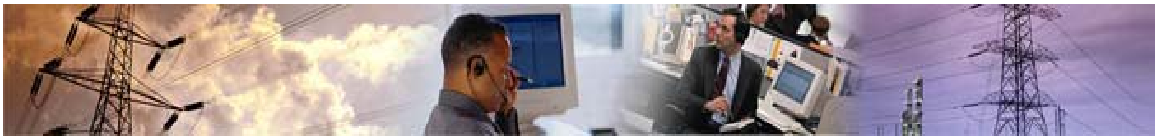

NETL Modern Grid Strategy
Powering our 21st-Century Economy

ADVANCED METERING INFRASTRUCTURE

Conducted by the National Energy Technology Laboratory
for the U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability
February 2008

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Office of Electricity
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EXECUTIVE SUMMARY

Deploying an Advanced Metering Infrastructure (AMI) is a fundamental early step to grid modernization. AMI provides the framework for meeting one of the Modern Grid's Principal Characteristics – Motivation and Inclusion of the Consumer.

AMI is not a single technology, but rather an integration of many technologies that provides an intelligent connection between consumers and system operators. AMI gives consumers the information they need to make intelligent decisions, the ability to execute those decisions and a variety of choices leading to substantial benefits they do not currently enjoy. In addition, system operators are able to greatly improve consumer service by refining utility operating and asset management processes based on AMI data.

Through the integration of multiple technologies (such as smart metering, home area networks, integrated communications, data management applications, and standardized software interfaces) with existing utility operations and asset management processes, AMI provides an essential link between the grid, consumers and their loads, and generation and storage resources. Such a link is a fundamental requirement of a Modern Grid.

Figure 1 below illustrates how AMI is the first step to the overall Modern Grid vision.

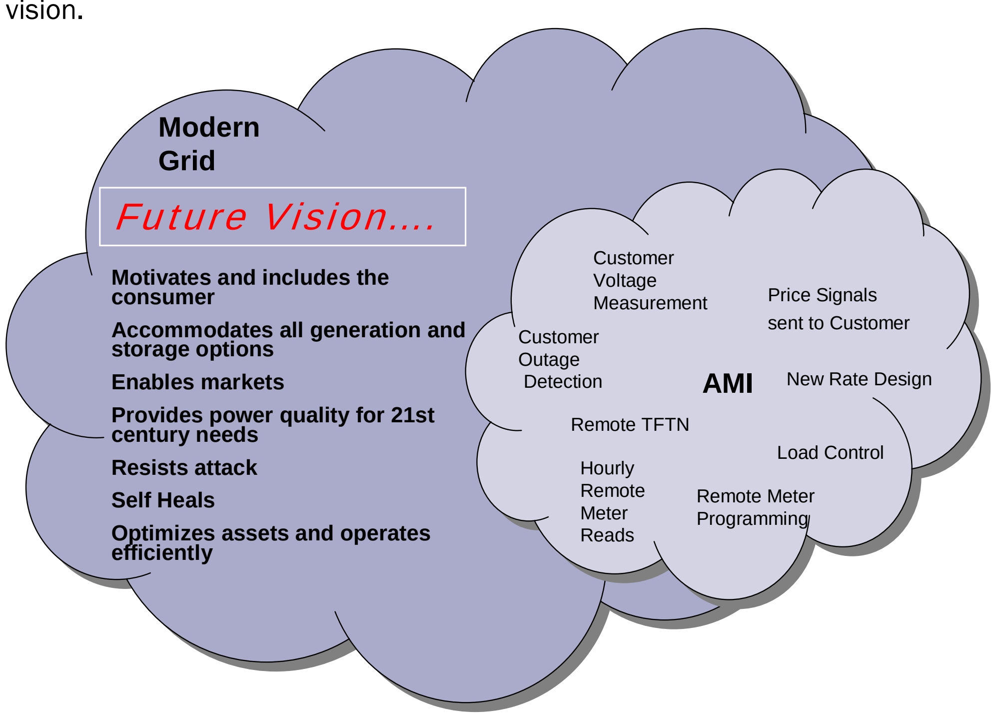

Figure 1: AMI – The first step to a Modern Grid

How does AMI support the vision for the Modern Grid? Initially, Automated Meter Reading (AMR) technologies were deployed to reduce costs and improve the accuracy of meter reads. A growing understanding of the benefits of two-way interactions between system operators, consumers and their loads and resources led to the evolution of AMR into AMI. The vision of the Modern Grid's seven principal characteristics (Figure 1) further reinforces the need for AMI:

- *Motivation and inclusion of the consumer* is enabled by AMI technologies that provide the fundamental link between the consumer and the grid.
- *Generation and storage options* distributed at consumer locations can be monitored and controlled through AMI technologies.
- *Markets are enabled* by connecting the consumer to the grid through AMI and permitting them to actively participate, either as load that is directly responsive to price signals, or as part of load resources that can be bid into various types of markets,
- AMI smart meters equipped with *Power Quality* (PQ) monitoring capabilities enable more rapid detection, diagnosis and resolution of PQ problems.
- AMI enables a more distributed operating model that reduces the *vulnerability of the grid to terrorist attacks*.
- AMI provides for *self healing* by helping outage management systems detect and locate failures more quickly and accurately. It can also provide a ubiquitous distributed communications infrastructure having excess capacity that can be used to accelerate the deployment of advanced distribution operations equipment and applications.
- AMI data provides the granularity and timeliness of information needed to greatly *improve asset management and operations*.

The purpose of this document is to describe AMI and discuss how it contributes to the achievement of the overall Modern Grid vision. AMI can be the first of four major milestones on the road to a modern grid:

- Advanced Metering Infrastructure (AMI)
- Advanced Distribution Operations (ADO)
- Advanced Transmission Operations (ATO)
- Advanced Asset Management (AAM)

By properly sequencing these milestones, a more cost effective modernization program can be achieved.

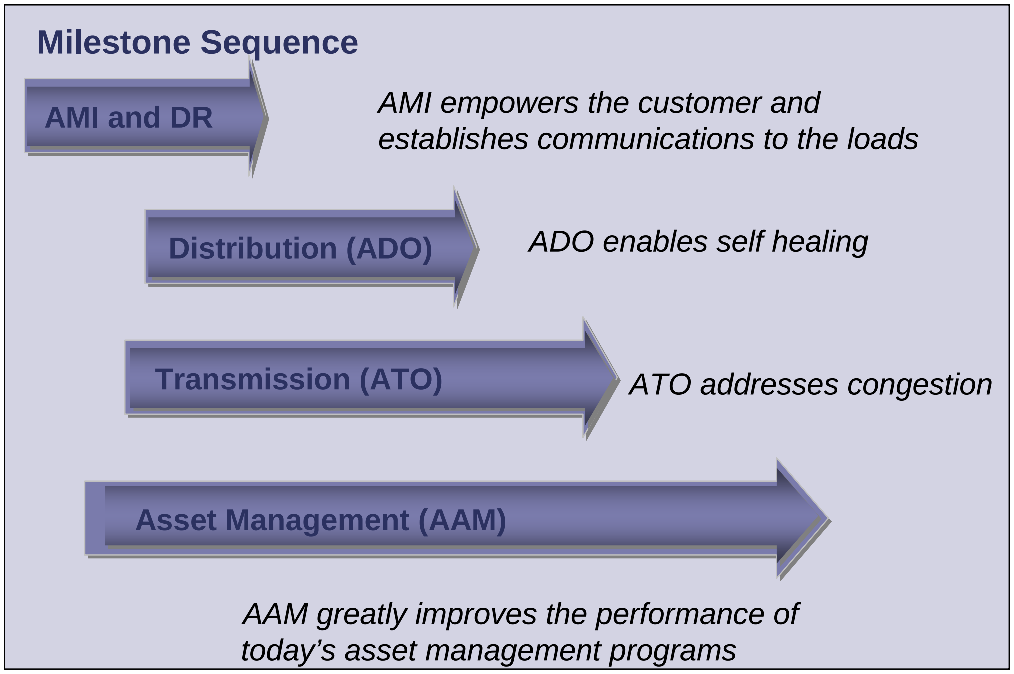

Figure 2: Milestone Sequence

A well-crafted sequence will allow applications to build on previous accomplishments, as shown below.

Sequence Has Value	
AMI	• Establishes communications with the consumer • Provides time stamped system information
ADO	• Uses AMI communications to collect distribution information • Uses AMI information to improve operations
ATO	• Uses ADO information to improve operations and manage transmission congestion and voltage • Uses AMI to give consumers access to markets
AAM	• Uses AMI, ADO, and ATO information and controls to improve: o Operating efficiency o Asset utilization

Figure 3: Sequence Has Value

WHAT IS AMI?

AMI is not a single technology implementation, but rather a fully configured infrastructure that must be integrated into existing and new utility processes and applications.

This infrastructure includes home network systems, including communicating thermostats and other in-home controls, smart meters, communication networks from the meters to local data concentrators, back-haul communications networks to corporate data centers, meter data management systems (MDMS) and, finally, data integration into existing and new software application platforms. Additionally, AMI provides a very "intelligent" step toward modernizing the entire power system. Figure 4 below graphically describes the AMI technologies and how they interface:

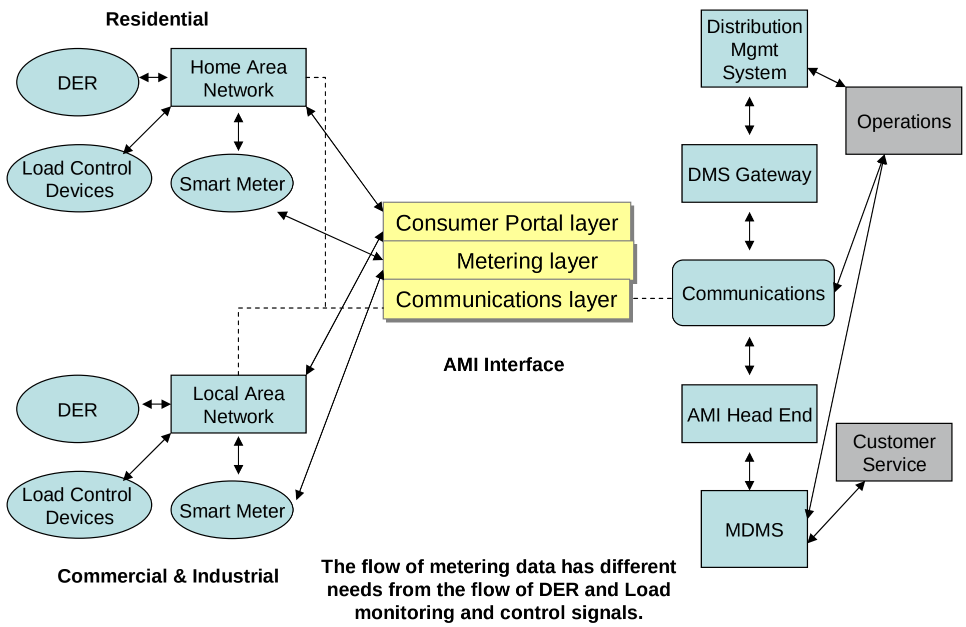

Figure 4: Overview of AMI

At the consumer level, smart meters communicate consumption data to both the user and the service provider. Smart meters communicate with in-home displays to make consumers more aware of their energy usage. Going further, electric pricing information supplied by the service provider enables load control devices like smart thermostats to modulate electric demand, based on pre-established consumer price preferences. More advanced customers deploy distributed energy resources (DER) based on these economic signals. And consumer portals process the AMI data in ways that enable more intelligent energy consumption decisions, even providing interactive services like prepayment.

The service provider (utility) employs existing, enhanced or new back office systems that collect and analyze AMI data to help optimize operations, economics and consumer service. For example, AMI provides immediate feedback on consumer outages and power quality, enabling the service provider to rapidly address grid deficiencies. And AMI's bidirectional communications infrastructure also supports grid automation at the station and circuit level. The vast amount of new data flowing from AMI allows improved management of utility assets as well as better planning of asset maintenance, additions and replacements. The resulting more efficient and reliable grid is one of AMI's many benefits.

What are the technology options for AMI?

An AMI system is comprised of a number of technologies and applications that have been integrated to perform as one:

- Smart meters
- Wide-area communications infrastructure
- Home (local) area networks (HANs)
- Meter Data Management Systems (MDMS)
- Operational Gateways

Smart Meters

Conventional electromechanical meters served as the utility cash register for most of its history. At the residential level, these meters simply recorded the total energy consumed over a period of time – typically a month. Smart meters are solid state programmable devices that perform many more functions, including most or all of the following:

- Time-based pricing
- Consumption data for consumer and utility
- Net metering
- Loss of power (and restoration) notification
- Remote turn on / turn off operations
- Load limiting for "bad pay" or demand response purposes
- Energy prepayment
- Power quality monitoring
- Tamper and energy theft detection
- Communications with other intelligent devices in the home

Figure 5: A Modern Solid State Smart Meter (left) and an older Electromechanical Watt hour Meter

And a smart meter is a green meter because it enables the demand response that can lead to emissions and carbon reductions. It facilitates greater energy efficiency since information feedback alone has been shown to cause consumers to reduce usage.

Communications Infrastructure

The AMI communications infrastructure supports continuous interaction between the utility, the consumer and the controllable electrical load. It must employ open bi-directional communication standards, yet be highly secure. It has the potential to also serve as the foundation for a multitude of modern grid functions beyond AMI. Various architectures can be employed, with one of the most common being local concentrators that collect data from groups of meters and transmit that data to a central server via a backhaul channel. Various media can be considered to provide part or all of this architecture:

- Power Line Carrier (PLC)
- Broadband over power lines (BPL)
- Copper or optical fiber
- Wireless (Radio frequency), either centralized or a distributed mesh
- Internet
- Combinations of the above

Future inclusion of smart grid applications and potential consumer services should be considered when determining communication bandwidth requirements.

Home Area Networks (HAN)

A HAN interfaces with a consumer portal to link smart meters to controllable electrical devices. Its energy management functions may include:

- In-home displays so the consumer always knows what energy is being used and what it is costing
- Responsiveness to price signals based on consumer-entered preferences
- Set points that limit utility or local control actions to a consumer-specified band
- Control of loads without continuing consumer involvement
- Consumer over-ride capability

The HAN/consumer portal provides a smart interface to the market by acting as the consumer's "agent." It can also support new value added services such as security monitoring.

A HAN may be implemented in a number of ways, with the consumer portal located in any of several possible devices including the meter itself, the neighborhood collector, a stand-alone utility-supplied gateway or even within customer-supplied equipment.

METER DATA MANAGEMENT SYSTEM (MDMS)

A MDMS is a database with analytical tools that enable interaction with other information systems (see Operational Gateways below) such as the following:

- Consumer Information System (CIS), billing systems, and the utility web site
- Outage Management System (OMS)
- Enterprise Resource Planning (ERP) power quality management and load forecasting systems
- Mobile Workforce Management (MWM)
- Geographic Information System (GIS)
- Transformer Load Management (TLM)

One of the primary functions of an MDMS is to perform validation, editing and estimation (VEE) on the AMI data to ensure that despite disruptions in the communications network or at customer premises, the data flowing to the systems described above is complete and accurate.

OPERATIONAL GATEWAYS

AMI interfaces with many system-side applications (see MDMS above) to support:

Advanced Distribution Operations (ADO)

- Distribution Management System with advanced sensors (including PQ data from AMI meters)
- Advanced Outage Management (real-time outage information from AMI meters)
- DER Operations (using Watt and VAR data from AMI meters)
- Distribution automation (including Volt/VAR optimization and fault location, isolation, sectionalization and restoration (FLISR))
- Distribution Geographic Information System
- Application of AMI communications infrastructure for:
    - Micro-grid operations (AC and DC)
    - Hi-speed information processing
    - Advanced protection and control
    - Advanced grid components for distribution

Advanced Transmission Operations (ATO)

- Substation Automation
- Hi-speed information processing
- Advanced protection and control (including distribution control to improve transmission conditions)
- Modeling, simulation and visualization tools
- Advanced regional operational applications
- Electricity Markets

Advanced Asset Management (AAM)

AMI data will support AAM in the following areas:

- System operating information
- Asset “health” information
- Operations to optimize asset utilization
- T&D planning
- Condition-based maintenance
- Engineering design and construction
- Consumer service
- Work and resource management
- Modeling and simulation

WHAT ARE SOME DEPLOYMENT APPROACHES?

Deployment approaches will depend upon the utility's starting point, geography, regulatory situation and long-term vision. For those utilities that already have deployed an AMR system, the question will be whether they can build on that system or need to start afresh. If the system includes a two-way communications infrastructure, it should be possible to upgrade the metering to accommodate a range of AMI applications. Where the communications infrastructure is unidirectional (i.e. outgoing only), it may be possible to overlay a return channel using a complementary technology. This option would have to be compared to the cost and benefits of installing a new integrated two-way communications infrastructure. The speed, reliability and security of the communications infrastructure will determine the range of applications it can support. For utilities with widespread and diverse territories, it may be that multiple communications solutions will be needed. Pilot programs that explore the performance of various solutions can be useful as the first phase of an AMI deployment.

The choice of an AMI communications infrastructure is also influenced by the utility's long-term vision for AMI. If AMI is seen as the foundation for overall grid modernization, the communications system will need to accommodate anticipated future needs and have the flexibility to handle applications that are not even currently on the utility's radar screen. Experience has shown that these evolving grid modernization applications often produce major benefits, as discussed in later sections.

The deployment of AMI is a strategic initiative that must be endorsed by the utility regulator. The benefits of AMI, and ultimately of overall grid modernization, flow to not just the utility, but also to the consumer and society in general. Hence regulators need to consider the possibility that traditional utility economic analysis may not capture the true value of an AMI strategic initiative and that an expanded framework may be more appropriate, as discussed later in this document. Some regulators may see AMI and grid modernization as very desirable and they will encourage their utilities to move aggressively. Others may be less proactive and will expect their utilities to broach AMI and bring with them a compelling argument on its merits. In either case, recognition of the wide-ranging societal benefits of AMI must be addressed.

Together, the utility and its regulators should communicate the full benefits of an AMI initiative to consumers and society at large. There is a general lack of understanding among the public regarding how electricity is produced and delivered, how it affects their quality of life and how it can meet their needs in the 21st century. In particular, the value of consumers' increased involvement in electricity markets, and the potential benefits for consumers involved in such programs needs to be explained.

WHAT ARE THE BENEFITS OF AMI?

AMI provides benefits to consumers, utilities and society as a whole.

CONSUMER BENEFITS

For the consumer, this means more choices about price and service, less intrusion and more information with which to manage consumption, cost and other decisions. It also means higher reliability, better power quality, and more prompt, more accurate billing . In addition, AMI will help keep down utility costs, and therefore electricity prices. And, as members of society, consumers also reap all the benefits that accrue to society in general, as described below.

UTILITY BENEFITS

Utility benefits fall into two major categories, billing and operations.

AMI helps the utility avoid estimated readings, provide accurate and timely bills, operate more efficiently and reliably, and offer significantly better consumer service. AMI eliminates the vehicle, training, health insurance, and other overhead expenses of manual meter reading, while the shorter read-to-pay time advances the utility's cash flow, creating a one-time benefit. And consumer concerns about meter readers on their premises are eliminated.

Operationally, with AMI the utility knows immediately when and where an outage occurs so it can dispatch repair crews in a more timely and efficient way. Meter-level outage and restoration information accelerates the outage restoration process, which includes notifying consumers about when power is likely to return.

Using AMI, the utility can receive significant benefits from being able to manage customer accounts more promptly and efficiently, starting with the ability to remotely connect and disconnect service without having to send personnel to the customer site. Similarly, many maintenance and customer service issues can be resolved more quickly and cost-effectively through the use of remote diagnostics. And AMI enables new programs and methods for creating and recovering revenue such as distributed generation and prepayment programs.

AMI also provides vast amounts of energy usage and grid status information that can be used by consumers to make more informed consumption decisions and by utilities to make better decisions about system improvements and service offerings.

Instead of relying on rough estimates, engineers armed with AMI's detailed knowledge of distribution loads and electrical quality can accurately size equipment and protection devices, and better understand distribution system behavior. This huge increase in valuable information helps the utility:

- Assess equipment health
- Maximize asset utilization and life
- Optimize maintenance, capital and O&M spending
- Pinpoint grid problems
- Improve grid planning
- Locate/ identify power quality issues
- Detect/reduce energy theft

SOCIETAL BENEFITS

Society, in general, benefits from AMI in many ways. One way is through improved efficiency in energy delivery and use, producing a favorable environmental impact. It can accelerate the use of distributed generation, which can in turn encourage the use of green energy sources. And it is likely that emissions trading will be enabled by AMI's detailed measurement and recording capabilities.

A major benefit of AMI is its facilitation of demand response and innovative energy tariffs. During periods of high energy demand, a small reduction in demand produces a relatively large reduction in the market price of electricity. And reduced demand can avoid rolling blackouts. According to Edison Electric Institute (EEI), the direct costs (e.g. power costs) of rolling blackouts in California have been estimated at tens of millions of dollars. Business and consumer losses may be many times higher. Hence, a modest demand response capability could produce a societal benefit worth billions of dollars.

The benefits accrued may vary depending on the type of demand response programs initiated. For instance, demand response distributed to the individual premise in forms like thermostat and pool pump control allows load to be reduced without sacrificing consumer satisfaction. However, even just shifting demand away from peak hours through time-of-use tariffs can have major benefits, including the reduced cost to both utilities and consumers by deferring building new, expensive peak generation facilities.

There is also a societal fairness issue that AMI addresses. Full deployment of AMI results in the elimination of old and obsolete electromechanical meters that tend to slow down as they age. Modern AMI meters maintain their accuracy over time, resulting in a more equitable situation for all consumers. In addition, modern meters are self monitoring, making it easier to identify inaccurate measurements, incorrect installations and, especially, electric energy theft.

As reported by Edison Electric Institute (EEI), price and demand reductions during high-demand periods lead to:

- Reduced
    - peak capacity requirements

  - congestion costs
  - T&D costs
  - electrical losses
  - generation costs
  - market influence by any one supplier
- Improved
  - electric system efficiency (lower operating costs)
  - electric system reliability (lower maintenance costs)
  - settlement data management

Added Benefits When AMI Serves As a Modern Grid Platform

Since smart metering and demand response programs can be one of the foundations of a modern grid, it is wise to also assess the associated communications infrastructure strategy to identify incremental investments in communications that might benefit the functional needs of ADO, ATO and AAM (see Operational Gateways above).

Increased bandwidth and broader area coverage generally lead to more opportunities for grid modernization. In other words, a ubiquitous AMI communications network could be designed, for a small incremental cost, to also accommodate transmission and distribution automation systems, reducing the total cost of both AMI and other forms of grid modernization. And a useful by-product could be the use of excess bandwidth to provide broadband services, such as internet access and voice over IP, to consumers.

Enhanced functionality can be achieved when the AMI infrastructure sequences into a fully enabled modern grid (see Figure 2.). When that occurs, EPRI (Electric Power Research Institute) estimates that at least a 4 to 1 total benefit to cost ratio will be realized.

As described in other Modern Grid Strategy white papers, achieving the vision of the Modern Grid depends on the correct and effective deployment of technologies and applications in five key technology areas (KTAs). AMI relates to each of these KTAs as described below:

- **Integrated Communications:** AMI provides the last and by far the most extensive link between the grid (including the consumer's load) and the system operator.
- **Sensing and Measurement:** Smart meters extensively measure system conditions (including PQ) down to the consumer level.
- **Advanced Control Methods:** Consumer-side applications process information and initiate control actions locally (sometimes based on real time pricing). Distribution operations centers process AMI information and take control actions at the system and regional level.
- **Advanced Grid Components:** AMI supports the deployment of distributed energy resources and can reduce the communication network costs of deploying pole-top distribution automation components.

- **Improved Interfaces & Decision Support:** AMI consumer portals, home area networks, and in-home displays provide the human interface and support consumer decision-making. Decision support at distribution operations centers is enabled by the additional information provided by AMI.

Common to all modern grid characteristics and key technologies is the pivotal role of information and knowledge. AMI information can support the vast majority of electric industry processes, as shown in Figure 6.

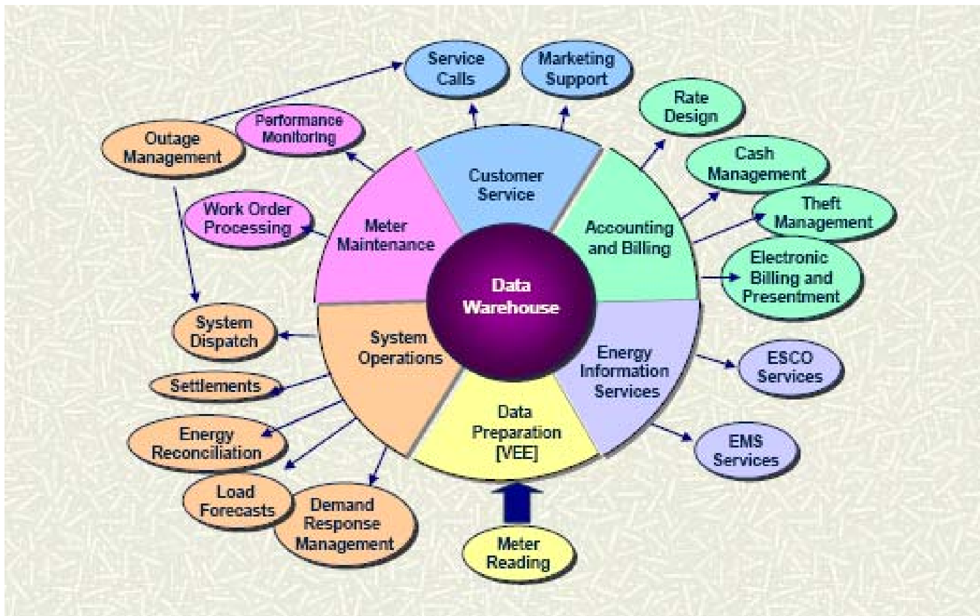

Figure 6 Full Utility Perspectives (Levy Associates, 2005)

It is clear from all the above that AMI provides many benefits to a wide variety of stakeholders, and that going beyond AMI to achieve a truly modern grid produces additional large improvements in the operations of an electric utility.

The list of benefits includes:

- Greatly improved outage management system (through links with GIS and real time consumer status)
- Improved system planning process and results
- Improved distribution asset management programs including equipment health assessment and condition-based maintenance
- Advanced distribution management systems (distribution automation, integrated operation of DR (and DER), micro-grid operation, self-healing, etc.)
- Improved mobile workforce management and operations
- New opportunities for consumer choice and new retail services
- Improvements to power quality issues

- Reduced environmental impact
- Distribution system support of transmission operations (transmission congestion relief, voltage support, loss reduction)

The MGS publication “Modern Grid Benefits” provides a more detailed discussion of modern grid benefits, including those that accrue to society as a whole.

WHAT POLICIES APPLY TO AMI?

HISTORY

For most of the history of the electricity industry, the area of metering has not seen major policy issues or developments. Those issues that did develop dealt with areas such as meter accuracy testing, frequency of billing, and other aspects of the meter reading function. Most of these were addressed via state legislation or regulation. There was little, if any, federal policy enacted with respect to metering.

Given that metering is part of the infrastructure of a regulated utility, and is in part a capital expense, metering investments by utilities have always been subject to the approval of policy makers. But this has mainly come in the form of specific approvals via rate cases and other policy proceedings. While involving policy makers, the proceedings to deal with costs have not been generic policy proceedings.

In the 1990's as a number of states moved to restructure their electricity industry to make the commodity subject to competitive retail markets, some states, notably New York and Texas, went further and "unbundled" or opened up distribution services such as metering for competition. The intent of this policy was to spur the introduction of advanced meters faster than the regulated system appeared to be deploying them.

Competitive metering did not work very well. The costs of ad hoc metering deployment (i.e. where meters are put in sporadically and with no geographic cohesion or proximity) proved to be 5 to 10 times the cost per meter as compared to a mass deployment by the utility. Competitive metering policy had even worse impacts on the deployment of advanced metering.   Because such policy granted competitors the ability to take away the metering part of the utility franchise, utilities around the country – not just in New York and Texas - quickly became wary of making metering investments that could potentially become stranded. Thus, competitive metering policy actually froze the introduction of advanced metering instead of fostering and accelerating it. Both Texas and New York have rescinded their competitive metering policy.

RECENT DEVELOPMENTS

Beginning in 2000, metering became a more important issue in the eyes of policy makers and the electricity industry. New metering and communications technologies brought forward new benefits. Most importantly, however, the rise in interest in demand response as a new policy and business component of the electricity industry– both at the wholesale and retail level – began to drive interest in advanced metering. This new interest in AMI occurred because demand response could now be based on a better ability to monitor and verify the time at which electricity was used.

FEDERAL POLICY

The first major federal policy on electricity metering was enacted in 2005. The Energy Policy Act of 2005 (EPACT) contained a Section entitled "Smart Metering." The Section put in place the following policy:

- Requirement on states and non-regulated utilities to investigate and consider providing Time-Based Rates and Advanced Metering to all consumers.
- Requirement that FERC conduct an annual assessment on demand response and advanced metering, which would include among other things, a national survey to determine the penetration and saturation of advanced metering.
- Requirement that DOE issue a report to Congress on demand response potential, together with recommendations on how to use policy to overcome barriers to advanced metering and demand response.
- Requirement that all Federal Buildings be equipped with advanced metering.

Both FERC and DOE completed their Requirements on time and both are available as reference documents (see bibliography). Both include discussion of potential policy options. In the case of the FERC assessment, the survey conducted represents the first nationwide survey on advanced metering.

The Federal Buildings Requirement has resulted in all federal agencies developing metering plans. They are now in the process of implementing those plans.

The requirement upon states, municipalities and cooperative boards has, for the most part, been pursued diligently by those entities affected. The language of EPACT required that investigations be concluded and decisions reached by August of 2007. More information on state developments in this area is available at www.demandresponsecommittee.org.

In December of 2007, new energy legislation entitled the Energy Independence and Security Act of 2007 was signed into law. Title XIII addresses the development of a Smart Grid. This new law will serve as a major catalyst for rapid deployment of AMI and grid modernization.

STATE POLICY

As is the case at the Federal level, States have begun to move in recent years to put policy in place that directly or indirectly affects the metering area. Much of it has come in response to the EPACT investigation requirement noted in the previous section. In some cases, States had initiated policy efforts prior to EPACT; in other cases, States have decided not to strictly implement the EPACT requirement but have instead set other policies in place or in motion to move the state forward on demand response and advanced metering. Many states have begun pilot programs that incorporate demand response and advanced metering. Among the states that are notable for their self-initiated efforts are New York, Texas, Connecticut and California.

California is an interesting example. Policy was first put in place to require a statewide level of demand response by a specified date. Then rules were established to require statewide deployment of advanced metering as the means of achieving the demand response policy. In the case of California, the Public Utility Commission first conducted a generic policy process to establish advanced metering objectives, requirements, etc. Then each of the major utilities was required to present to the Commission for its approval a business case on how to implement the generic policy in a way best suited to their individual situations.

One of the areas facing States with respect to metering is the need to facilitate the replacement of existing meters and metering systems with new technology and infrastructure – even though the existing metering may still be within its useful life and may also still be functioning satisfactorily for its original intended purpose. Recognizing this issue, the Board of Directors of the National Association of Regulatory Utility Commissioners (NARUC) in February of 2007 adopted a resolution calling for Commissions to recognize the need to consider faster regulatory depreciation of existing meters and metering systems.

WHAT BARRIERS IMPACT SUCCESSFUL DEPLOYMENT OF AMI?

The transition to AMI and ultimately to a modern grid is not without obstacles.

- **Business Case Limitations:** Limiting the assessment of AMI benefits to just those associated with utility operations biases the business case against deployment. A more complete societal business case often produces a different conclusion. If one includes such items as the avoided societal costs and consequences of rolling and regional blackouts, AMI benefits can be many times the utility operating benefits. While some of these benefits accrue to constituents outside the utility, they are nonetheless direct consequences of AMI and should be addressed in the business case.
- **Depreciation Rules:** The accounting treatment of the value of in-service meters is another important element in any AMI decision. In most cases it will be necessary to replace obsolete meters before they have been fully depreciated, creating a write-down (i.e. an expense that reduces utility earnings) that can affect regulated income.
- **Standards:** While AMI technology is moving at a rapid pace, standards are needed to ensure interoperability among the many AMI offerings. Open standards are the best way to drive down the costs of AMI deployments and to give utilities the assurance that a large AMI investment will not become stranded if the selected vendor fails.
- **Rate Designs:** Innovative rate designs that reflect actual market conditions are needed to complement the capabilities of AMI technology and realize the potential of demand response. Current ratemaking structures make it difficult to roll out new technologies. Utilities that install energy-saving systems can see their sales drop without any offsetting benefit
- **Education:** Consumer education is needed regarding the merits of AMI, DR and the societal benefits from grid modernization. Consumers also need to understand and demand a modern electric grid that will improve their overall quality of life and enhance US competitiveness in a global economy.
- **Technical Resources:** Utility and vendor technical staffs have been cut back over the past decade. Rebuilding these staffs and attracting the needed technical talent is a barrier to the full realization of AMI's potential.
- Regulatory Barriers - Overlapping federal, regional, state and municipal agencies create an impediment. The industry is neither fully regulated nor completely deregulated.
- Financial Constraints - The grid is capital intensive and faces problems imposed by utilities' constrained balance sheets.
- Technology Hurdles – It is a challenge to "fix a moving train." Utilities cannot turn off the power for a year or two while they install upgrades.

WHAT ARE THE BUSINESS CASE CONSIDERATIONS?

The development of the AMI business case can be conceptually straight forward, but difficult in the quantification of details.

Instead of the conventional regulatory framework, a more expansive AMI framework (Figure 7) has been suggested by Levy Associates. This new framework is expected to produce a very positive business case for both AMI and grid modernization in general. Conversely, the traditional framework is likely to produce only a marginal net benefit.

Comparing Business Case Options

	Conventional Framework	Proposed Framework
1	Methodology - Net Present Value of Costs and Benefits.	Methodology - Net Present Value of Costs and Benefits
2	Utility owns and rate bases all investment.	Consider financed or outsourced options.
3	Focus on utility revenue requirement.	Focus on system wide net benefits.
4	Metering assumed independent of other systems and applications.	Metering considered part of an integrated suite of utility applications.
5	Customer impacts not considered.	Customer impacts considered.
6	Demand response, innovative pricing and customer education not considered.	Demand response, innovative pricing and customer education considered.
7	New customer service and revenue opportunities not considered.	New customer service and revenue opportunities considered.

Figure 7 Comparing Business Case Options (Levy Associates, 2005)

In the discussion paper "The Power of Five Percent: How Dynamic Pricing Can Save $35 Billion in Electricity Costs" (Faruqui, 2007), the Brattle Group estimates that full AMI deployment across the US would cost about $26 billion and that utility operational savings would cover anywhere from 50% to 80% of this cost. It then goes on to estimate a long-run generation, transmission and distribution system capital savings of $35 billion, along with an additional $5 to 10 billion per year in reduced electricity prices.

Using an average of 65% for utility operational savings as an expected value, the remaining cost to be justified would be $9.1 billion (.35 x $26 billion). Since the long-run savings in capital investment is $35 billion, the benefit/cost ratio is about 4:1. Adding in the resulting reduced electricity prices, a particular concern to low income consumers, makes the case all the more compelling.

And, as suggested in Figure 7, additional benefits such as improved reliability and power quality, greater consumer choice, reduced environmental impact and others associated with a modern grid should also be recognized.

What are some experiences with AMI to date?

Some utilities have been moving in the direction of AMI for a number of years.

As their experience has grown, so has their insight into the advantages of moving beyond AMR to AMI and eventually to a smart or modern grid. The following cases illustrate that evolution and describe ways to approach an AMI deployment. It is important to note that a number of applications not initially contemplated are now adding great value. This strongly suggests that AMI systems that have the flexibility to readily accommodate new applications will prove to be the best long-term investments. Close coordination and cooperation between state regulators and utilities is a key to a smooth, successful AMI deployment.

Case 1

A Southeastern utility (see bibliography; "Meter Data Management System - What, Why, When, and How.") that primarily used AMI technologies for billing, added an integrated MDMS. As a result:

- Costs of billing research are now being reduced by 25%
- 95% of field service orders for special reads have been eliminated
- A 30% improvement in theft detection and recovery is being realized
- Trouble call handling costs are being reduced by 25%

In addition, consumer satisfaction and service reliability have improved.

Case 2

The following excerpts from John Luth's (2006) "10 Years of Results: AmerenUE's AMR Business Case Evolves to Support AMI" describe one utility's decade-long transition from AMR to AMI.

1994–1997: The UE Business Case & Initial Rollout

By early 1997, nearly 400,000 St. Louis area meters were on-line delivering 24x7 data available in 15-minute increments.

The initial business case was conservative. It focused largely on rapid payback, hard-dollar benefits across areas including meter reading, customer service and operations.

A Platform for the Future

Anticipated benefits beyond hard-dollar meter reading savings were a significant part of UE's decision to begin implementing a wireless fixed-network AMR system. The original sponsoring executives and the UE project team saw the implementation as a long-range strategic initiative that would ultimately help achieve the corporate goals of maintaining competitive energy costs while improving customer service. Early project charters also emphasized the longer term vision of implementing an intelligent network platform.

From Meter Read Savings to Advanced Distribution Applications

[Figure 2 depicts] the change in relative percentage values across a sampling of Ameren business case benefit categories comparing the original 1996 values with relative values taken from 2003 when the system was deployed to nearly 1.4 million end points.

Figure 2
Comparison of Relative Total Benefit Percentages across a Sample of AmerenUE Business Case

Selected Benefit Area	1996 Percentage	2003 Percentage
Meter Labor Savings	43	26
Vehicle & Office Savings	5	3
Move In/Move Out	31	25
High Bill Special Reads	0	1
Meter Accuracy Improvements	8	8
High Bill & Outage Calls	2	2
Estimated Bills Savings	3	1
Single Light Out	5	3
Load Analysis & Research	0	2
Energy Theft Savings	3	3
Improved Cash Flows	0	6
Load & Distribution Network Optimization	0	20

What is particularly revealing is a review of the change in relative value in the area of load management and distribution network optimization. This is now a major benefit area with many components that are summarized in the category “load and distribution network optimization.”

Case 3

Internationally, there are a number of AMI installations, as described in the following list (see bibliography; "Advanced Metering Infrastructure – MGI View"**):**

- Italy's Enel has installed over 27 million communicating solid-state meters. (completed in 2006 – 4 year ROI)
- Sweden's Vattenfall is in middle of rolling out 600,000 advanced meters and E.ON Sweden is in the early stages of rolling out 370,000 advanced meters.
- The Netherlands government has announced its intent to replace all 7.5 million electric meters in the country by the end of 2012.
- In Austria, Linz STROM recently announced plans to deploy advanced meters to 75,000 of its customers.
- In Canada, Hydro One has begun installation of smart meters in southern Ontario and expects to complete the installation of 1.3 million throughout its service territory by 2010.
- Norway recently announced a smart meter roll-out to 2.6 million customers by 2013.
- Australia/United Kingdom and others.

SUMMARY

AMI is an integration of technologies that provides an intelligent connection between consumers and system operators. Through the integration of technologies such as smart metering, home area networks, integrated communications, data management applications, and software interfaces with existing utility operations and asset management processes, AMI provides the needed link between the grid, consumers and their loads, and generation and storage resources – a link that is fundamental to the creation of a Modern Grid.

AMI is the first of four major modern grid milestones:

- Advanced Metering Infrastructure (AMI)
- Advanced Distribution Operations (ADO)
- Advanced Transmission Operations (ATO)
- Advanced Asset Management (AAM)

By properly sequencing these milestones, the most cost effective modernization program can be achieved.

AMI deployment approaches will depend upon the utility's starting point, geography, regulatory situation and long-term vision. Pilot programs that explore the performance of various solutions can be useful as the first phase of an AMI deployment. The choice of an AMI communications infrastructure is influenced by the utility's long-term vision for AMI. If AMI is seen as the foundation for overall grid modernization, the communications system will accommodate anticipated future needs and have the flexibility to even handle applications that are not currently on the utility's radar screen.

Utilities have been moving in the direction of AMI for a number of years. As their experience has grown, so has their insight into the advantages of moving beyond AMR to AMI and eventually to a smart or modern grid.

The first major federal policy on electricity metering was enacted in 2005. The Energy Policy Act of 2005 (EPACT) contained a Section entitled "Smart Metering." Many states have begun pilot programs that incorporate demand response and advanced metering. Among the states that are notable for their self-initiated efforts are New York, Texas, Connecticut and California.

In December of 2007, new energy legislation entitled the Energy Independence and Security Act of 2007 was signed into law. Title XIII addresses the development of a Smart Grid. This new law will serve as a major catalyst for rapid deployment of AMI and grid modernization.

The transition to AMI and ultimately to a modern grid is not without obstacles. Areas of concern include business case limitations, standards, depreciation rules, rate designs, education, and technical resources.

Traditional utility economic analysis may not capture the true value of an AMI strategic initiative; an expanded framework may be more appropriate since AMI provides benefits to consumers, utilities and society as a whole.

For the consumer, this means more choices about price and service, less intrusion and more information with which to manage consumption, cost and other decisions.

AMI helps the utility avoid estimated readings, provide accurate and timely bills, operate more efficiently and reliably, and offer significantly better consumer service.

Society in general benefits from AMI in many ways. One is the improved efficiency in energy delivery and use, producing a favorable environmental impact. A major benefit of AMI is its facilitation of demand response and innovative energy tariffs. During periods of high energy demand, a small reduction in demand produces a relatively large reduction in the market price of electricity. And reduced demand can avoid rolling blackouts.

Together, the utility and its regulators should communicate the full benefits of an AMI initiative to consumers and society at large.

Enhanced functionality can be achieved when the AMI infrastructure sequences into a fully enabled modern grid. When that occurs, EPRI estimates that at least a 4-to-1 total benefit-to-cost ratio will be realized. As described in other Modern Grid Strategy white papers, achieving the vision of the Modern Grid depends on the correct and effective deployment of technologies and applications in 5 key technology areas. AMI supports each of these KTA's.

A May 2007 discussion paper by the Brattle Group estimates that full AMI deployment across the US would cost about $26 billion and that utility operational savings would cover anywhere from 50% to 80% of this cost. It then goes on to estimate a long run generation, transmission and distribution capital savings of $35 billion, along with an additional $5 to 10 billion per year in reduced electricity prices.

The expected benefit/cost ratio is at least 4 to 1. Additional benefits such as improved reliability and power quality, greater consumer choice, reduce environmental impact and others associated with a modern grid should also be considered.

It is clear that AMI provides many benefits to a wide variety of stakeholders, and that going beyond AMI to achieve a truly modern grid produces additional benefits to all, including:

- Greatly improved outage management
- New opportunities for consumer choice and new retail services
- Improvements to power quality

- Virtual elimination of cascading outages, such as occurred August 2003
- Increased national security through deterrence of organized attacks on the grid
- Improved tolerance to natural disasters
- Improved public and worker safety
- Reduced energy losses and more efficient electrical generation
- Reduced transmission congestion, leading to more efficient electricity markets
- Reduced environmental impact
- Improved US competitiveness, resulting in lower prices for all US products and greater US job creation
- Fuller utilization of grid assets and better prediction of when these assets need repair or replacement
- More targeted and efficient grid maintenance programs and fewer equipment failures
- New consumer service benefits such as remote connection, more accurate and frequent meter readings, flexible billing and prepayment services, a variety of rate choices, outage detection, and restoration
- Improved system planning process and results
- Improved mobile workforce management and operations

The MGS publication *Modern Grid Benefits* provides a more detailed discussion of modern grid benefits, including those that accrue to society as a whole.

CALL TO ACTION

The electric power grid is a basic enabler of society, without which our nation would return to a 19th-century economy and life style. America's grid, once the envy of the world, has lost that premier status. The path to regaining that status and to realizing the many associated benefits has been defined by the NETL Modern Grid Strategy and others. Fundamental to this journey is the adoption of AMI across the nation. The benefits of AMI alone are substantial, but when AMI serves as the stepping-stone to a fully modern grid they are increased many fold. Modernizing the power grid must become a national priority, similar to the 20th century program to create a national interstate highway system.

For more information

This document is part of a collection of documents prepared by The Modern Grid Strategy team. All are available for free download from the Modern Grid Web site.

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BIBLIOGRAPHY

- "Establishing the AMI Business Case Framework: Advanced Technology to Support Utility, Consumer and Societal Needs" (Levy Associates, PowerPoint presentation, May 2005)

- "Assessment of Demand Response and Advanced Metering" (FERC Report 2006). http://www.ferc.gov/legal/staff-reports/demand-response.pdf

- "Benefits of Demand response in Utility Markets and Recommendations for Achieving Them" (DOE Report 2006). http://www.oe.energy.gov/DocumentsandMedia/congress_1252d.pdf.

- "Advanced Metering Infrastructure – MGI View" (NETL PowerPoint Presentation July 2007 at Public Utilities Commission of Ohio – Technical Conference)

- Evans, Jeff. "AMI and Smart Grid Deployment: Geographic Sequencing by Benefit Maximizes Utility ROI." *Utility Automation and Engineering T&D*, http://uaelp.pennnet.com/articles/article_display.cfm?Section=ARCHI&C=INDUS&ARTICLE_ID=274755&KEYWORDS=AMI%20and%20Smart%25.

- Faruqui, Ahmad et al. "The Power of Five Percent: How Dynamic Pricing Can Save $35 Billion in Electricity Costs." (The Brattle Group, discussion paper, May 16, 2007.)

- Luth, John F. "10 Years of Results: AmerenUE's AMR Business Case Evolves to Support AMI." *Utility Automation and Engineering T&D* (April 2006), http://uaelp.pennnet.com/articles/article_display.cfm?Section=ARCHI&C=Feat&ARTICLE_ID=252019&KEYWORDS=ameren&p=22

- Plexus Research, Inc. "Deciding on 'Smart' Meters: The Technology Implications of Section 1252 of the Energy Policy Act Of 2005" (Edison Electric Institute, report, September 2006).

- Schoenwetter, Sara. "Plan for the Deployment of Advanced Electric and Gas Metering Infrastructure by Consolidated Edison Company of New York, Inc. and Orange and Rockland Utilities, Inc." (Proposal, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc., New York, New York, March 28, 2007).

- Tram, Hahn and Chris Ash. "Meter Data Management System - What, Why, When, and How." *Energy Central Network* (August 29, 2005), http://topics.energycentral.com/centers/datamanage/view/detail.cfm?aid=1061.

- Welch, Mark and Kieran McLoughlin. "Information is Power: The Intelligent Utility Network" (IBM Global Business Services, white paper).

ACRONYMS

AAM	Advanced Asset Management
AC	Alternating Current
ADO	Advanced Distribution Operations
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
ATO	Advanced Transmission Operations
BPL	Broadband Over Power Lines
CIS	Consumer Information System
CSR	Consumer Service Representative
DC	Direct Current
DER	Distributed Energy Resources
DR	Demand Response
EEI	Edison Electric Institute
EPACT	The Energy Policy Act of 2005
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
HAN	Home Area Network
IP	Internet Protocol
KTA	Key Technology Area
MDMS	Meter Data Management Systems
MWM	Mobile Workforce Management
NARUC	National Association of Regulatory Utility Commissioners
O&M	Operations and Maintenance
OMS	Outage Management System
PLC	Power Line Carrier
PQ	Power Quality
ROI	Return on Investment

RTP	Real Time Pricing
T&D	Transmission and Distribution
TFTN	Turn On Turn Off
TOU	Time-of-use
UE	Union Electric Company (Now Ameren UE)