves grid stability for the RTO.
  + Improve situational awareness – Improved condition monitoring of transmission level assets in near real time can improve situational awareness.
* Society
  + Improve public safety – Reduced equipment failure rates results in fewer outages.
  + Improve economic productivity – Reduced equipment failure rates results in fewer outages.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Enhanced System Modeling and Planning

* + - 1. **Description:**

Data from AMI meters and distribution system sensors provide the utility an increased ability to validate system models and efficiently plan for system upgrades. When sufficient numbers of sensors and data is available, some traditional models can be updated with true representations of the system.

Modeling and planning are mature applications that benefit from the increase in data. New models and systems may be developed to take full advantage of the available data.

* + - 1. **Potential Sources of Costs:**

The utility can take advantage of AMI meters or other smart grid devices to provide data. The utility may require new or upgraded electric system modeling and planning systems.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Extend asset life – This benefit assumes that improved modeling and planning enhance the utility’s ability to correctly size assets and operate them within design parameters.
  + Improve system reliability – Improved modeling and planning may decrease the number of outages that occur.
  + Improve forecasting – Improved modeling and planning benefits short and long term forecasting.
  + Reduce non-energy procurement cost – Improved planning reduces unexpected, high cost procurement needs.
* RTO/ISO
  + Improve forecasting – Improved modeling and planning benefits short and long term forecasting.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Improve system availability – Improved modeling and planning may decrease the number of outages.
* Utilities
  + Reduce failure rates – This benefit assumes that improved modeling and planning enhance the utility’s ability to correctly size assets and operate them within design parameters.
  + Improve asset performance – This benefit assumes that improved modeling and planning enhance the utility’s ability to correctly size assets and operate them within design parameters.
  + Improve situational awareness – Improved models that correlate well with measured data can improve a utility’s situational awareness.
* RTO/ISO
  + Increase grid stability – This benefit assumes that improved modeling and planning enhance the utility’s ability to correctly size assets and operate them within design parameters.
  + Improve situational awareness – Improved models that correlate well with measured data can improve a utility’s situational awareness.
* Society
  + Improve public safety – Reduced equipment failure rates results in fewer outages.
  + Improve economic productivity – Reduced equipment failure rates results in fewer outages.
  + Improve system resiliency (disaster recovery) – Improved system models and planning can improve system recovery time
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

## Distributed Resource Applications

The distributed resource applications group focuses on customer owned generation or storage and better integration of electric vehicles. The first two applications provide a view about customer owned generation and storage and primarily focus on smaller resources. The second application recognizes the importance of integrating larger resources but provides a high level view of how the integration should occur. The electric vehicle applications assume that electric vehicles will be increasingly used and detail how the smart grid should incorporate large numbers of cars in the future.

The Distributed Resource Applications are:

* Customer Distributed Resource Interconnection
* Coordinated Management of Distributed Resources
* Electric Vehicles: Optimized Charging
* Dispatch of Electric Vehicle Storage

### Customer Distributed Resource Interconnection

* + - 1. **Description:**

Customer owned generation resources can provide power into the distribution system and help defer construction of new generation or increase the use of renewable energy. The smart grid can facilitate the interconnection of customer generation and storage by providing technical support and through the implementation of other applications that incentivize the installation of distributed resources. The Collaborative recognized that customer owned generation is possible today but that AMI and other smart grid applications could allow customers to better utilize their own generation and to potentially provide their generation back to the electric system.

Customer owned distributed resources are mature and this application is focused on using other smart grid applications to increase the deployment of distributed resources.

* + - 1. **Potential Sources of Costs:**

The utility would require an AMI metering system and potential upgrades to a distribution management system. Customers would pay for their generation or storage devices and installation.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Facilitate customer generation – Customers could better determine the economic case for installing and operating distributed resources, especially if time varying electric rates are implemented.
  + Improve system availability – Customers with some types of generation and storage are better protected against outages.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties could develop aggregated distributed resource offerings into the electric market or provide remote equipment monitoring and maintenance.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Increase ability to manage energy cost – Customers participating in time varying rates could use generation or stored energy during times of high prices or provide energy into the grid.
* Regional Electricity Market
  + Reduce market price of energy -- This benefit assumes that sufficient numbers of participating customers will shift the entire load curve down
  + Reduce market price of capacity -- This benefit assumes that sufficient customer participation leads to a reduction in peak energy demand and a reduction in peak energy prices.
* RTO/ISO
  + Increase market competitiveness (ancillary services) – Customers could be incentivized to use their generation at the direction of the RTO.
* Society
  + Increase use of renewables – Some rate and market structures could incentivize customers to install solar or wind power.
  + Reduce carbon footprint – If larger numbers of renewable generation sources are installed, some carbon based generation could be reduced.
  + Improve air quality – Assumes that distributed resources are solar, wind or fuel cell based.
  + Improve economic productivity – Increased numbers of distributed resources could reduce the impact of system outages and allow customers to operate as normal.
    - 1. **Potential Negative Impacts:**

Potential negative impacts for this application are the challenges with existing utility system protection schemes if distributed generation is widely used. This concern is addressed by the application, *Dynamic System Protection for Two-Way Power Flows and Distributed Resources*. Potential back feed into the system and employee safety is another concern.

### Coordinated Management of Distributed Resources

* + - 1. **Description:**

Permitting the utility to communicate with customer owned generation can allow the utility to better manage the distribution system. A utility system that is aware of the operating condition and output of distributed resources can provide better system protection and reliability. This application envisions a scenario where utilities or third parties enroll customers with distributed resources in a program that allows the utility or third party to operate the customers’ generation based on market conditions or for purposes of reliability. This application includes both small and large scale generation and storage devices.

This application depends on the further development of standards for in-premises communications and devices to allow customer owned generation and storage to be remotely monitored and controlled.

* + - 1. **Potential Sources of Costs:**

The utility would require an AMI metering system and upgrades to a distribution management system. Customers would pay for their generation or storage devices and installation.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Facilitate customer generation – Customers could see an improved economic case for installing and operating distributed resources.
  + Improve system availability – Customers with some types of generation and storage are better protected against outages.
* Utilities
  + Improve system reliability – Utilities could manage distributed resources to improve system reliability.
  + Improve situational awareness – Utilities would have information about the operational status and availability of distributed resources.
* RTO/ISO
  + Increase grid stability – Coordinated management of large and small distributed resources could improve stability.
  + Improve situational awareness – The RTO would have information about the operational status and availability of distributed resources.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties could develop aggregated distributed resource offerings into the electric market or provide remote equipment monitoring and maintenance.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Increase ability to manage energy cost – Customers participating in time varying rates could use generation or stored energy during times of high prices or provide energy into the grid.
  + Enhance services to the customers – Customers could be informed about the reliability and status of their distributed resource.
* Regional Electricity Market
  + Reduce market price of energy -- With sufficient numbers of distributed resources, peak loads and prices could be lowered, benefiting all customers
  + Reduce market price of capacity -- With sufficient numbers of distributed resources, peak loads and prices could be lowered, benefiting all customers.
* RTO/ISO
  + Increase market competitiveness (ancillary services) – Customers could be incentivized to use their generation at the direction of the RTO.
* Society
  + Increase use of renewables – Some rate and market structures could incentivize customers to install solar or wind power.
  + Reduce carbon footprint – If larger numbers of renewable generation sources are installed, some carbon based generation could be reduced.
  + Improve air quality – Assumes that distributed resources are solar, wind or fuel cell based.
  + Improve public safety – Assumes significant numbers of distributed resources that can be managed to reduce the impact of outages.
  + Improve economic productivity – Increased numbers of distributed resources could reduce the impact of system outages and allow customers to operate as normal.
  + Improve broadband/communications network – This benefit may be achieved if public communications networks are expanded or improved in order to support communications to customer generation
    - 1. **Potential Negative Impacts:**

Potential negative impacts for this application are the challenges with existing utility system protection schemes if distributed generation is widely used. This concern is addressed by the application, *Dynamic System Protection for Two-Way Power Flows and Distributed Resources*. Potential back feed into the system and employee safety is another concern.

### Electric Vehicles: Optimized Charging

* + - 1. **Description:**

High market penetration of electric vehicles will add significant load to the system which can be managed through the use of smart charging systems. Also, dense localized deployment of electric vehicles may strain local distribution system devices. Managed charging could mitigate these localized impacts.

This application is immature and requires the development of standards for vehicle charging and communications and in-premises communications. An additional challenge is how utilities will address mobile charging.

* + - 1. **Potential Sources of Costs:**

The utility would require a communications capability to vehicles which the Collaborative assumed to be base on an AMI metering system. The utility would also require a charging management system which could be provided by a demand response system. Customers would require a communicating vehicle charging portal which could be part of the car or a separate device.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Enhance services to the customers – Customers could see improved charging and higher charging availability with a well managed system.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Increase ability to manage energy cost – Customers could better take advantage of time based energy rates to charge during periods of low cost.
  + Improve information availability – Customers could provide charging preferences and receive feedback.
  + Reduce market price of energy – Customers could see lower prices by preventing new system peaks.
  + Improve power quality – Optimized charging could eliminate localized voltage sags by spreading out charging cycles.
* Utilities
  + Improve system reliability – Optimized charging could reduce overloading on distribution system devices.
  + Improve forecasting – An optimized charging system would provide better data about charging behavior.
  + Improve situational awareness – An optimized charging system could report real time charging conditions.
* Regional Electricity Market
  + Reduce market price of capacity -- Customers could see lower prices by preventing new system peaks.
* RTO/ISO
  + Increase grid stability – An optimized charging system could signal an on demand reduction of charging to improve grid stability.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – With time varying rates or incentives for electric vehicles, third parties and customers may find mutually beneficial service opportunities.
    - 1. **Potential Negative Impacts:**

A potential negative impact that was expressed in the Collaborative was the potential use of base load coal generation for vehicle charging. It’s not clear that this issue is made worse by this application or if it is a more general aspect of electric vehicle charging.

### Dispatch of Electric Vehicle Storage

* + - 1. **Description:**

A potential application of electric vehicles is to allow them to provide stored energy as a backup resource when system and market conditions are appropriate. Vehicle to grid (V2G) dispatch may have a difficult economic case based on the increased wear on a vehicles battery and trade off evaluation by customers between maintaining vehicle charge and the market value of the provided electricity.

This application is not mature and requires standards and technology development for vehicle communications and in-premises communications. Improved battery life cycle and a vehicle charging infrastructure are also desirable.

* + - 1. **Potential Sources of Costs:**

Utility costs include an AMI metering system or other communications pathway, a demand response system and a distribution management system. Customers would require a vehicle charging portal.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Regional Electricity Market
  + Reduce market price of energy -- Customers would benefit from reduced energy prices as vehicle storage could be used during times when energy costs are high
  + Reduce market price of capacity -- Dispatch of vehicle based storage could be used to reduce system peaks.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Increase ability to manage energy cost – Customers would voluntarily participate in V2G transactions based on the economic advantage.
  + Enhance services to the customers – Improved interfaces allow customers to define their preferences for when they provide energy, level of vehicle charge to maintain and V2G price point.
  + Facilitate customer generation – Allows customer to gain additional benefit from their electric vehicle by selling stored energy.
  + Improve system availability – Customers benefit from the increased reliability provided by widespread V2G programs.
* Utilities
  + Improve system reliability – Utilities are provided with additional resources to meet demand.
* RTO/ISO
  + Increase grid stability – Assuming wide support, V2G can be dispatched as needed to provide grid support.
* Competitive Suppliers and Third Parties
  + Improve/expand products and services – Third parties could aggregate groups of customers in V2G programs and provide stored energy back to the grid.
    - 1. **Potential Negative Impacts:**

A potential negative impact for this application is the reduction of customers’ battery life when used for to provide energy to the grid. Batteries have a limited number of charge-discharge cycles and V2G decreases the useful life of the battery. The price paid to customers for their stored electricity has to include the value of incremental battery wear.

## Transmission Applications

The transmission applications group focuses on scenarios that improve the reliability and security of the bulk transmission system.

The Transmission Applications are:

* Wide Area (Phasor) Measurement
* Wide Scale Outage Recovery
* Enhanced Physical Security

### Wide Area (Phasor) Measurement

* + - 1. **Description:**

Improved communications and sensors allow better visibility and decision making for transmission system operations.

Phasor measurement units in various substations measuring system phase angles 30 times per second. The data is transmitted back to a control center to determine phase angle differences at various points of the grid. The phase angle differences provide improved situational awareness and should improve grid stability.

The technology for this application is mature and wide area measurement devices and systems are being increasingly deployed.

* + - 1. **Potential Sources of Costs:**

Utilities must install phasor measurement devices, upgrade communications and upgrade their transmission control systems.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Improve situational awareness – improves transmission system situational awareness.
* RTO/ISO
  + Increase grid stability – Improved situational awareness allows for controllers to rapidly respond to adverse system conditions.
  + Improve situational awareness – improves transmission system situational awareness.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Improve system reliability – Improved situational awareness allows for controllers to rapidly respond to adverse system conditions.
* Society
  + Improve public safety – Increased transmission reliability prevents lengthy, wide spread outages.
  + Improve economic productivity – Increased transmission reliability prevents lengthy, wide spread outages.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Wide Scale Outage Recovery

* + - 1. **Description:**

Smart grid devices at the transmission and distribution system level allow for better measurement and control of the electrical system when restoring from a wide scale outage. Utilities and the RTO can use improved sensing devices to measure existing grid conditions and more discrete controls to improve speed of restoration. This application also includes improved fault location.

* + - 1. **Potential Sources of Costs:**

Utilities will require additional switching and sensing devices and expanded field communications.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Utilities
  + Increase field labor productivity – Utilities can use improved fault location to increase field crew efficiency.
  + Improve situational awareness – Increased sensing capability.
* RTO/ISO
  + Improve situational awareness – Increased sensing capability.
* Society
  + Improve system resiliency (disaster recovery) – Improved sensing and control reduces outage impact and allows for quicker outage recovery.

Additional Potential Sources of Benefits and Beneficiaries:

* Customers
  + Improve system availability – Quicker outage recovery.
* Utilities
  + Improve employee safety – Field crews spend less time in restoration efforts.
* Society
  + Reduce carbon footprint – This benefit is likely to be minor and for this specific application is obtained by the reduction in the utility’s use of vehicles for field crews.
  + Improve public safety – Reduced outage durations improve public safety.
  + Improve economic productivity – Quicker outage recovery.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.

### Enhanced Physical Security

* + - 1. **Description:**

Enhanced physical security of substations and their assets is a valuable application. It can be employed at the transmission and at the distribution level, but the increased impact of transmission level events is important to note. This application can overlap with the Asset Condition Monitoring application if infrared capable cameras are used for both security surveillance and asset monitoring.

Physical security is a mature application.

* + - 1. **Potential Sources of Costs:**

The utility will require access control systems, cameras, and a high capacity network.

* + - 1. **Potential Sources of Benefits and Beneficiaries:**

The Collaborative agreed that the following benefits were both likely and significant:

* Customers
  + Improve system availability – Assumes that improved security prevents outages.
* Utilities
  + Improve system reliability – Assumes that improved security prevents outages.
  + Reduce procurement cost – This benefit is achieved by reducing damage to utility assets.

Additional Potential Sources of Benefits and Beneficiaries:

* Utilities
  + Increase field labor productivity – Utilities will have to spend less time repairing and replacing damage due to unauthorized access.
  + Extend asset life – This benefit is achieved by reducing damage to utility assets.
  + Reduce failure rates – This benefit is achieved by reducing damage to utility assets.
  + Improve asset performance – This benefit is achieved by reducing damage to utility assets.
  + Improve employee safety – Employees will be less exposed to damaged and potentially dangerous equipment.
  + Improve situational awareness – Improved security systems can provide additional, near real time data to the utility.
* RTO/ISO
  + Increase grid stability – Assumes that improved security prevents outages.
* Society
  + Improve public safety – Assumes that improved security prevents outages.
  + Improve economic productivity – Assumes that improved security prevents outages.
  + Improve system resiliency (disaster recovery) – Improved security can enhance system resiliency, but likely won’t have an impact on disaster recovery.
    - 1. **Potential Negative Impacts:**

The Collaborative found no negative impacts related to this application.