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Obsolescence Planning of Domestic Electronic Meters

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Technical Update, December 2007

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PRODUCT DESCRIPTION

Automatic meter infrastructure (AMI) is "the collection at a remote central location of data from meters and other devices at customers' premises via telecommunications." AMI ultimately resides in the realm of the "Smart Grid," most commonly articulated in the IntelliGrid Architecture. There are many visions of AMI in the context of the Smart Grid. Most components of Smart Grid concepts are in the early roll-out or pilot phase, and there is limited information on actual economic and technical performance, let alone consensus. The environment—regulatory, technology, vendors, costs—is constantly changing.

Technological obsolescence is an important concern when deploying AMI for the simple reason that deployments are on a very large scale. PG&E alone started deployment of AMI in 2005 planned at 9.1 million meters. It is important to minimize the impact of technology obsolescence on AMI deployments because failure to do so will lead to opportunity costs in realizing benefits and increases investment risks. Recognizing the impact of technology obsolescence on AMI leads to continuous enhancements and infrastructure development that optimize functionality and return on investment.

Results & Findings

The report lays the groundwork for its discussion of AMI with an in-depth description of basic concepts of obsolescence, functional and technological. The document then details the impact of technology obsolescence on AMI followed by specific ways to minimize that impact. A case study describing Southern California Edison's approach to AMI and its recognition of the importance of technological obsolescence concludes the study.

Challenges & Objective(s)

AMI must be designed with the future in mind. AMI's environment is constantly changing not only with respect to technological advancements, but also in the broader areas of regulations, pricing, and business models. Technological obsolescence is relevant to AMI deployments for three major reasons:

- AMI deployments are on a very large scale,
- AMI deployments require very large capital expenditures with long payback periods, and
- AMI takes a long time to deploy.

Applications, Values & Use

Advanced meters will be programmable and offer a wide range of functionality. Utilities will be able to use new AIM host software systems to collect, store, analyze, and process data from the extended application of sensing, metering, and measurements. The processed data will then be handed off to existing and new utility information systems that carry out the many core functions of the business, including billing, planning, operations, maintenance, customer service, forecasting, and statistical studies.

EPRI Perspective
Views on technology obsolescence are major considerations when analyzing technology selection and deployment decisions for AIM. In many cases, conclusions on technology obsolescence will impact the return on investment calculations that determine whether to deploy AMI.

Technology obsolescence impacts AMI in the following areas:

- Selection decision for optimum time for large-scale deployment
- Replacement of legacy systems (that are still functional)
- Cost recovery formula (depreciation lifetime)
- Risk factors (viability, parts, and services, including telecommunications and useful life)

AMI’s technology matrix can be examined against the measures for obsolescence both as a solution and by component. Technology obsolescence may be expressed through the S-curve, which illustrates the introduction, growth, and maturation of innovations as well as technological cycles. Taken as a solution, AMI fits the S-curve well. The S-curve for AMI shows Smart Grid to be in the early stages of its lifecycle, with the vision still alive and adaptation underway. Other components, such as advanced meter management, are just entering the adaptation stage, as is real-time monitoring. Broadband over power line (BPL) communications technology is past the adaptor stage, fully launched and ready for either application growth or maturity.

Approach
AIM will be built on the digital communications capabilities of the Internet and employ standard Internet protocols. It will use reliable and well-established communications media such as wireless, BPL, or even FTTH (fiber to the home). The consumer interface will be user-friendly, with increasing levels of sophistication as product features are added.

There are three major technology components to AMI: metering, communications, and meter data management. Both metering and telecommunications technologies are undergoing several transitions. For meters, the changeover from electromechanical to digital is well established and well understood. The transitions in telecommunications are less well understood, although they are at the core of AMI solutions. To avoid early obsolescence, meter-management systems should be installed in an open architecture frame, scalable, and upgradeable.

Keywords
AMI
AMR
Revenue metering
Obsolescence

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TECHNOLOGY OBSOLESCENCE

Technology Obsolescence

Obsolescence is one stage in the technology lifecycle. The technology lifecycle starts when innovation and through a process of evolution substitutes the old technology with new technology, thus rendering the old technology obsolete. For this reason, any discussion of technology obsolescence necessarily involves a discussion of the technology lifecycle and innovation.

In this chapter, we will first set out some basic concepts of obsolescence, functional and technological obsolescence. Then, we will introduce the S-curve, which illustrates the introduction, growth, and maturation of innovations as well as technological cycles. We will be ready to discuss the technology lifecycle, innovation, and technological obsolescence.

The Certainty of Obsolescence

Obsolescence is the inevitable fate of all systems, whether they are electronic, mechanical, or biological. Obsolescence is necessary if change, and hence progress, is to take place.[1]

Obsolescence

The concept of obsolescence is discussed using three major terms: design life, useful life, and economic life.

- Design life (physical depreciation)
  Design life is the term most commonly associated with physical depreciation. Functional or technological obsolescence is distinct from physical depreciation where a technology can have many years of useful life for the purpose that it was originally intended (or designed).
- Useful life
  Useful life is the term most commonly associated with functional obsolescence.
- Economic life
  Economic life is a term used for obsolescence that is other than physical or functional.[2]

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[1] "Combating Obsolescence in Electronic Systems," David Shand, Nallatech Ltd, published in IET.
[2] For example, the loss of customers (in case of AMI, off-grid independent power; self supply, not metered).

For purposes of this discussion of technological obsolescence, the concept of useful life will be applied to obsolescence. Its meaning is described in the Useful Life section.

Useful Life[3]

First there is the question of what is the "operational" or "service" or "useful" or "functional" life of the Advanced Metering Infrastructure (AMI) system. These terms all have different shades of meaning. We will consolidate all of these terms into one: useful life. We define useful life to mean the continuous period of time when the components and system of the AMI project operate correctly and reliably to perform their designed functions. In regulatory jargon, this is the period when a system is considered to be "used and useful."

Functional Obsolescence

Definition of Functional Obsolescence

Technology obsolescence is commonly thought of as the loss in value from the substitution of one technology for a newer technology (see Figure 1-1). More precisely, technology obsolescence is the substitution of an older, established technology for a newer technology having a higher level of functionality. In the case of technologies with long lead times for development and acceptance with markets that demand large-scale deployments at very high infrastructure costs, such as electric meters, technology obsolescence is more gradual for the simple fact that the substitution takes a substantial amount of capital and time. However, when a technology no longer services its intended purpose, and another technology is available, it may be said to be functionally obsolete.[4]

[3] D0607027 Authorizing PG&E to Deploy Advanced Metering Infrastructure, CPUC June 25, 2007.
[4] Functional obsolescence is especially relevant with technologies that have microprocessors.

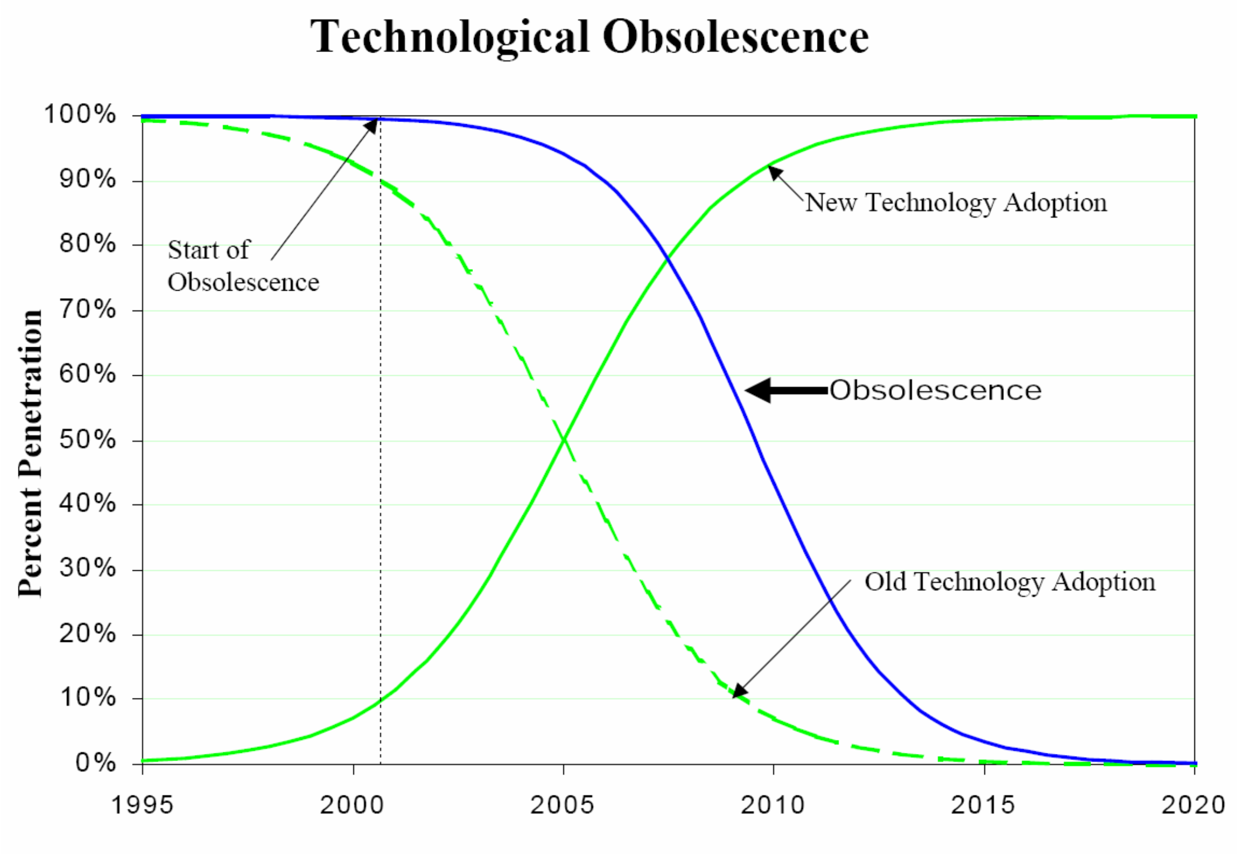

Figure 1-1
Functional Obsolescence[5]

Causes of Functional Obsolescence

The causes of functional obsolescence are multiple. Among the most important[6] are:

- Regulatory changes
- Changes in market demands and expectations
- Improved efficiency of new equipment
- Lower prices for new equipment
- Increased functionality of new equipment
- Greater capacity of new equipment
- Other technical changes

[5] Stephen L. Barreca, "Assessing Functional Obsolescence in a Rapidly Changing Marketplace," BCRI, Inc., August 1999.
[6] These are the most important causes of functional obsolescence as far as their relative impact on AMR/AMI.

Once the functional obsolescence pattern is established, the annual impacts of obsolescence may be calculated in terms of the annual rates of obsolescence. These rates reflect the probabilities of depreciation (or displaced value) resulting from functional obsolescence. This is accomplished using the obsolescence curve of Figure 1-1.

For any given year, the net annual probability of depreciation, *p(t),* is equal to the remaining value, *Ob(t),* at beginning of year less the end of year value, divided by the beginning of year value. The formula is provided mathematically in Equation 1-1:

$$\rho(t) = \frac{Ob(t) - Ob(t+1)}{Ob(t)}$$

Eq. 1-1

Functional Obsolescence

Functional obsolescence is the loss in value (i.e., depreciation) resulting from a relative deficiency of the asset to function for its intended purpose. The functional requirements of equipment are subject to change over time. Changing consumer expectations, for example, may promote new functionality that older equipment cannot accommodate; or enhancements to new generations of equipment may increase efficiency. In both of these situations, the functionality of the older equipment relative to its intended purpose is reduced. Both examples are a form of functional obsolescence. The relative loss in functionality reduces the value of the older equipment to the property owner.

Source: Assessing Functional Obsolescence in a Rapidly Changing Marketplace, Stephen L., Barreca, PE, CDP, President, BCRI Inc., August 1999 Copyright© BCRI Inc.

The S-Curve

The technology S-curve has become a way of thinking about technological improvement over a period of time. The theory is that in the early stages improvement in performance is slow; as the technology is understood and diffused, the rate of improvement increases.

The S-curve illustrates the introduction, growth, and maturation of innovations as well as the technological cycles that most industries experience. In the early stages, large amounts of money, effort, and other resources are expended on the new technology, but small performance improvements are observed. Then, as the knowledge about the technology accumulates, progress becomes more rapid. As soon as major technical obstacles are overcome and the innovation reaches a certain adoption level, an exponential growth will take place. During this phase, relatively small increments of effort and resources will result in large performance gains. Finally, as the technology starts to approach its physical limit, further pushing the performance becomes increasingly difficult, as Figure 1-2 shows.

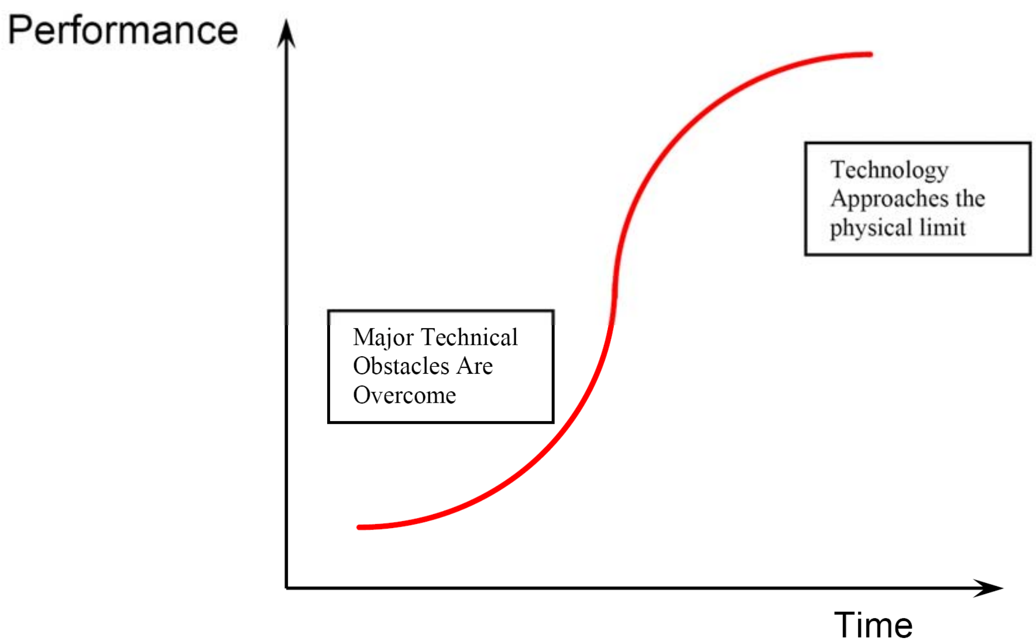

Figure 1-2
The S-Curve

Consider the supercomputer industry, where the traditional architecture involved single microprocessors. In the early stages of this technology, a huge amount of money was spent in research and development, and it required several years to produce the first commercial prototype. Once the technology reached a certain level of development, the know-how and expertise behind supercomputers started to spread, boosting dramatically the speed at which those systems evolved.

After some time, however, microprocessors started to yield lower and lower performance gains for a given time/effort span, suggesting that the technology was close to its physical limit (based on the ability to squeeze transistors in the silicon wafer). In order to solve the problem, supercomputer producers adopted a new architecture composed of many microprocessors working in parallel. This innovation created a new S-curve, shifted to the right of the original one, with a higher performance limit (based instead on the capacity to co-ordinate the work of the single processors). This process, where one S-curve is replaced by another, is called *discontinuity.*

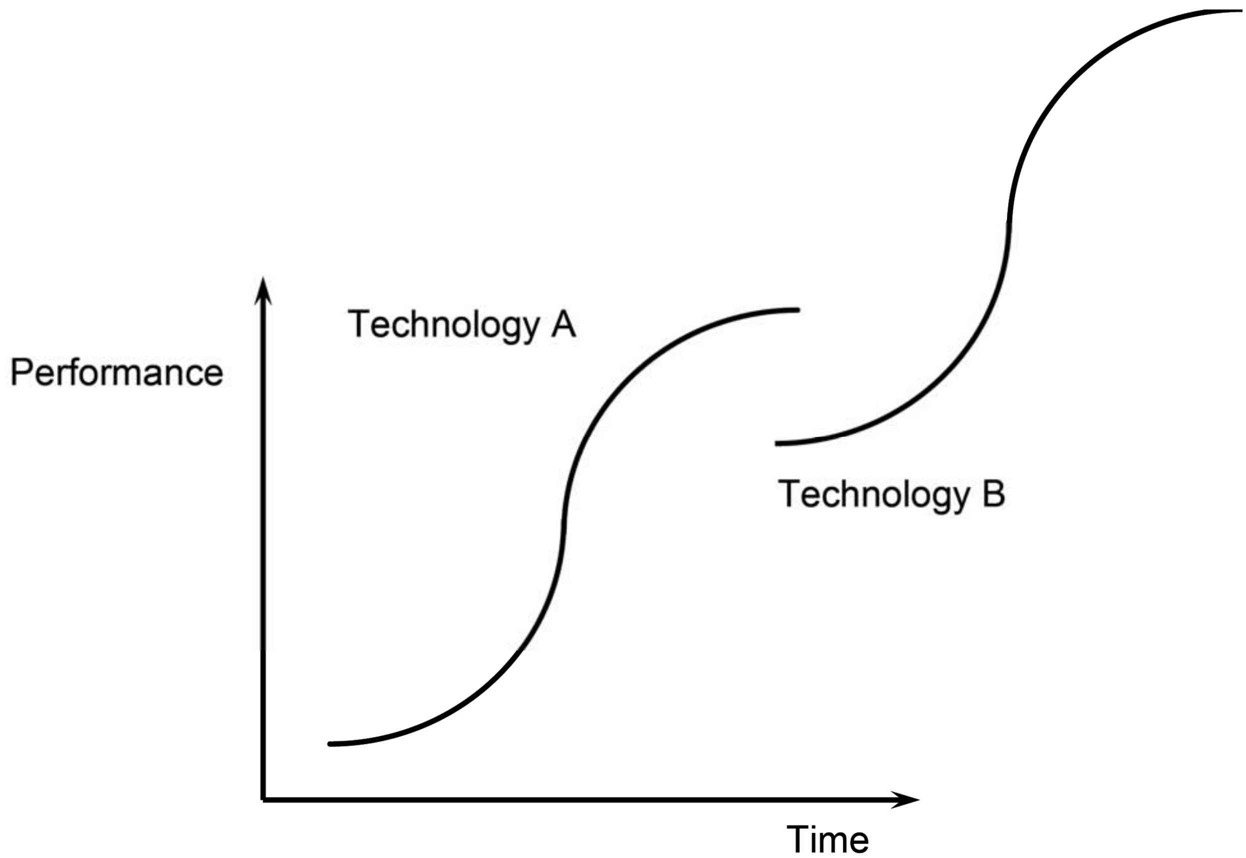

Figure 1-3
Discontinuity

Usually the S-curve is represented as the variation of performance in function of the time/effort. Overall the S-curve is a robust yet flexible framework to analyze the introduction, growth and maturation of innovations and to understand the technological cycles. The model also has plenty of empirical evidence. It has been studied exhaustively in many industries, including semiconductors, computers, and telecommunications. The classic example of the S-curve is the vacuum tube, described in the next section.

Example: Vacuum Tube

The vacuum tube is the usual example of a technology that has followed this path. Vacuum tube technology was limited by the tube's size and the power consumption of the heated filament. Both of these factors were natural barriers to electron conduction in a vacuum tube. Electronic engineers could not overcome these limitations. The arrival of the solid-state technology, or transistor, which permitted electron conduction in solid material, changed the physical barriers of size and power. The transistor technology started a new technology lifecycle and rendered the vacuum-tube technology obsolete.

The evolution of vacuum technology to the transistor to integrated circuits and eventually microprocessors is shown in Figure 1-4.

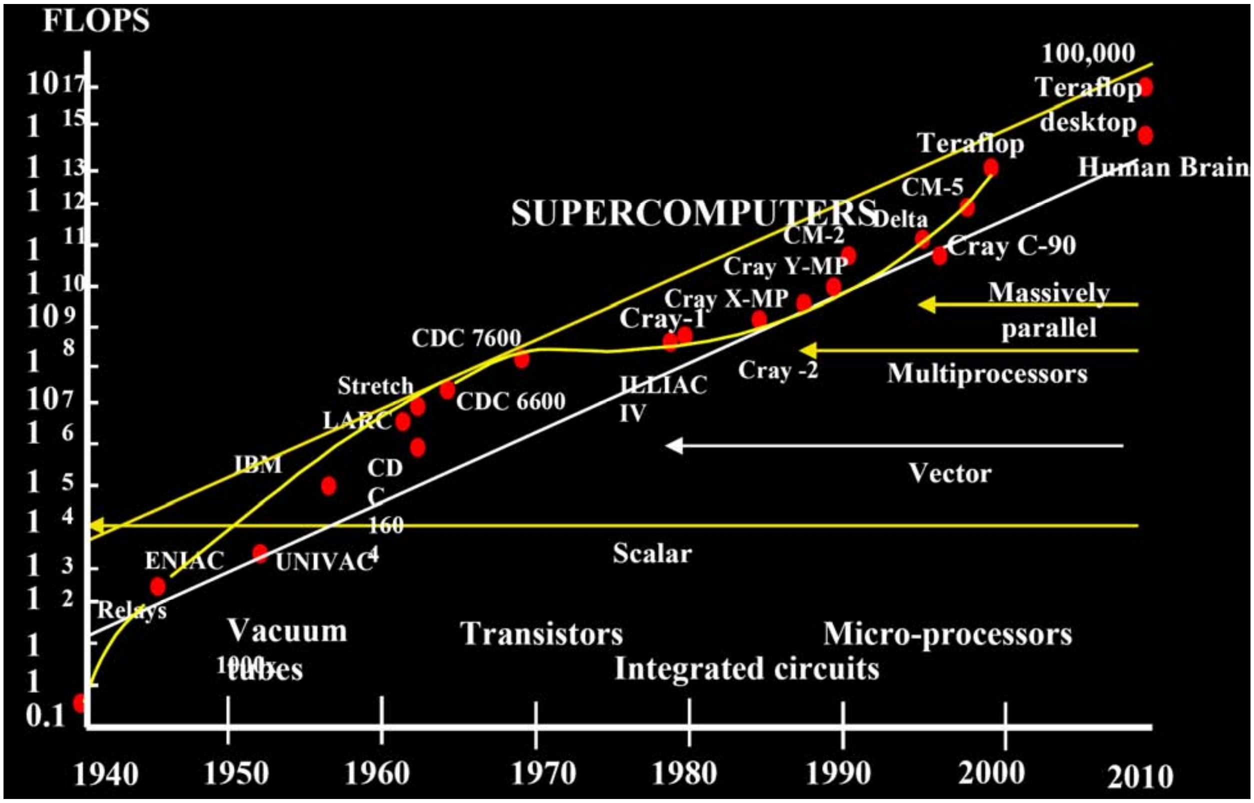

Figure 1-4
Computational Capability

Technology Life Cycle

Different Phases of the Technology Lifecycle7

The rate of technology innovation follows a general pattern. This pattern can be used to manage the process of technological innovation.[8] When a new technology or solution is introduced, it creates certain energy within the innovation community, triggering a series of changes and inspiring new applications. Over time, the rate of innovation of new technology or solution increases, reaching a plateau, and then decreases. At the early stages of technological development, competition in innovation and improvements delays agreement on a standard design. At some time there is a need to set a standard. This may precede or follow deployment, but usually early innovators have already started at least pilot deployments. Once a dominant design is established in the market, the benefits of the technology are already beginning to be realized.

[7] Note: Watch for these as technology evolves with innovation, but it can be radical, e.g. AMR to AMI, but only if there is a real need defined by operations, service, or regulatory mandate.
[8] Recognizing these patterns is very important for utilities and regulators alike. Doing so allows for the efficient and timely introduction of technology and solutions and the realization of the full benefits of innovations.

Six Technology Phases

There are six technology phases, as follows:

- Technology development phase
- Application launch phase
- Application growth phase
- Mature technology phase
- Technology substitution phase
- Technology obsolescence phase

The six technology phases are shown in Figure 1-5.

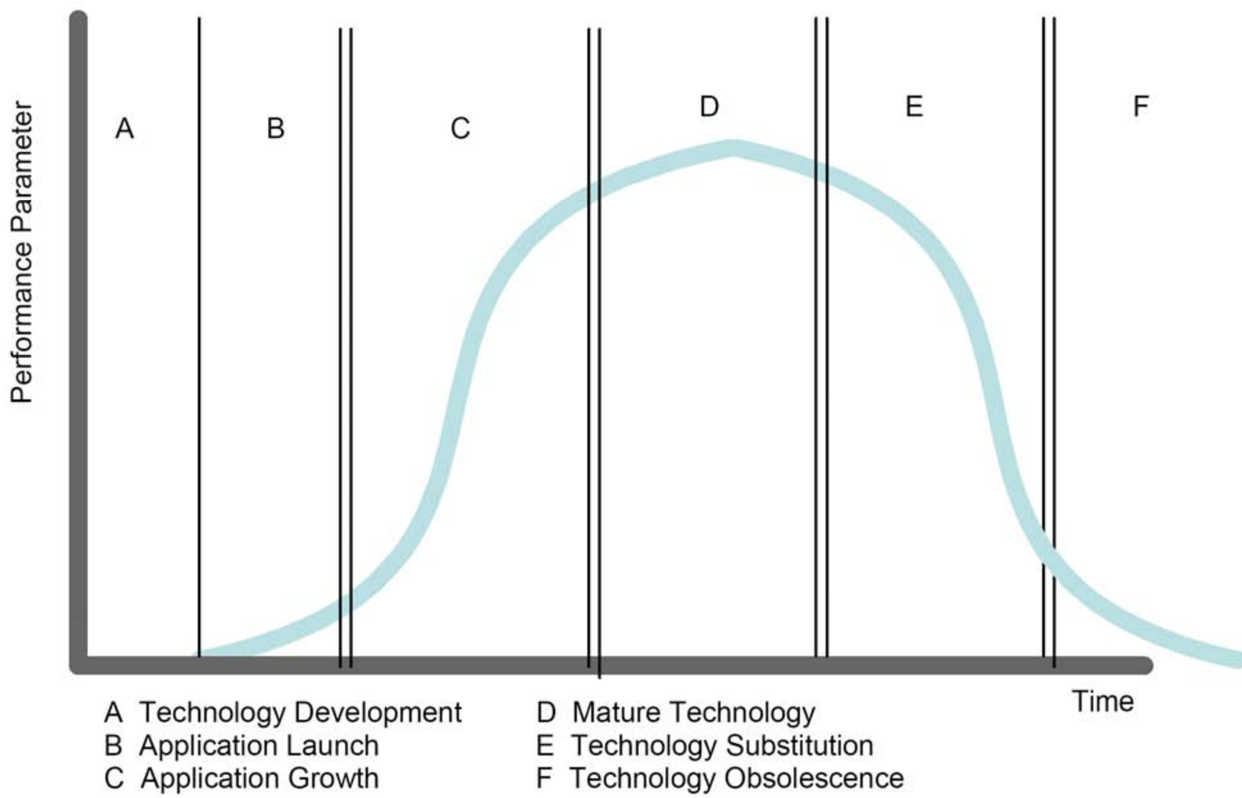

Figure 1-5
Six Phases of the Technology Life Cycle

Technology Development Phase

During the technology development phase, the market does not recognize the technology at all—it has zero response. This is an important period in which scientists and engineers spend significant amounts of effort and money to create the technology, develop prototypes, and test the new technology.

Application Launch Phase

Once the first wave of the new technology application is launched into the market, the market volume follows the path of technological progress. This is characterized by slow initial growth during the launching period, followed by rapid growth.

Technology helps expand the market size for the product or service offered. Technology becomes a pacing technology in that it has the potential for changing the basis of the delivery of service. During this stage, it is important that the company continue to pay attention to the need for continuing innovation.

Application Growth Phase

During the growth phase of the technology, penetration into the market depends on the rate of innovation and the market needs for the new technology. Once the innovation has proved itself in the market, it permits its owner to take a patented position or to define the industry standard. A dominant design of the product emerges, and the technology has a major impact on the value-added stream of performance, cost, and quality.

Mature-Technology Phase

This phase starts when the upper limit of the technology is approached and progress in performance slows down. Technology reaches its natural limits as dictated by factors such as physical limits. The technology becomes vulnerable to substitution or obsolescence when a new or better-performing technology emerges.

When a technology reaches its natural limits, it becomes a mature technology vulnerable to substitution or obsolescence when a new or better-performing technology emerges.

When the technology reaches a stage of maturity, the rate of innovation declines. Technologies in this category are also recognized as base technologies and have little ability to enhance the delivery of services to customers. During this phase, there are often difficulties obtaining spare parts and maintenance services, especially if warranties have expired.

Technology Substitution Phase

In this phase, deployments of the technology slow, and the market for the existing technology begins to decline. Companies that continue to use the old technology in this phase will be faced with low functionality in relationship to their peers

Technology Obsolescence Phase

This is the phase when technology has little or no value.

Crossing the Chasm

Moore describes a "chasm" in the adoption lifecycle. He proposes that many new technologies do not make it across the chasm between visionaries and pragmatists. They fall into the chasm. The technology S-curve with the chasm is shown in Figure 1-6.

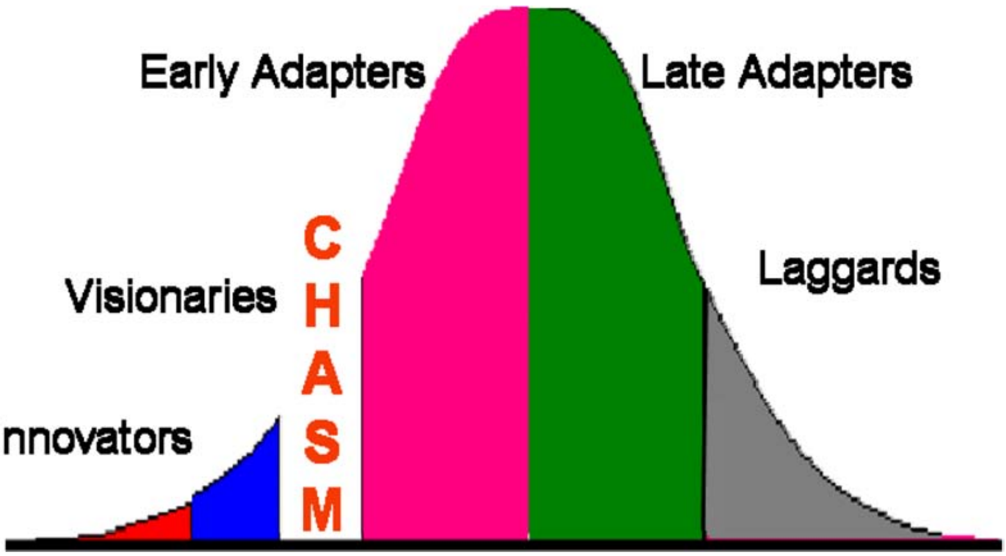

Figure 1-6
The Technology S-Curve

Multiple-Generation Technologies

Technology, like all systems, has a hierarchy. A system can consist of a number of sub-systems, and each subsystem may have a number of components. Technology can consist of multiple technologies and derive from different generations of innovation, as shown in Figure 1-7.

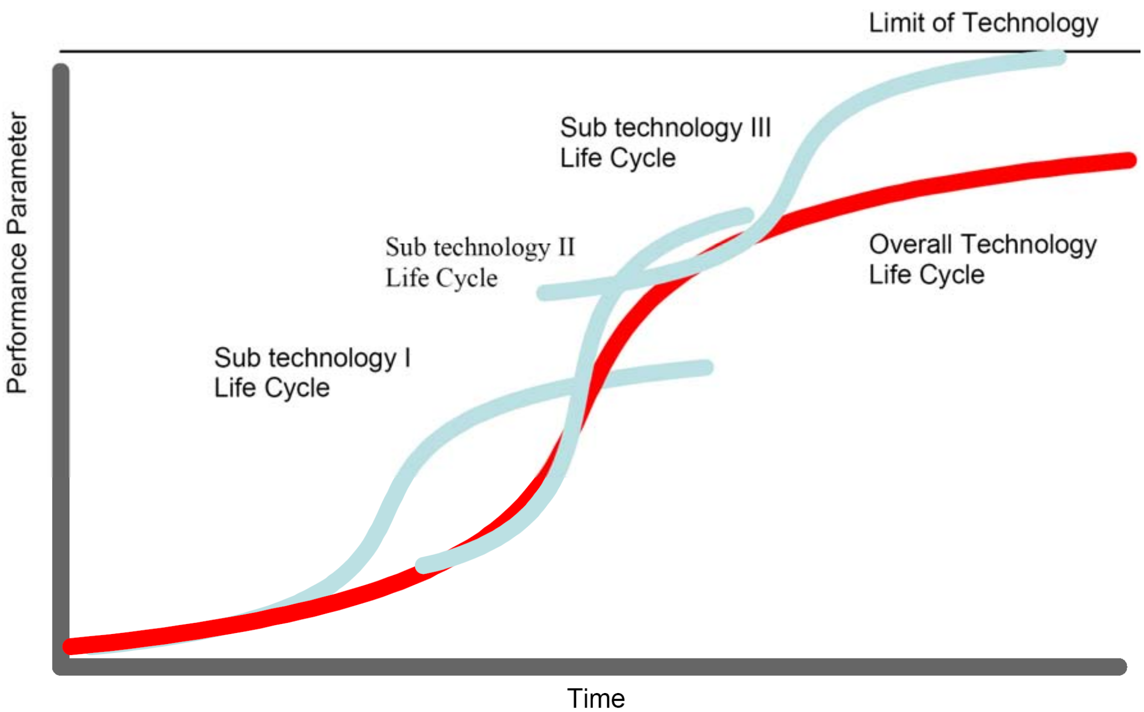

Figure 1-7
Multiple-Generation Technologies

Examples of Multiple-Generation Technologies

Microprocessor

The micro-processor can be defined as a technology with a technology lifecycle of its own. In turn, the microprocessor has its own multiple-generation technologies or sub-technologies. Microprocessor technology has undergone several generations of changes (8088, 286, 386, 486, and Pentium I, II, III). Each of these generations of innovation helped boost the technology lifecycle of microprocessors and, in turn, that of the PC.

Software Production

Any software developed for a major application undergoes several generations of change. The changes improve the software and extend its useful life, but this also requires additional investment. If existing software is not updated after one generation, it will be rendered functionally obsolete by newer-generation technology. Software has a short life.[9]

[9] This is the basis for considering software upgrades as expenses, or a cost of business, rather than a capital asset to be depreciated.

Technology and Market Interaction

A very strong dynamic relationship exists between technological innovation and the marketplace. The presence of a market or the creation of a new market represents the reward for technological development. It is only when technological developments find a market that scientific research pays off and the development cost is reimbursed in economic or social terms.

Technological development is also stimulated by market pull; in the case of AMI, this is changing utility requirements and regulatory orders. This is the most effective way to connect technology with changing requirements.

In the majority of cases, market pull is stimulated by drivers. Oftentimes engineers may or may not know whether a new technology exists or is being developed, or if they do, they may not understand the technology.

Most of the technological developments stimulated by market pull are of an incremental nature, or represent improvements to existing technologies. Incremental technological improvements have a cumulative effect, and they can have a tremendous impact on productivity and competitiveness.

Market pull (with strong collective demand) may provoke major breakthroughs. When there is a strong collective demand for a solution to a specific problem (such as a vaccine for AIDS or AMI for energy conservation), market pull may provoke major breakthroughs.

Integrate Technology Push and Market Pull

Both mechanisms (technological push and market pull) contribute to stimulating innovation and technological change. Integrating them accelerates change. Commitment to technology adoption is dependent on an integrative approach to technology push and market pull combined with management's attitude toward technology, as well as technical and financial resources.[10]

Diffusion of Technology

A technological innovation or a new system is considered to be successful when it is adopted by users and diffused through the user population. Diffusion is the process by which an innovation is communicated, over time, through certain channels to members of a social system. The term "innovation" is frequently used in the diffusion literature as being synonymous with "technology."

Adoption of a certain type of technology is usually based on the possible efficacy of that technology in solving a perceived problem. The rate of adoption is determined by the degree to which the innovation is seen, and its results are observed, by potential adopters.[11]

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[10] H. Munro and H. Noori, "Measuring Commitment to New Manufacturing Technology: Integrating Technological Push and Marketing Pull Concepts," *Engineering Management, IEEE Transactions*, Volume 35, Issue 2, May 1988.
[11] Industry leaders in AMR and AMI.

There are many factors that influence the rate of adoption of a new technology. The rate of adoption of an innovation by members of a social system is dependent on the following factors:

- The degree to which the innovation or technological solution is perceived to be offering better advantage than existing practice.
- The degree to which the innovation or technological solution is compatible with the values and needs of the users.
- The degree to which the innovation is considered complex and difficult to use. An example is a new process that requires a great deal of effort in retraining employees and has a high cost of implementation.

A major factor influencing the rate of adoption of a new technology is the degree to which an innovation can be introduced on a trial basis before users must fully commit to its adoption. For commercial products, this might be free samples. For complex technological systems, pilot projects and field trials are often undertaken before technology acceptance, selection, and implementation plans.

Innovations that are perceived by individuals as having greater relative advantage, compatibility, and less complexity and that can be tried and observed will be adopted more rapidly than other innovations.

Rogers[12] also proposed a five-stage model for the diffusion of innovation:

1. Knowledge: Learning about the existence and function of the innovation
2. Persuasion: Becoming convinced of the value of the innovation
3. Decision: Committing to the adoption of the innovation
4. Implementation: Putting it to use
5. Confirmation: The ultimate acceptance (or rejection) of the innovation

Technology Evolution

Technology Evolution over Technology Lifecycle

Technology is changing rapidly and radically. The evolution of technology is the changing of fundamental design to meet new challenges. Adaptation is the fast use of existing technology in new ways to meet a challenge. Adaptation and evolution are different, but each is equally important. Adaptation ensures short-term survival in the face of short-term changes. Evolution ensures continuing efficiency and hence long-term sustainability.

Successful systems must also evolve and adapt. Like organisms, they must adapt to tackle short-term threats and evolve to meet longer-term challenges. The engineer must be able to do both and know where the balance lies. Adaptation may lead to systems that are poorly designed and ill-matched to short-term requirements. Evolution may lead to the failure to meet short-term requirements.

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[12] E. M. Rogers, *Diffusion of Innovations,* Fifth Edition. New York, NY: Free Press. 2003.

Traditionally, engineers have been principally involved in the evolution or redesign of systems. Adaptation was, as often as not, undertaken by the users of systems more to fit specific requirements than as a means of ensuring global system survival. As systems need more adaptations just to survive, engineers have been drawn into this fast-moving, uncontrolled world.

Two models of technological evolution are commonly used. These are the Foster "S-curve" model and the Abernathy-Utterback model. Each gives different insights into the evolutionary processes.

Foster S-Curves

One of the most popular models describing the evolution of a technology is the S-curve proposed by Foster[13]. Foster proposes that the performance of a particular technology increases at a very slow rate in its initial stages, much faster in later stages, and then slows down again as that particular technology reaches its technical limits. This is shown in the Figure 1-2. The process whereby performance increases along an S-curve is one of incremental innovation, as performance bottlenecks are removed bit-by-bit.

Abernathy-Utterback Model

The Abernathy-Utterback model[14] divides up the evolution of a technology into two main phases, a *fluid phase* and a *specific phase*, linked by a *transitional phase*. The fluid phase generally coincides with the predominant design stage, and the specific phase with the post-dominant design phase. The model is useful in explaining the patterns of industry and organizational dynamics as technologies mature.

The model postulates that the small, entrepreneurial organization that innovates new products and the large, rigid, cost-driven organization focusing on process innovation are at opposite ends of the innovation spectrum. The change in the rate of innovation and the transition from product to process innovation is shown in Figure 1-8.

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[13] S. Foster, "The S-Curve: A New Forecasting Tool." Chapter 4 in *Innovation: The Attacker's Advantage.* New York: Summit Books. 1986.
[14] W. J. Abernathy and J.M. Utterback, "Patterns of Industrial Innovation," *Technology Review*, MIT Alumni Association, Cambridge, 1978.

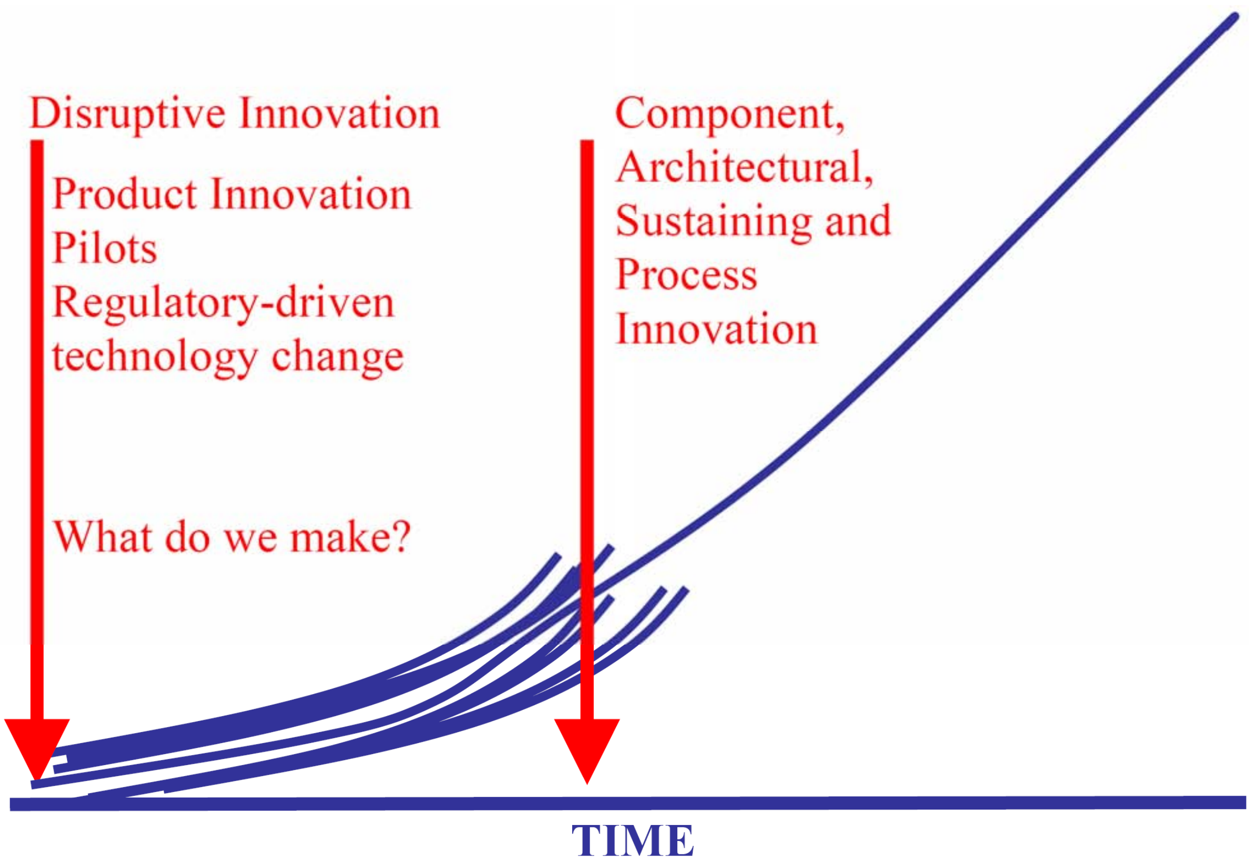

Figure 1-8
Innovation and Technology Cycle

In the early stages of a technology, the focus of the innovators is on producing new products or on products that have significantly better features or performance. This focus is stimulated by the identification of user needs and by matching technological solutions to those needs. Sometimes the source of innovation is the changes and modifications that users themselves have made to existing products. In this phase, the product line is often diverse, with custom-made products sometimes being made for industrial rather than consumer users. Most of the products are made with standard equipment and by using standard off-the-shelf components. Although it is not always the case, the organizations that compete in the fluid stage are often numerous, small, loosely organized, and dynamic in nature.

The change form the fluid pattern to the specific pattern generally coincides with the emergence of the dominant design. At this point, the industry often experiences a shakeout as the nature of competition shifts. Many companies are not willing or able to make these shifts and go out of the industry or out of business altogether. These changes in the competitive environment are in many ways as important as the discontinuities that occur when radical innovation produces technological discontinuities.

In the late stages of a technology, the focus of the innovators is on incremental improvements to products or on new or improved manufacturing processes. In most cases, the driver for this innovation is cost pressures from competitors and customers. The product line tends to be more standard so that costs can be reduced by mass-production processes. Products tend to be made with specialized equipment and by using purpose made components. As a result, economies of scale play a large role in determining which organizations are able to prosper in the specific phase.

In summary, in the *fluid phase,* when there is considerable uncertainty about the technology and its market, firms experiment with different product designs. After a dominant design emerges, the *specific phase* begins when firms focus on incremental improvements to the design and manufacturing efficiency. Technological change tends to be cyclical. Each discontinuity, or new S-curve, ushers in an initial period of turbulence and uncertainty (era of ferment, as shown in Figure 1-9), until a dominant design is selected, ushering in an era of incremental change. This is followed by rapid improvement, then diminishing returns, and ultimately displacement by a new technological discontinuity.

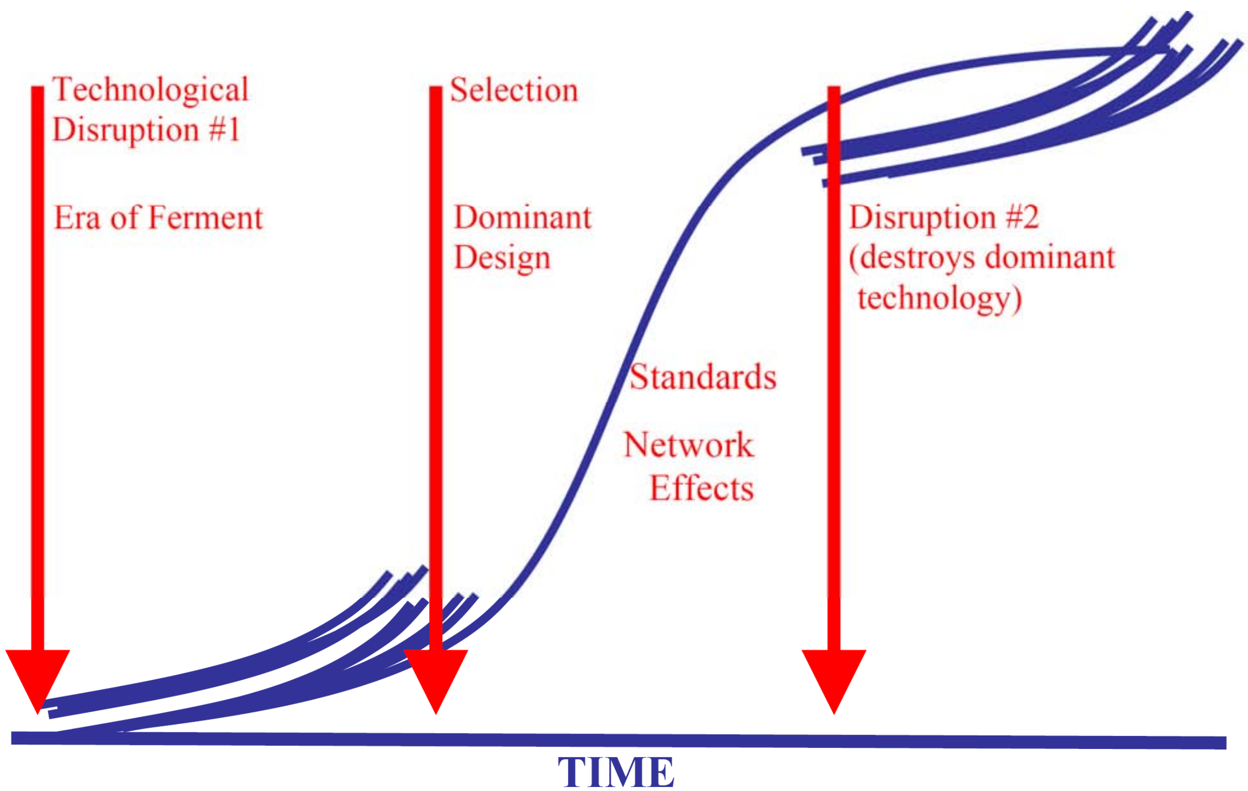

Figure 1-9
Disruption in the Technology Cycle

Dominant Design

The point at which the technology performance suddenly starts to increase rapidly generally coincides with the emergence of the dominant design. The dominant design is defined as technology solution or combination of components that is accepted into the market place as meeting most of the users' needs. Before the emergence of the dominant design, a lot of effort is spent in developing a variety of new product designs that may not gain wide acceptance in the marketplace. It is only when a dominant design emerges that efforts are focused on improving the performance and price of the technology.

A dominant design always rises to command the majority of market share unless the next discontinuity arrived too early.[15] The dominant design is never in the same form as the original discontinuity, but is also not on the leading edge of technology. It bundles the features that would meet the needs of the majority of the market. During an era of incremental change, firms often cease to invest in learning about alternative designs and instead focus on developing competencies related to the dominant design. This explains in part why incumbent firms may have difficulty recognizing and reacting to a discontinuous technology.

After a dominant design has been established, the technology performance increases rapidly, and the costs of the products based on the technology decrease. Thereafter, a mature stage is reached where the fundamental technical limits to the technology are approached. It is at this stage that companies selling products based on the old technology are most vulnerable to radical innovations in that technology.

Example of Dominant Design: Digital Cameras

Currently one can see the plethora of different designs available for digital cameras. Models use different storage media, have varying memory capacities, have varying resolution capabilities, and do not look the same. Once the market has decided which of these combinations of features satisfies most needs, a dominant design will emerge and digital camera performance will increase rapidly.

The new technology created by the radical innovation initially has substantially inferior performance characteristics relative to the old technology. However, the same pattern emerges as the new technology establishes a dominant design and eventually overtakes and replaces the old technology. The Foster model proposes that these cycles continue indefinitely—as one technology matures, another replaces it.

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[15] M.L. Tushman, P. Anderson, and C.A. O'Reilly, *Technology Cycles, Innovation Streams, and Ambidextrous Organizations: Organizational Renewal Through Innovation Streams and Strategic Change, in Managing Strategic Innovation and Change,* Tushman and Anderson, eds., Oxford University Press, New York, 1997.

Technology Trajectories

Technologies often improve faster than customer or regulatory requirements demand. This enables low-end technologies to eventually meet the needs of the mass market.

Timing of Adoption

There is no relationship between timing of adoption and performance improvement.[16] Early adopters often do not see any clear improvement. Later adopters are often able to work with the technology and improve performance. Companies have different strategies in the way they adopt component technologies. For example, in the case of disk drives, some companies (IBM) chose to switch to new technologies, and others (HP) preferred to improve existing technologies

When resources spent in engineering improve the performance of a technology, there is less of an incentive to switch to alternate technologies. Component technologies reinforce existing competencies. Architectural technologies look at competencies with a different lens. From a technical perspective, the more specialized the system and the more dependent on other specific systems, the greater the risk of early obsolescence.

Innovation

Innovation may be generally defined as the use of new technological or market knowledge to offer a new product or service that customers want. Innovation comprises both invention and commercialization. It is the adoption of ideas that are new to a new organization or enterprise, such as an electric utility.

Innovation is characterized by many dimensions. These dimensions help clarify how different innovations offer different opportunities (and pose different demands) on producers, users, and regulators. The path that a technology follows through time is termed its *technology trajectory*. Many consistent patterns have been observed in technology trajectories; these patterns give insights into how technology changes and is diffused.

Typologies of Innovation

Innovation takes place at the various levels, with different implications for technological obsolescence. The typologies of innovation can be described as models[17], namely:

- Architectural vs. component innovation
- Radical vs. incremental innovation
- Competence-enhancing vs. competence-destroying innovation

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[16] Clayton Christensen, “Exploring the Limits of the Technology S-Curves,” Component Technologies, NJIT, 2002.
[17] W. Drago, “Models of Innovation,” Lecture 2, Pennsylvania State University.

Architectural vs. Component Innovation

Architectural innovation refers to rearrangement of the way in which components are related to each other. An architectural innovation entails changing the overall design of the system or the way components interact (such as the transition from high-wheel bicycle to safety bicycle). Most architectural innovations require changes in the underlying components also.

Component innovation (or modular innovation) entails changes to one or more components of a product system without significantly affecting the overall design. A simple example would be adding gel-filled material to a bicycle seat.

Radical vs. Incremental Innovation

Radical innovation is a change in architecture and new approach in the component level. The *radicalness* of an innovation is the degree to which it is new and different from previously existing products and processes.

Incremental innovations may involve only a minor change from (or adjustment to) existing practices. The *radicalness* of an innovation is relative; it may change over time or with respect to different observers, such as digital photography, which was a more radical innovation for Kodak than for Sony. Incremental innovations are often modular in nature. Incremental change relates to improvements in component performance, such as better-quality memory chips. Fundamental change can take place in a component, while the overall architecture of the technology remains the same, such as changing the type of motor in a ceiling fan.

Competence-Enhancing vs. Competence-Destroying Innovation

Competence-enhancing innovations build on the firm's existing knowledge base, such as Intel's Pentium 4 built on the technology for Pentium III.

Competence-destroying innovations renders a firm's existing competencies obsolete, such electronic calculators rendered Keuffel & Esser's slide rule expertise obsolete. Whether an innovation is competence-enhancing or competence-destroying depends on the perspective of a particular firm. This is especially important when considering the replacement of legacy systems with new technology.

Innovation Diffusion

"Diffusion of innovations" theory was formalized by Everett Rogers in a book called *Diffusion of Innovations.*[18] Rogers stated that adopters of any new innovation or idea could be categorized as innovators, early adopters, early majority, late majority, and laggards, based on a bell curve (see Figure 1-10). Each adopter's willingness and ability to adopt an innovation would depend on their awareness, interest, evaluation, trial, and adoption. Some of the characteristics in Rogers' typology of adopters are described in the next section.

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[18] E. M. Rogers, *Diffusion of Innovations,* Fifth Edition. New York, NY: Free Press. 2003.

Innovation Diffusion: Adopter Characteristics

Innovators: the first 2.5% of individuals to adopt an innovation. They are adventurous, comfortable with a high degree of complexity and uncertainty, and typically have access to substantial financial resources.

Early Adopters: the next 13.5% to adopt the innovation. They are well integrated into their social system and have great potential for opinion leadership. Other potential adopters look to early adopters for information and advice; thus early adopters make excellent “missionaries” for new products or processes.

Early Majority: the next 34%. They adopt innovations slightly before the average member of a social system. They are typically not opinion leaders, but they interact frequently with their peers.

Late Majority: the next 34%. They approach innovation with a skeptical air and may not adopt the innovation until they feel pressure from their peers. They may have scarce resources.

Laggards: the last 16%. They base their decisions primarily on past experience and possess almost no opinion leadership. They are highly skeptical of innovations and innovators and must feel certain that a new innovation will not fail prior to adopting it.

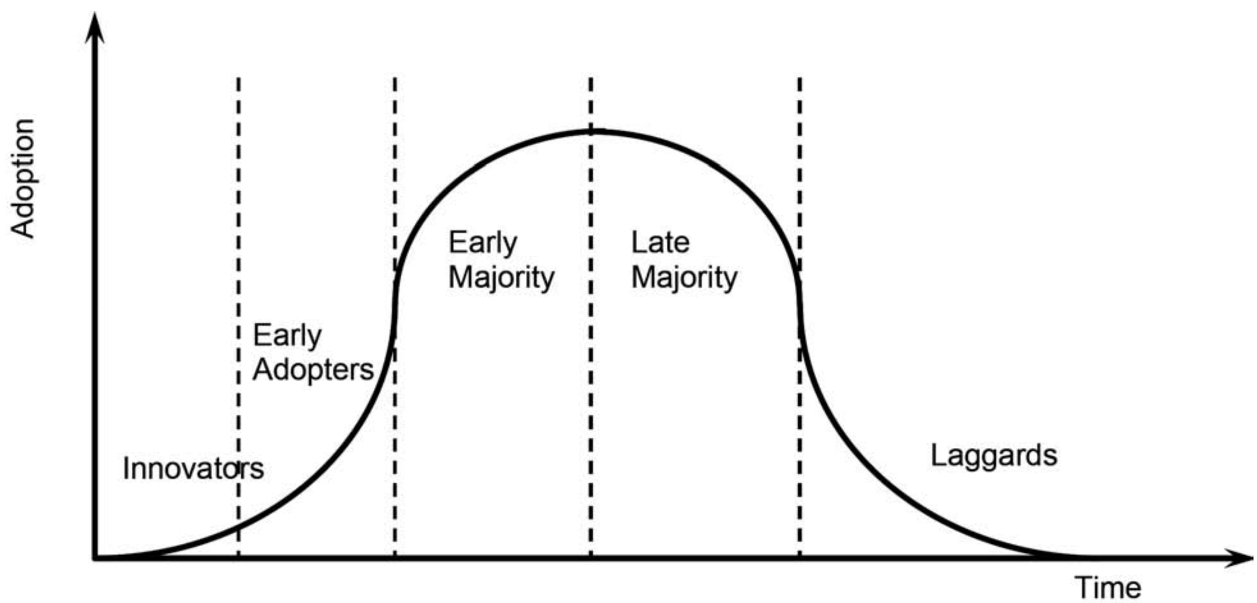

Figure 1-10
Innovators, Early Adopters, Early Majority, Late Majority, and Laggards

Technology S-Curves in Technological Advancement

Both the rate of a technology's advancement and its rate of diffusion to the market typically follow an S-shaped curve. Technology improves slowly at first because it is poorly understood; it then accelerates as understanding increases; finally, it tapers off as limits are approached.

Technologies do not always get to reach their limits. They may be displaced by new, *discontinuous technology*. A discontinuous technology fulfills a similar market need by means of an entirely new knowledgebase, such as the switch from carbon copying to photocopying, or vinyl records to compact discs. Companies may be reluctant to adopt new technology because performance improvement is initially slow and costly, and they may have significant investment in incumbent technology.

S-Curves in Technology Diffusion

Adoption is initially slow because the technology is unfamiliar. It accelerates as technology becomes better understood. Eventually market is saturated and rate of new adoptions declines. Technology diffusion tends to take far longer than information diffusion. Technology may require acquiring complex knowledge or experience. Technology may require complementary resources to make it valuable (such as cameras not being valuable without film).

S-Curve and Technology Adoption

There is an S-curve for diffusion and substitution. Diffusion is the rate at which new users are created. Substitution is the rate at which existing users switch. The adoption curve becomes an S-curve when cumulative adoption is used. Innovations would spread through society in an S curve, as the early adopters select the technology first, followed by the majority, until a technology or innovation is common.

The speed of technology adoption is determined by two characteristics: p, which is the speed at which adoption takes off, and q, the speed at which later growth occurs. A cheaper technology might have a higher p, such as taking off more quickly, while a technology that has network effects (like a fax machine, where the value of the item increases as others get it) may have a higher q.

Disruptive technologies may radically change the diffusion patterns for established technology by starting a different competing S-curve. Path dependence may lock certain technologies in place, as in the QWERTY keyboard.

Technological Exhaustion

Electronic Parts Obsolescence

The rapid growth of the electronics industry has spurred dramatic changes in the electronic parts that comprise the products and systems that the public buys. Increases in speed, reductions in feature size and supply voltage, and changes in interconnection and packaging technologies are becoming events that occur continuously. Consequently, many of the electronic parts that compose a product have a lifecycle that is significantly shorter than the lifecycle of the product they go into.[19] A part becomes obsolete when it is no longer manufactured, either because demand has dropped to low enough levels that it is not practical for manufacturers to continue to make it or because the materials or technologies necessary to produce it are no longer available. Therefore, unless the system being designed has a short life (manufacturing and field), or the product is the driving force behind the part's market (such as personnel computers driving the microprocessor market), there is a high likelihood of a lifecycle mismatch between the parts and the product.

There are significant product sectors that cannot be on the cutting edge of technology and have to be sustained for long periods of time; these are significantly impacted by electronic part obsolescence. Examples include: airplanes, ships, traffic lights, and computer networks for air traffic control and power grid management. These product sectors often "lag" the technology wave because of the high costs and/or long times associated with technology insertion/design refresh. Many of these product sectors involve "safety critical" systems where lengthy and expensive certification/qualification cycles may be required even for minor design changes and systems are fielded (and must be maintained) for long periods of time. Such systems can derive significant cost avoidance from understanding the risk of obsolescence of their constitute parts, optimization of approaches when obsolescence does occur, and planning/budgeting for design refreshes.

Standards and "Tripping"

A standard is a specification that allows for interoperability, like cups and lids, pistons and engines, speakers and amplifiers, and hardware and software. A standard is a particular interface, format, or system that allows for interoperability. Switching costs are incurred when one technology is substituted for another. The greater the costs, the more difficult it is to switch. The greater the investment in legacy systems, the greater the reluctance to change.

A product or technology benefits from network effects or network externalities if a significant part of its value to a consumer lies in the size of its (actual or anticipated) installed base, or market share. Success becomes self-reinforcing with increasing returns to scale. Demand creates further demand.

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[19] R. Solomon, P. Sandborn, and M. Pecht, "Electronic Part Life Cycle Concepts and Obsolescence Forecasting," *IEEE Trans. on Components and Packaging Technologies*, December 2000, pp. 707-713.

If technology users believe that one standard is going to capture a very large share of the market, and that a competing standard is not viable, then the market will “tip” towards the more successful standard. Lock-in occurs once a market has tipped. Switching costs may be high, and it is therefore difficult to get a market to tip to an alternative standard.

Standard Selection

These transitions raise both strategic and organizational questions, creating the rationale for public open standards. Standards can be created by market preference for single product offerings or solutions or through formal standards bodies working with multiple technology providers and technical experts.

The selection of standards is a dynamic process involving the evolution of functional requirements, public policy, and technology. Within this dynamic major sub sets of technology must be analyzed with respect to specific standards. For advanced metering infrastructure, for example, these technology sub sets include not only the evolution of metering, but telecommunications networks and the distribution system past the meter at the substation as well.

Tipping

Technologies “tip” when one standard becomes the preferred choice of nearly every consumer. Examples are VHS and Windows on the PC. When a technology “tips,” it is a signal to deploy, but all the while meeting local needs.

Not all technologies tip; multiple standards co-exist for some technologies. Examples are UNIX vs. Windows on servers; Sony vs. Microsoft in video games; Palm vs. Windows CE in PDAs; and multiple standards in cellular phones.

The number of people that are likely to buy a product depends upon signals from marketplace. This may be called the network effect. These network effects are derived from the installed base of a particular product, the availability of complementary products, and other factors influencing the use of the product. With strong network effects, the market share of a particular technology or solution itself creates momentum and gains added perceived value by public. If network effects are important, the technology may “tip.” Tipping dynamics differ with the strength of network effects. Technologies or solutions with moderate network effects only tip once critical thresholds are reached.

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- The VHS format's defeat of the Betamax format became a classic marketing case study, now identified with the verbal phrase "to Betamax", wherein a proprietary technology format is overwhelmed in the market by a format allowing multiple, competing, licensed manufacturers, as in: "Apple Betamaxed themselves out of the PC market."
- Sony's confidence in its ability to dictate the industry standard backfired when JVC made the tactical decision to engage in open sharing of its VHS technology. JVC sacrificed substantial potential earnings by going the open sharing route, but that decision ultimately won the standards war. By 1984, forty companies utilized the VHS format in comparison with Betamax's twelve. Sony finally conceded defeat in 1988 when it too began producing VHS recorders.

Figure 1-11
Example of "Tipping" – Betamax and VHS

2
IMPACT OF TECHNOLOGY OBSOLESCENCE ON AMI

The AMI definition of *automatic meter infrastructure* (AMI) is "the collection at a remote central location of data from meters and other devices at customers' premises via telecommunications." Before examining the impact of technology obsolescence on AMI, one must first understand the technology framework. AMI ultimately resides in the realm of the "Smart Grid," most commonly articulated in the IntelliGrid Architecture. Within this framework there are multiple technologies for automatic meters; moreover, AMI can be configured with multiple, alternative telecommunications media.

Future View

The modern grid is one in which electromechanical customer meters and meter readers will no longer exist. Invented at the turn of the 20th century, the mechanical meter has outlived its usefulness. Twenty-first century technology renders the opportunity cost of retaining these meters too high. Instead, consumers will be fitted with a modern solid-state meter that can communicate with both the consumer and the service provider. This meter will be composed of one or several microprocessors that can be programmed to offer a wide range of functionality. At a minimum, these functions include the ability to record usage associated with different times of day (and therefore different costs of production). Most will also include the ability to register a critical peak-pricing signal sent by the service provider and to charge at that critical rate while it is in effect. At the same time, the meter will notify the customer that the critical rate has been implemented.

The system will be built upon the digital communications capabilities of the Internet and will employ standard IP protocols. It will use reliable and ubiquitous communications media such as wireless, BPL, or even FTTH (fiber to the home). The consumer interface will be user-friendly, with increasing levels of sophistication as product features are added. The security of this system shall be designed to prevent tampering or disruption.

The utility will employ new host software systems that can collect, store, analyze, and process the abundance of data that flows from the extended application of sensing, metering, and measurements. The processed data will then be handed off to the various existing and new utility information systems that carry out the many core functions of the business (such as billing, planning, operations, maintenance, customer service, forecasting, and statistical studies).

Source: *A Systems View of the Modern Grid,* Appendix B2: Advanced Sensing, Metering, and Measurement, May 1, 2006. (Developed for the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability by the National Energy Technology Laboratory.)

Vision of AMI in the Smart Grid

There are many visions of AMI in the context of the Smart Grid. Most components of Smart Grid concepts are in the early roll-out or pilot phase, and there is limited information on actual economic and technical performance, let alone consensus. The environment—regulatory, technology, vendors, costs—is constantly changing. Regulatory imperatives are reassessed in light of high energy prices, technology, economics, blackouts, and conservations concerns. Technology for metering, data processing, and communications continues to evolve. New vendors are entering the market, and others are consolidating. Costs are falling for some components and rising for other, newer technologies offering enhanced features.

IntelliGrid

The IntelliGrid Architecture brings together the power infrastructure and the information technology infrastructure (including telecommunications). The IntelliGrid Architecture is shown in Figure 2-1.

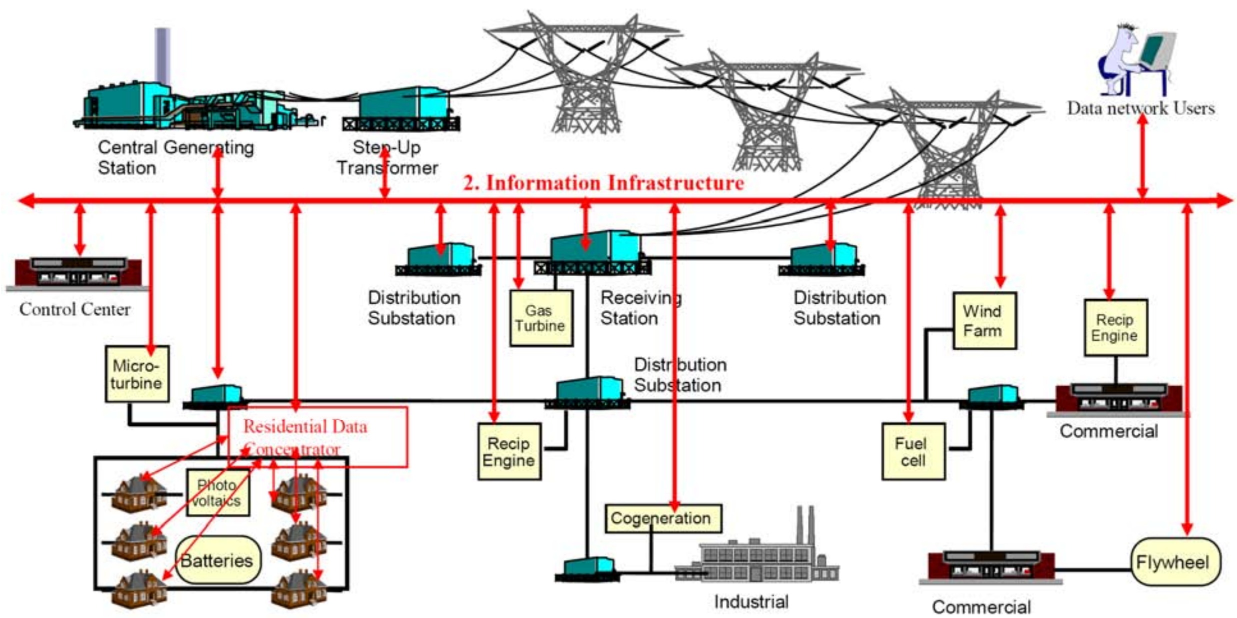

Figure 2-1
IntelliGrid Architecture

Smart Grid Technologies That Impact AMI

There are many technologies in the Smart Grid that impact on AMI. These are shown in Figure 2-2. Most important among them are the telecommunications technologies, wireless, and fixed line.

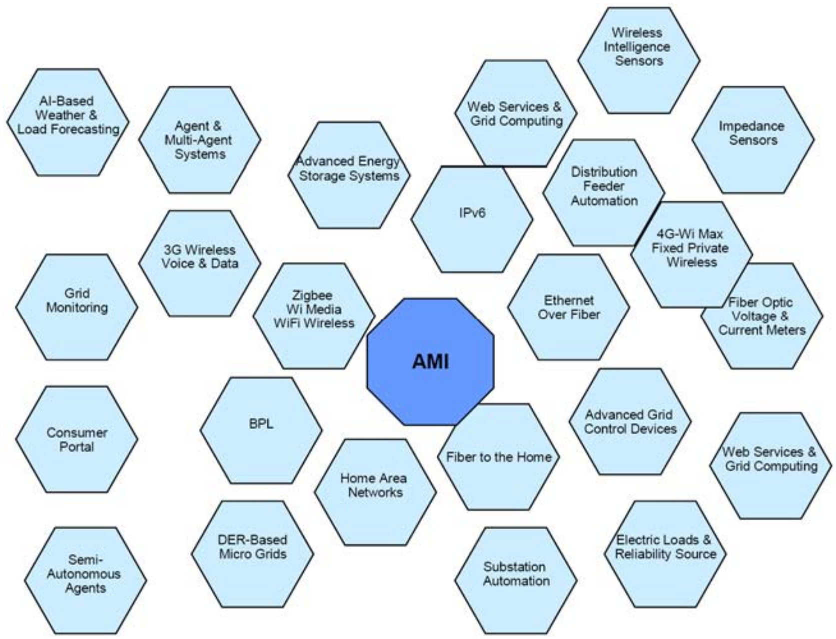

Figure 2-2
Technologies in the Smart Grid that Impact AMI

AMI Architecture

Within the framework of the Smart Grid, as expressed in the IntelliGrid Architecture, there is the architecture for AMI.[20] This is shown in Figure 2-3.

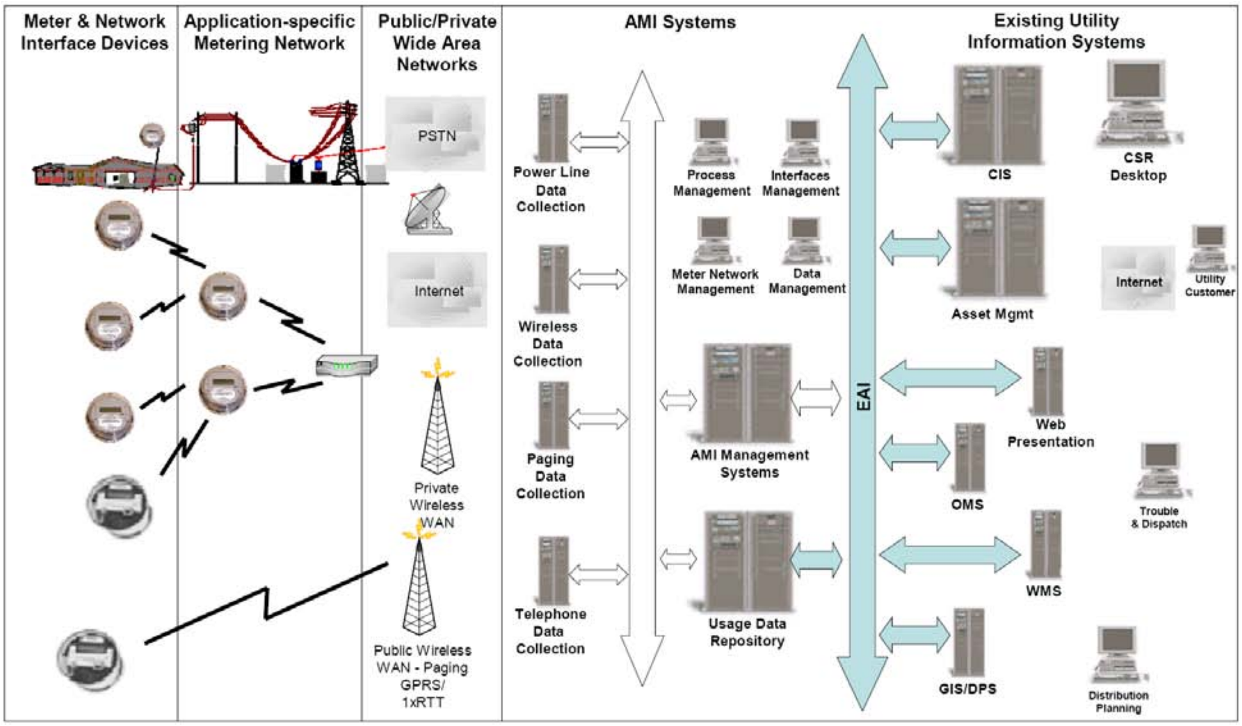

Figure 2-3
IntelliGrid Architecture

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[20] Note that AMI is only one component of the IntelliGrid.

The IntelliGrid Architecture is highly useful when implementing AMI systems. It has standardized interfaces providing access to data from equipment from multiple vendors; it includes redundancy and network management; and it is based on technology layering so that as new technologies and applications are developed, it can be upgraded without major loss of investment. It includes equipment that can be reprogrammed and reconfigured remotely over the metering network. All of these characteristics serve to mitigate against technological obsolescence.

Further, IntelliGrid offers a Technology Assessment Method[21] for developing AMI solutions. The three pillars of the IntelliGrid approach are:

- Use cases, which capture the requirements
- Technology assessment methodology, which maps those requirements to available technology
- Systems engineering, which translates the findings from the first two steps into a design for the entire system

AMI Matrix of Components

AMI comprises the integration of the following components:

- Meter.
- Meter register or index capable of generating pulses corresponding to the consumption through the meter or creating an electronic data stream containing its current reading as well as additional information (cumulative consumption, peak demand, alarm flags, etc.).
- Telemetry interface unit (TIU) connected to the meter that transmits the information.
- Communication network or system to transfer the data from the TIU to the utility's offices. For radio systems, there may also be a local data collection unit (DCU) that gathers data from many nearby TIUs and transmits it over the communications network to the utility's offices.
- An AMR control computer or utility terminal unit (UTU) to receive, collect, and manage this data.
- Software to run the system and present the data to the utility's billing and other information systems.

Effectively, there are three major technology components to AMI: metering, communications, and meter data management. Both metering and telecommunications technologies are undergoing several transitions. For meters, the changeover from electromechanical to digital is well established and well understood. The transitions in telecommunications are less well understood, although they are at the core of AMI solutions.

AMI telecommunications systems are usually characterized by the technology used for the "first hop" the TIU to the next point of data communications. Among these are shown in the following section.

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[21] "The Case for Use Cases," *SmartGrid Newsletter,* GridWise™. September 18, 2006.

AMI Technology Components

Meter

- Microprocessor components
- Telemetry interfaces

Communication Networks

- Wide area networks (WAN)
- Ethernet in the substation
- Home area networks (HAN)
- Neighborhood area networks (NAN)

Communication Technologies (IECSA)

- Multiple communications technologies (wired and wireless)

Wired Networks

- PSTN POTS
- Leased Lines (X.25, T1, other)
- Fiber Networks (ATM/SONET/Gigabit Ethernet)
- Broadband DSL
- Broadband cable
- Narrowband power line (PLC)
- Broadband power line (BPL)

Wireless Networks

- Microwave
- Serial radios (FreeWave, Locus)
- WiFi/WiMax
- Cellular
- Two-way pager

Information Technology

- Host hardware and applications
- Interfaces (billing, customer service, outage management, and asset management)

MDM

Meter data management refers to systems that manage large volumes of data supplied by a variety of meter data-collection methods. Key feature are:

- Persistent storage of meter data
- Interfaces to AMI/AMR networks
- Capabilities for validation and editing
- Interfaces to billing, outage management, other key systems

In order to avoid early obsolescence, meter-management systems should be installed in an open architecture frame, scalable, and upgradeable.

AMI and Technology Obsolescence

AMI and the S-Curve

The technology matrix for AMI can be examined against the measures for obsolescence both as a solution and by component. Technology obsolescence may be expressed through the S-curve that has been discussed earlier. Taken as a solution, AMI fits the S-curve well. The S-curve shows the evolution of AMI technology in the context of the Smart Grid and the technologies that preceded AMI and are components of existing solutions. These are shown in Figure 2-4.

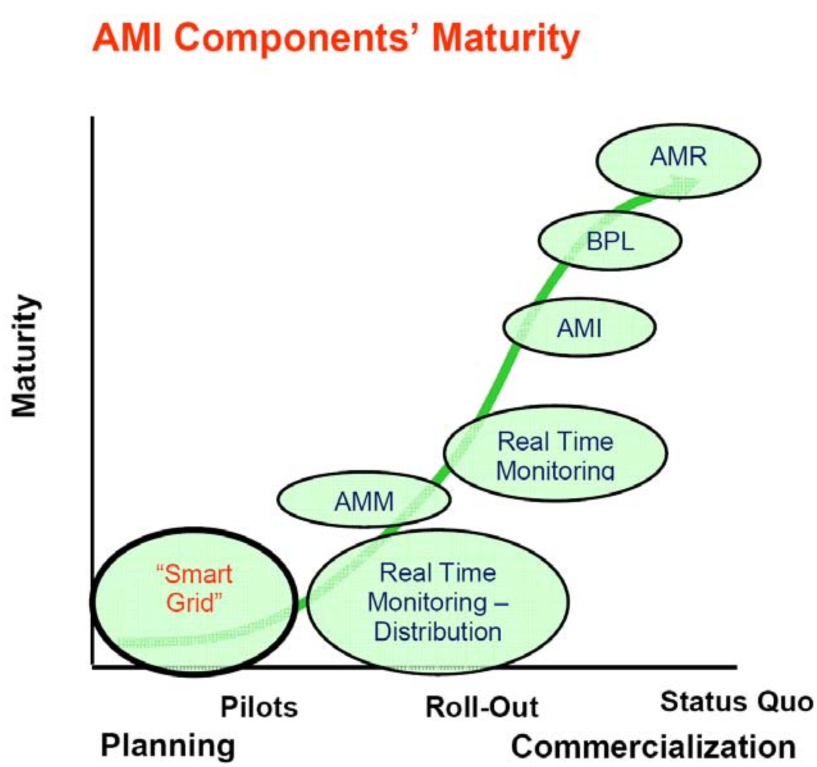

Figure 2-4
AMI and the S-Curve

The S-curve for AMI shows the Smart Grid, for example IntelliGrid Architecture, to be in the early stages of its lifecycle, with the vision still alive and adaptation underway. At the same time, other technologies, such as advanced meter management, are just entering the adaptation stage, as is real-time monitoring. BPL (broadband over power line) communications technology is shown to have past the adaptor stage, fully launched and ready for either application growth or maturity.[22]

Evolution (innovation and obsolescence) is evident in almost every facet of 21st century technology; it is demonstrably accelerating exponentially. Experience suggests that technological changes should be anticipated and, at some point along the S-curve, that a paradigm shift will occur to initiate the start of a new S-curve. Paradigm shifts are difficult to predict and are prone to spontaneous eruption, as was dramatically true in the case of the Internet. It was virtually impossible to anticipate the explosive demand bandwidth which would render communication systems of the 1980s obsolete.

This evolution is abundantly evident for the metering and communications technologies that define AMI. It may even be said that these technology evolutions enabled AMI by the very fact that they took place within overlapping time frames. Furthermore, the availability of these technologies for AMI may be said to be a necessary pre-condition for demand management mandates by regulatory bodies. It is almost impossible to think about public utility commissions ordering time-of-use pricing in real-time without two-way communications and solid-state electronic meters.

Evolution of Metering Requirements and Communications Technologies

Metering requirements for demand management and operational efficiencies have evolved over the past twenty years in the classic pattern of substitution as described in the literature on innovation and technological obsolescence. When metering requirements were limited to read only for monthly billing cycles, and operational efficiencies could be obtained cost effectively from advanced meter reading systems with drive-by communications technologies, communications networks using 1-G wireless one-way technology fit the bill. When metering requirements increased to more frequent reads, 2-G wireless one-way technology worked well. With the introduction of demand management systems and the need for frequent reads, at short intervals, 3-G, open two-way technology over fixed links was necessary. In all of these cases, wireless and wireline telecommunications technology was evolving along with the needs for more frequent reads in real-time, and two way communications for time-of-use pricing. The evolution of metering requirements and communications technologies is shown in Figure 2-5.

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[22] The case for BPL is still out. PLC is sufficient for AMI applications (Narrow bandwidth [3 - 148.5 kHz] < 9.6 kbps); BPL is overkill for AMI (broad bandwidth [150 – 450 kHz] > 1.8 mbps). BPL is only justified for AMI if it is part of a broader strategy to offer voice and video services. Otherwise it is costly and holds risk of obsolescence as fiber to the home and other broadband connectivity becomes more prevalent.

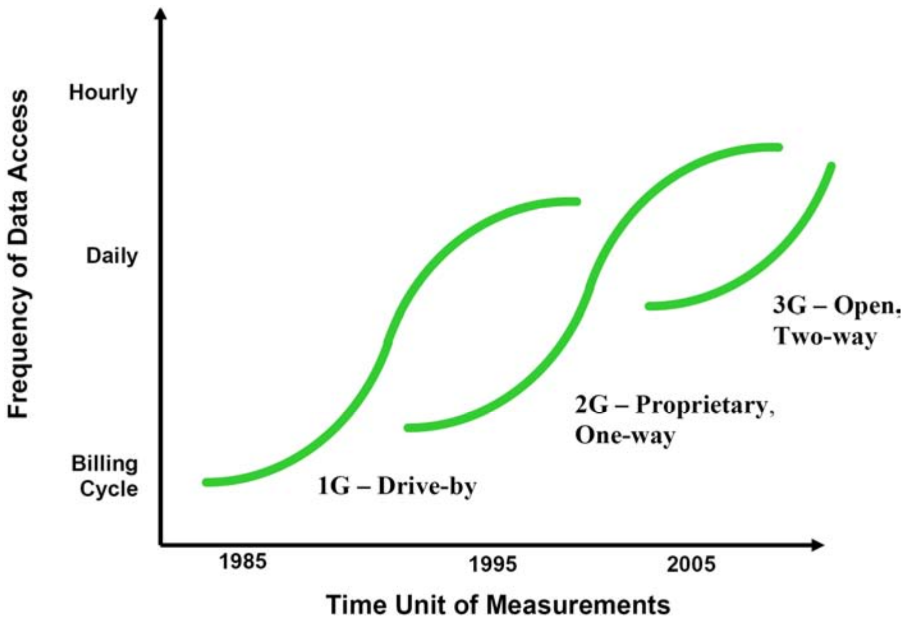

Figure 2-5
The Evolution of Metering Requirements and Communication Technologies

AMI Evolution

The evolution of AMI technology follows the familiar path from innovation to technological obsolescence, along S-curves, as well. AMR solutions were adequate for operating efficiencies and a cost-effective substitution for manual reads. The technology was limited to one-way communications, and the frequency of reads was low. When data-management systems developed in response to the increased availability of data, AMR technology solutions were adequate, and the technology entered the stage of a mature technology. AMR technology does not meet the requirements of demand management for two-way communications in real-time and is thereby entering a stage of technological obsolescence. On the other hand, AMI technology and solutions meet the needs of demand management and are therefore passing through the innovation stage, in some cases as a substitution for AMR.

The evolution of AMI from 1985 to 2006 is shown in Figure 2-5. It is interesting to observe that the S-curves for each of the technologies follow the classic pattern from technological development to technological obsolescence. It is noteworthy that there are innovators, visionaries, and early adaptors in the utility industry who are moving along these technological paths.[23]

[23] It should not be overlooked that the vision of the “Smart Grid” architectures, such as the IntelliGrid, has been helpful in avoiding technological obsolescence as AMI solutions are methodically deployed, one might say, along the S-curve of AMI.

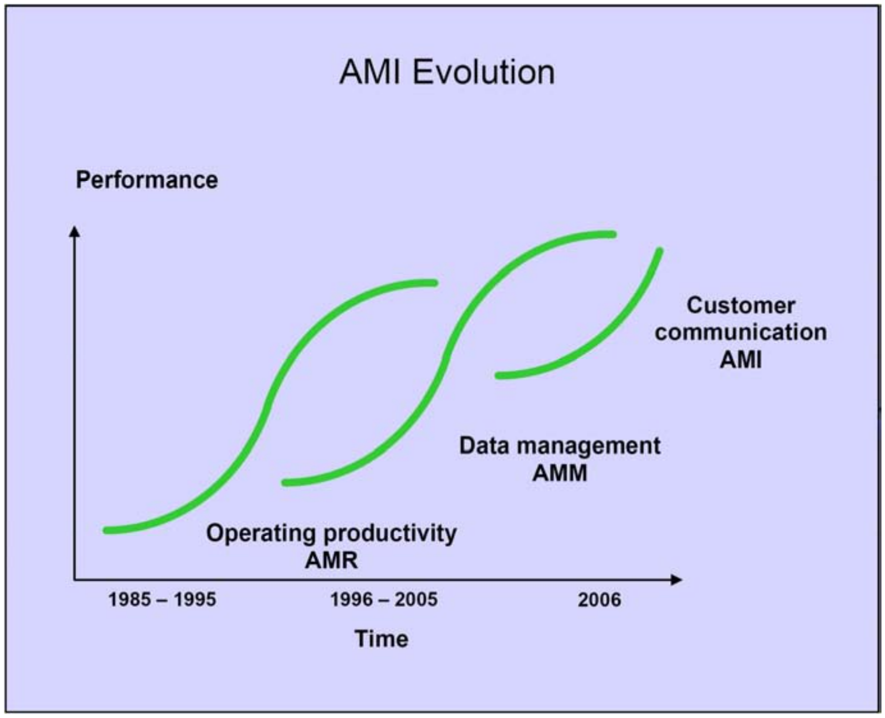

Figure 2-6
AMI Evolution

AMI Component Evolution – Electric Meter Technology

The evolution of the AMI component technologies, meters, and communications followed the S-curve of innovation and technological obsolescence. Electric meter technology developed along the lines of solid state Gen2 and Gen3 technology, corresponding to changing requirements for functionality, especially storage and communications interfaces. This is shown in Figure 2-7.

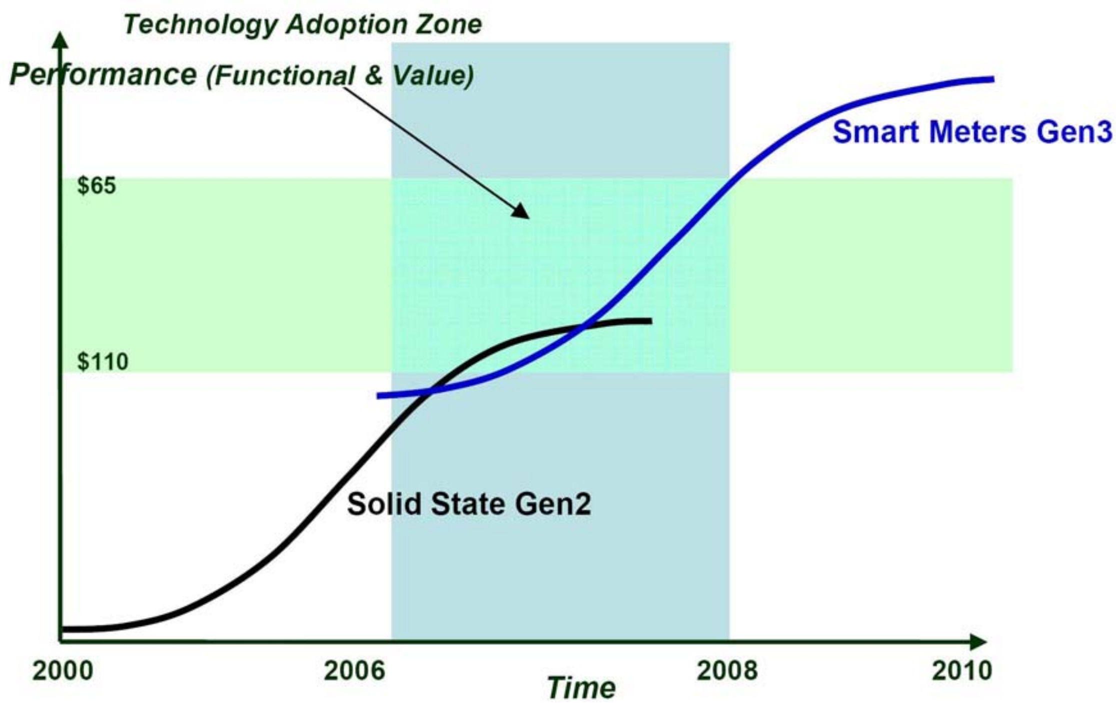

Figure 2-7
Electric Meter Technology

It is interesting to note that the evolution of electric meter technology not only changed with performance and functionality, with Gen3 technology substituting for Gen2, but that there was an inverse relationship with costs. Gen3 smart meters cost less than Gen2.[24]

AMI Component Evolution – Electric Meter Communication Technologies

Electric meter communication technologies proceeded along similar S-curves in support of AMR and AMI. RF or microwave technology was sufficient for AMR technologies; PLC performs well for AMR, as well as other fixed-line communications, RF mesh technologies, and WiMax. This progression of technologies has rendered RF technology with narrow ranges obsolete for AMI, while introducing WiFi, WiMax, and PLC technologies that offer fixed-network connectivity. The S-curves for electric meter communications technologies are shown in Figure 2-8.

[24] Much of the explanation for the decrease in unit cost is attributable to the falling price of microprocessors and increased production volumes for microprocessors designed for electronic meters.

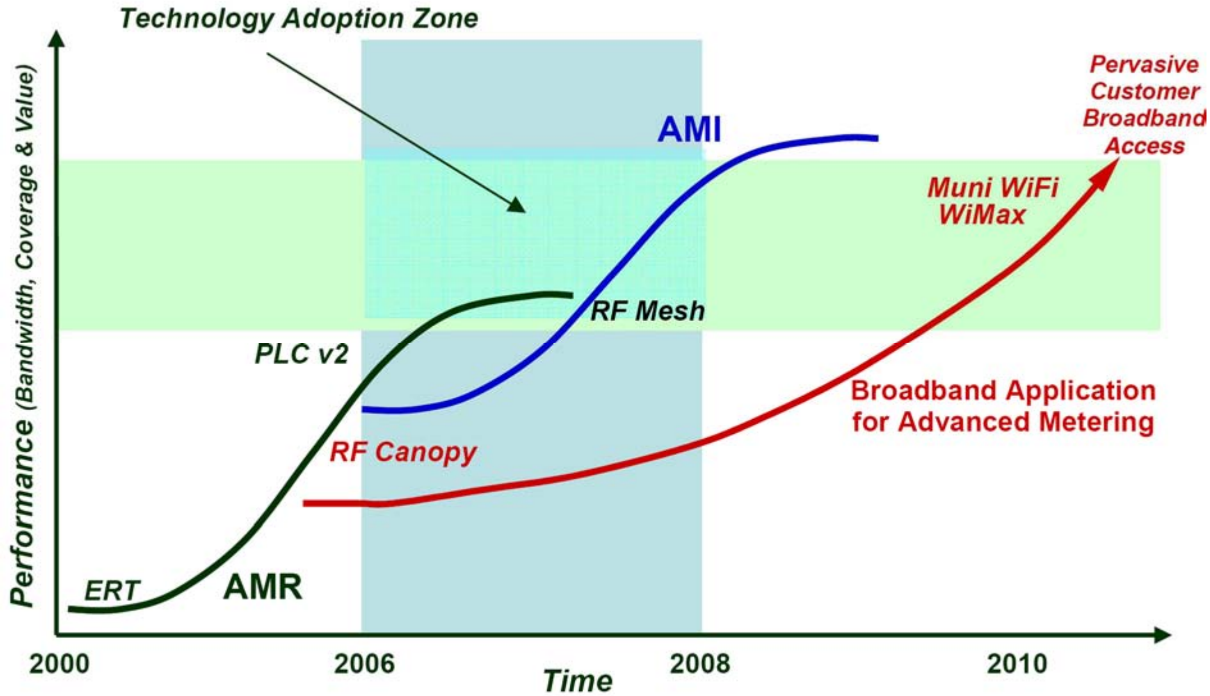

Figure 2-8
Electric Meter Communication Technologies

Technology Obsolescence Impact on AMI

Technology obsolescence impacts AMI in the following areas:

- Selection decision for optimum time for large-scale deployment
- Replacement of legacy systems (that are still functional)
- Cost recovery formula (depreciation lifetime)
- Risk factors (viability, parts, and services, including telecommunications and useful life)

Views on technology obsolescence are major considerations in the analysis of these important elements in technology selection and deployment decisions. In many cases, conclusions on technology obsolescence will impact the return on investment calculations that determine whether to deploy AMI or not.[25]

[25] This is especially important when determining depreciation and cost recovery, which directly impact cash flow and the rate of return.

Importance of Technology Obsolescence to AMI Deployments

Although in many ways AMI technologies are maturing, they can hardly be characterized as being fully mature at this point. While concerns about inadequate technologies and customer interest linger, a significant number of utilities are taking leaps of faith towards developing AMI/Smart Grid strategies. Technological obsolescence is relevant to AMI deployments for three major reasons that are not related to technology or technological risk per se. The reasons are:

- AMI deployments are on a very large scale.
- AMI deployments require very large capital expenditures with long payback periods.
- AMI takes a long time to deploy.

Large-Scale Deployments

Technological obsolescence is an important concern when deploying AMI for the simple reason that deployments are on a very large scale. As shown in Table 2-1, by 2006 the top 20 deployments of AMR technology totaled over six million.

Table 2-1
Top 20 Deployments of AMR Technology by Company in 2006

Company	Total AMI
PECO Energy Co	1,759,913
PPL Electric Utilities Corp	1,353,024
Wisconsin Electric Power Co	723,000
Wisconsin Public Service Corp	396,837
United Illuminating Co	324,992
Kansas City Power & Light Co	262,892
Kansas City Power & Light Co	210,971
Pedernales Electric Cooperative	200,698
Lee County Electric Cooperative	158,800
Austin Energy	125,864
Bangor Hydro-Electric Co	107,758
Rappahannock Electric Cooperative	95,023
First Electric Cooperative Corp	76,757
Avista Corp	61,661
Alabama Power Co	52,000
Ozarks Electric Cooperative Corp	48,731

Table 2-1 (continued)
Top 20 Deployments of AMR Technology by Company in 2006

Company	Total AMI
Florida Power & Light Co	43,657
TXU Electric Delivery Co	40,000
Jackson Energy Coop Corp	37,810
TOTAL	**6,080,388**

Deployments of AMI are planned on an even larger scale. Wherever there is a mandate for demand management and regulatory authorities are supportive, AMI technology will substitute for AMR. This is a definite trend, as shown in Table 2-2. PG&E alone started deployment of AMI in 2005 planned at 9.1 million meters.

Table 2-2
AMR Deployment Trend to AMI

Name	Start	Supplier	Solution	Coverage	Meters
KCPL	94	Cellnet	AMR	All	450,000
DQE	95	Itron	AMR	Residential	550,00
AmerenUE	95	Cellnet	AMR	All	1,300,000
NSP	96	Cellnet	AMR	All	1,900,000
PSE	97	Cellnet	AMR	All	1,325,000
IPALCO	97	Cellnet	AMR	Residential	415,000
United Ill.	99	Cellnet	AMR	Residential	320,000
PECO	99	Cellnet	AMR	All	2,100,000
WPS	99	ESCO-DCSI	AMR	All	250,000
PREPA	99	ESCO-DCSI	AMR	All	1,400,000
JEA	01	Cellnet	AMR	All	450,000
PPL	02	ESCO-DCSI	AMI	All	1,300,000
WE Energies	02	Cellnet	AMR	All	950,000
Idaho Power	04	ESCO-DCSI	AMI	All	25,000
Bangor Hydro	04	ESCO-DCSI	AMR	All	110,000
Laclede	05	Cellnet	AMR	All	650,000
Colorado Springs	05	Cellnet	AMR	All	400,000
PG&E (electric)*	05	ESCO-DCSI	AMI	All	5,100,000
PG&E (gas)*	05	ESCO-Hexagram	AMI	All	4,100,000
Total					**23,400,000**

*Planned

Large Capital Investments

AMI requires very large capital investments. Project costs for the PG&E deployment are $2.258 billion dollars.[26]

Long-Term Deployment Period

Studies on current or planned AMI pilots and large-scale deployments[27] show that there is a long lead time for AMR/AMI projects, as shown in Table 2-3.

Table 2-3
The Long Lead Time for AMR/AMI Projects

Average Length of Projects	Average Number of Total Meters	Average Number of Electric Meters	Average Length of Pilots
5.7 Years	2.6 M	2.2 M	9 Months

With a pilot lasting thirty-six months, Pacific Gas & Electric had the longest duration. Regarding full deployment, Southern Company had the longest deployment schedule with nine years, and Portland General Electric and Baltimore Gas & Electric had the shortest deployment schedules, each with three years. Pacific Gas & Electric has the largest planned deployment with a total of 9.3 million endpoints. All utilities in the study are deploying AMI in phases, typically based either on geographic region or customer class. The years to deploy large number of meters are shown in Table 2-4 below.

Table 2-4
AMR Years to Install

Utility	Number of Meters[28]	Years
PECO Energy	1,730 (E)	4
	470 (G)	
Puget Sound	1,600 (E)	5
Ameren	1,300 (E)	5
	139,000 (G)	
Xcel Energy	1,100 (E)	4
	360 (G)	

[26] *Application of Pacific Gas and Electric Company for Authority to Increase Revenue Requirements to Recover the Costs to Deploy an Advanced Metering Infrastructure.* Application 05-06-028 (Filed June 16, 2005) Final Opinion Authorizing Pacific Gas and Electric Company to Deploy Advanced Metering Infrastructure (Decision 06-07-027 July 20, 2006)
[27] "Many Utilities Starting to Develop AMI and Utility-of-the-Future Strategies," Will McNamara, Principal Consultant, KEMA, May 29, 2007.
[28] Electric (E), Gas (G) and Water (W)

Table 2-4 (continued)
AMR Years to Install

Utility	Number of Meters[28]	Years
WE Energies	736 (E)	4
	612 (G)	
PPL	1,400 (E)	4
Puerto Rico EPA	1,400 (E)	9
Wisconsin PS	430 (E,G,W)	4

The timeframe from decision to deployment for AMI is exceptionally long. First, utilities must determine the requirements, and then they must assess the technologies and vendors. Pilot projects are necessary, contracts need to be negotiated, and regulatory approvals are required all along the way.

Risk

Advanced metering infrastructure must be designed with the future in mind. The environment in which AMI is deployed is constantly changing not only with respect to the evolution of technology, but in the broader areas of regulations, pricing, and business models. (*The Dangers of Advanced Metering*, Jesse Berst, Grid Automation. Feb 12, 2006.)

The major risk in deciding on an AMI system is making a commitment to an obsolete system or one with technology that cannot expand to offer full benefits. Commitment to an obsolete system may lead to agreements with regulators on a pricing model that allows for cost recovery for a period of time long after the investment in the technology is obsolete, or even stranded.

Another major risk is commitment to a proprietary system that requires dependence on a single vendor. The vendor may not survive consolidation, leaving the utility without maintenance, technical support, and upgrades. Many vendors have undergone ownership changes as the result of mergers and acquisitions over the last five years. Meanwhile, several new companies have entered the market. The risk of vendor selection is closely tied to the risk of technology obsolescence.

Metering Development

Watt-Hour Meters

Traditionally, utilities measured electricity usage as energy in kWh (kilowatt-hours) and as demand in kW (kilowatts). Initially, metering was accomplished utilizing electromechanical meters. The first electromechanical meters were energy only, with a four or five dial mechanical register to indicate the energy consumption. Today, most residential customers still utilize this metering technology.

As demand was recognized as an important element, electromechanical meters were developed that also measured demand (kW) in addition to energy consumption.[29] Electromechanical demand meters were manually read on a regular schedule, most often monthly or bi-monthly.

Interval Metering and Recording

As electricity usage grew, the need for additional data changed metering requirements. Interval metering became a method to look at energy usage by time intervals. A recording/translation system was developed to provide interval data. During the 1970s, electronics had not progressed sufficiently to record interval data within the small spaces inside the meter. To meter for interval data, an electromechanical recording system was developed that consisted of a pulse initiator located inside the meter and a magnetic tape pulse recorder located outside the meter.

Hybrid Meters

The introduction of electronic registers into electromechanical metering increased the functionality of metering by offering new provisions such as interval metering and time-of-use measurements. Because the electronics were internal to the meter, no external recorders were required.

Solid-State Meter

The solid-state meter replaced the electromechanical portion of the hybrid meter, making the full meter electronic, thereby eliminating all moving parts.

AMR – Automatic Meter Reading

This technology does not enable the utility to implement time-based dynamic pricing nor did it "enable" the customer from a demand response standpoint. It is important to note that AMR systems that rely on mobile or "drive-by" technology are generally unable to be modified to provide advanced metering capabilities, because these capabilities require a fixed network.

Advanced Meters

During the 1990s, advances in communications technology (such as internet, power line communications, and wireless) began to be applied to metering to create "advanced metering." The meter itself also advanced technologically with the introduction of solid-state metering technology with more accurate measurement capability as well as new capabilities to measure parameters other than simply usage and demand.

An essential ingredient for advanced metering is the fact that communications now become continuously available, because advanced meters communicate via a fixed network, not a van driving by once a month as is typical with AMR.

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[29] *Demand* is defined as the maximum rate of energy usage over a specified period of time, such as 15 or 30 minutes.

An advanced meter can be defined as a solid-state meter that typically provides:

- Interval data and time-of-use functions
- Measurement and display of per phase information
- Site diagnostics
- Power quality monitors
- Outage and tamper detection
- Communications interface

AMR to AMI

The evolution from standard AMR to AMI is mostly defined by the telecommunications infrastructure that is deployed as part of the integrated system. Standard AMR can use mobile communications technologies, one-way fixed RF networks, or one-way narrowband PLC. The quantity and timeliness of data are limited but can be used nonetheless for many applications that enable applications that yield cost savings for utilities, mostly from meter reading itself.

The advent of low-cost digital technology has spawned more advanced metering in recent years. And these digital meters can be readily equipped with communications ports to accommodate automatic meter reading (AMR). At the same time, new digital communications technologies have been developing that can facilitate more complex and more frequent meter reading, including direct interaction between the service provider and the consumer.

The integration of advanced digital measurements and digital communications is a key element of this transformation. Simply put, metering technologies have evolved basically because of the need for more and more data to be captured and transmitted more frequently. It is important to note that currently no single solution for advanced metering meets the total needs in any given service territory.

Timeline – Electric Meters

There are many lessons that can be learned from the timeline of electric meters (shown in Table 2-5). These insights are helpful in understanding the impact of obsolescence on AMI.

Table 2-5
Electric Meters Technology Timeline

Year	Technology
1872	First patent on an electric meter
1878	First patent on an AC lamp hour meter
1882	Chemical ampere-hour meter
1885	Development started on induction-type meter
1886	First meter for use on AC circuit
	Development of recording wattmeter begun
1888	Shallenberger ampere-hour meter
1889	Thompson Recording Wattmeter
1892	Duncan developed single disk meter
1894	First commercial induction watt hour meter
1896	Need for a meter that would work on a polyphase circuit
1897	Need for smaller, lighter, lower-cost meter
	Shallenberger ampere-hour meter redesigned
1899	Thomson Polyphase Wattmeter
	Westinghouse Polyphase Meter
	Prepayment meter introduced (GE IP-5 and IP-14
1902	Westinghouse type A meter with ball bearing instead of pivot bearing
1903	GE Type A Meter - First modern meter
1912	Duncan developed induction type meter, Model M
1920	Key advances in meter design: cabinets; terminal chambers; temperature compensation; overload compensation; size
1931	Two new standardized designs: “s-type and “A-base”
1934	Last mechanical prepayment meter introduced on market, Sangamo Type HFP
1948	GE I-50 single phase magnetic bearing meter “First all-new meter in 50 years”
1960	All major manufacturers introduce meters using magnetic bearings
1975	Electronic registers and automatic meter reading devices introduced

Table 2-5 (continued)
Electric Meters Technology Timeline

Year	Technology
1985	Hybrid meters with electronic registers mounted on induction-type meters
1990	Introduction of fully electronic meters with no moving parts
	Phase out of induction-type polyphase models
2000	Four major companies primarily manufacture electronic meters; only two continue to offer a few electromechanical models

Source: Watthour Meter (http://watthourmeters.com). David Dahle

Among the risks that the above timeline illustrates are issues with new technology patents, patent lawsuits, companies going out of business and consolidating, technologies being discontinued and technologies being improved and shared, and base technologies with reasonably long manufacturing lifetimes. Among the issues particular to electric meters are the decision as to what is measured, size and weight, location (inside/outside, communications links, individual appliances), materials, components, and additional features and other uses at site.

In looking at the timeline, it is important to note that changes are occurring at exponential rates. This is especially true for the telecommunications technologies available for AMI. Changes in metering and telecommunications technology can have a cumulative impact as well, further compounding the consequences of obsolescence for utilities. These consequences must be considered in order to minimize the impact on AMI over time.

Obsolescence may relate to technologies other than the customer meter, such as home automation/appliance metering and distributed generation metering. With respect to communications, there is the prospect that "always connected" devices, home area networks, and high-capacity wireless networks may be the norm. Foresighting, one might envision gigabit wireless in the home by 2011 to 2015.[30]

Drivers

The drivers for AMI are important factors in any analysis of technological obsolescence because they define the underlying reasons for technology selection and deployment. The regulatory mandates that flow from the drivers are at the foundation of the social benefits that justify AMI. Without the rationale provided by these drivers, most AMI systems would be obsolete because they would have no purpose. The drivers mostly translate into demand-management schemes that require AMI.

The key driver is compliance with local, state, and national government mandates, which have as their objective conservation and reduced growth in consumption through time of use (TOU) and critical peak pricing (CPP). Other motivations are the reduction in new plant construction, the reduction in environmental impact, and compliance with the Kyoto Treaty.

[30] *BT Technology Timeline.* August 2005.

On an industry-wide basis, these drivers have translated into a number of Global Smart Energy Initiatives. Foremost among these are the IntelliGrid and GridWise™ programs. Nevertheless, the most important drivers of all are mandates and orders flowing from state and federal regulations.

Regulation Drivers for AMI

There are several major drivers for advanced metering and demand response that influence utility consideration of AMI. Some relate to utility operations—cost savings from meter reading or outage management. Others relate to customer service enhancements, such as billing. However, the strongest drivers are from government regulation.

Policy makers at both the federal and state levels look at what options they have to address today's energy challenges, and the focus is on demand response. As such, attention turns to the most common enabling technology for demand response—advanced metering infrastructure—and solutions for dynamic pricing.[31]

Energy Policy Act of 2005

The Demand Response and Advanced Metering Provisions of the Energy Policy Act of 2005 (EPAct) are major drivers for AMI. Section 1252 states that all utilities, not just investor-owned utilities, will "provide customers with time-based rates and the ability to receive and respond to electricity price signals." Although it does not dictate how utilities should do this, it is generally understood that to achieve this mandate, utilities will need more than an intelligent transmission and distribution grid; they will also need an intelligent connection to the customer (hence, AMI). There is a further requirement in Section 1252 that the states consider a new standard, which would require time-based pricing and advanced meters to be offered by utilities or otherwise provided. In this way, it may be said that AMI is on the national energy agenda.

U.S. Government Policy Statement

"It is the policy of the United States that time-based pricing and other forms of demand response, whereby electricity customers are provided with electricity price signals and the ability to benefit by responding to them, shall be encouraged, the deployment of such technology and devices that enable electricity customers to participate in such pricing and demand response systems shall be facilitated, and unnecessary barriers to demand response participation in energy, capacity and ancillary service markets shall be eliminated. It is further the policy of the United States that the benefits of such demand response that accrue to those not deploying such technology and devices, but who are part of the same regional electricity entity, shall be recognized." (Source: Energy Policy Act of 2005.)

[31] Time-of-use, real-time, and critical peak pricing.

Smart Grid Facilitation Act

Legislation is pending that would impact AMI even more than EPAct.[32] The Smart Grid Facilitation Act provides a nationwide focus on the development of a Smart Grid. In fact, it requires utilities to justify any "non-Smart" Grid technologies. The Act (i) establishes a Federal Grid Modernization Commission, (ii) requires development of protocols and standards for information management, (iii) establishes a Smart Grid investment grant program that will match 25% of qualifying Smart Grid investments ($250M appropriated for 2008 and $500M appropriated per year for 2009-2012). Further, and most importantly, it requires (not asks as in EPAct 2005) utilities to consider ways to encourage Smart Grids, energy efficiency, and demand response.

An extract of the section of the bill that relates to state consideration of incentives for smart grid facilitation is shown in the insert below.

Smart Grid Facilitation Act of 2007, PART 1 – SMART GRID

SEC. 9117. STATE CONSIDERATION OF INCENTIVES FOR SMART GRID.

(a) Consideration of Additional Standards- Section 111(d) of the Public Utility Regulatory Policies Act of 1978 (16 U.S.C. 2621(d)) is amended by adding at the end:

(16) UTILITY INVESTMENT IN SMART GRID INVESTMENTS- Each electric utility shall prior to undertaking investments in non-advanced grid technologies demonstrate that alternative investments in advanced grid technologies have been considered, including from a standpoint of cost-effectiveness, where such cost-effectiveness considers costs and benefits on a life-cycle basis.

(17) UTILITY COST OF SMART GRID INVESTMENTS- Each electric utility shall be permitted to--

`(A) recover from ratepayers the capital and operating expenditures and other costs of the utility for qualified smart grid system, including a reasonable rate of return on the capital expenditures of the utility for a qualified smart grid system, and

`(B) recover in a timely manner the remaining book-value costs of equipment rendered obsolete by the deployment of a qualified smart grid system, based on the remaining depreciable life of the obsolete equipment.

(18) RATE DESIGN MODIFICATIONS TO PROMOTE ENERGY EFFICIENCY INVESTMENTS-

(A) IN GENERAL- The rates allowed to be charged by any electric utility shall--

(i) align utility incentives with the delivery of cost-effective energy efficiency; and

(ii) promote energy efficiency investments.

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[32] *Smart Grid Facilitation Act of 2007, Part 1—Smart Grid, Sec. 9111. Statement of Policy on Modernization of Electricity Grid. (HR3221).* This bill was passed by the House of Representatives on August 4, 2007, and was sent to a Senate-House conference committee to be reconciled with an earlier Senate bill.

(B) POLICY OPTIONS- In complying with subparagraph (A), each State regulatory authority and each non regulated utility shall consider--

(i) removing the throughput incentive and other regulatory and management disincentives to energy efficiency;

(ii) providing utility incentives for the successful management of energy efficiency programs;

(iii) including the impact on adoption of energy efficiency as 1 of the goals of retail rate design, recognizing that energy efficiency must be balanced with other objectives;

(iv) adopting rate designs that encourage energy efficiency for each customer class;

(v) allowing timely recovery of energy efficiency-related costs; and

(vi) offering home energy audits, publicizing the financial and environmental benefits associated with making home energy efficiency improvements, and educating homeowners about all existing Federal and State incentives, including the availability of low-cost loans, that make home energy efficiency improvements more affordable.

State Requirements and Regulations

Customer metering and tariffs have always fallen within the purview of state regulatory bodies. Hence, transformation of the metering cannot occur without the support and encouragement of these regulators.

California

Some state regulators have mandated AMI. The most obvious example is California, where in 2004 the California Public Utilities Commission (CPUC) directed Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric to develop AMI business cases.

New York

Prior to EPAct, the New York Public Service Commission issued an order directing all state utilities to “develop and deploy, to the extent feasible and cost effective, advanced metering systems for the benefit of all customers.” In February and March 2007, utilities filed a plan with the New York regulator that calls for some utilities to rollout the new meters starting in 2008.

Texas

And in Texas, although regulators determined that AMI deployment was voluntary, utilities must receive approval from the Public Utility Commission of Texas of AMI six months prior to installation; file deployment progress reports every six months following filing of initial deployment plan; file the number of meters that have been replaced due to malfunction; and use only AMI systems that have been successfully deployed on 500 meters or more in North America (excluding pilots). Texas also established certain features that must be included should a utility choose to implement AMI, such as having two-way communication features, remote connect/disconnect, and timestamp meter data that can be sent to independent organizations for settlement purposes. The status of smart grid activity in the United States is shown in Figure 2-9 below.

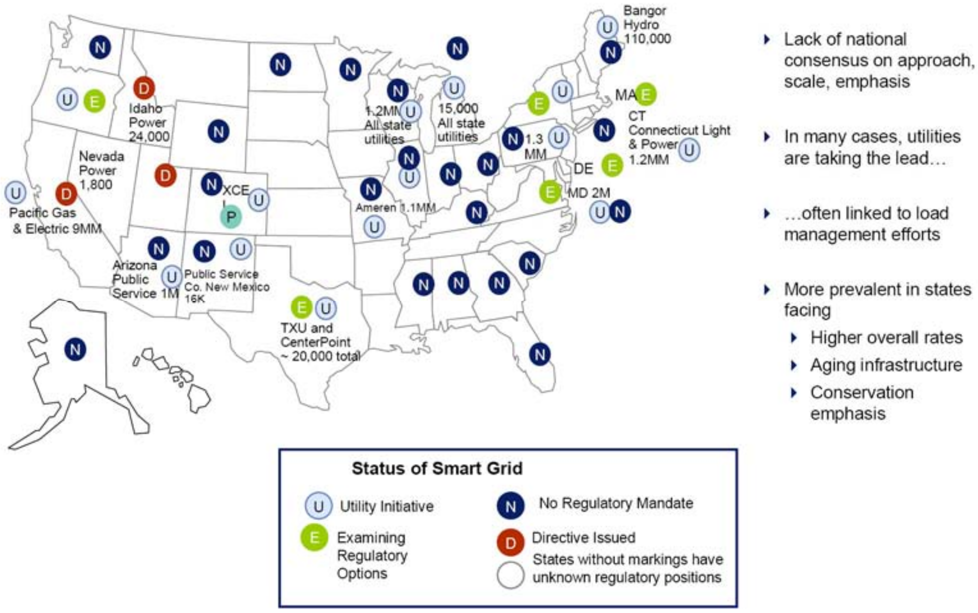

Figure 2-9
State Activity Summary

AMI – Technology Substitution for AMR

Most importantly for regulators, AMI enables real-time demand management. Thus, utilities that have deployed AMR systems for their own purposes in states where regulators are calling for demand management are finding their investment obsolete or outdated and in need of substantial upgrades. This is especially the case with respect to communications interfaces and links to utility or public telecommunications networks.

With the advent of metering applications that offer administrative savings and efficiencies and the availability of two-way communications, the benefits from AMI became more attractive to both regulators and utilities. However, utilities should be careful to weigh the operational benefits to themselves and their customers against the social benefits as asserted by regulatory bodies.

Risk of Obsolescence

Utilities would be well-advised to pay close attention to the attitudes of regulatory bodies toward demand management. In response to political pressures for demand management, regulatory bodies may issue rulings mandating AMR or AMI systems whose functionality may not be economically or technical feasible. Such systems may become obsolete before deployment.

3
MINIMIZATION OF IMPACT OF TECHNOLOGY OBSOLESCENCE ON AMI

From Order Relating to Electric and Gas Metering Services, Cases 94-E-0952, 00-E-0165 and 02-M-0514. New York Public Service Commission (Issued and Effective August 1, 2006):

"Electric utilities should explain in their plans the future options available for modifying and upgrading their selected systems for future advanced metering needs and avoidance of early obsolescence and stranded costs that can be anticipated and prevented. It would be beneficial to customers if utility advanced metering systems, including automated meter reading, did not restrict future use of sophisticated pricing and load management programs due to prohibitive incremental costs or technological impediments."

It is important to minimize the impact of technology obsolescence on AMI deployments because failure to do so will lead to opportunity costs in realizing benefits and increases investment risks. Recognizing the impact of technology obsolescence on AMI leads to continuous enhancements and infrastructure development that optimize functionality and return on investment.

Assumptions and Limitations

The first assumption is that the benefits of advanced sensing, metering, and measurement will exceed the cost of implementation. Here, the key variable is the installed cost of the sensing, metering, and communications facilities. A related variable is the value assigned to the benefits, some of which reach beyond the utility function and actually impact the society as a whole. It is the role of governments to place a value on these extended benefits (public goods). There is little doubt that modern digital technology can produce low-cost, highly effective solutions. All such technological developments depend on two major factors:

- Scale of deployment
- The continued reduction in the price of digital integrated circuits

The scale of deployment is potentially enormous; a global metering transformation would employ hundreds of millions of intelligent, communicating meters. And, as Moore's Law has consistently shown, the price of chips will continue to drop, even as their processing power grows. Also, as history has shown us, the associated requirement of ubiquitous, reliable, inexpensive communications will become increasingly available as the revolution in digital communications continues to play out

Source: A Systems View of the Modern Grid, Appendix B2: Advanced Sensing, Metering, and Measurement May 1, 2006. Developed for the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability by the National Energy Technology Laboratory.

Technology Strategy

Managing technological innovation requires that a utility continue to introduce incremental innovations and forecast future changes in order to ensure continued existence in the face of discontinuous innovation. This is the period of transformation that minimizes the impact of technological obsolescence. The period of transformation between AMR and AMI is shown in Figure 3-1 below.

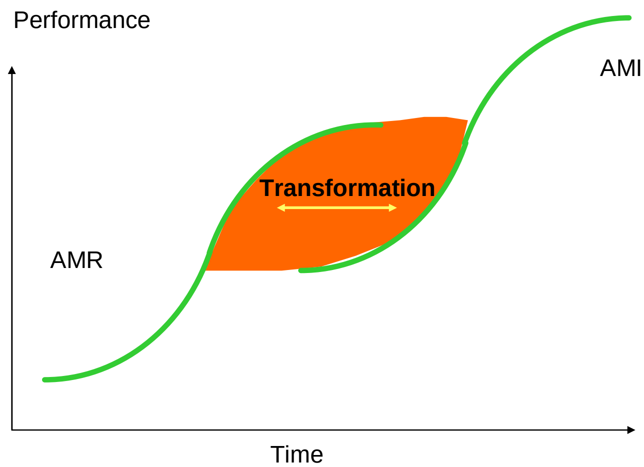

Figure 3-1
A Technology Strategy Is Fundamental to the Transformation Process

Technology strategy is the road map for creating value for the utility and its customers. The evolution of technology and the impact of technological changes on the utility should be analyzed within this framework. From this point, one can consider alternatives for capturing the value in the technological change to the benefit of the utility and its customers. In order to capture this value, it is necessary to have a business model that is designed for the implementation of the technology, in this case AMI. The business model answers questions regarding when deployment makes the most sense for the utility and the customer. It answers questions regarding the architecture, solution, applicable standards, regulation, return on investment, and the risk of technological obsolescence. These are all questions that must be answered as part of the justification for any technology program, especially those that are characterized by large-scale deployments and large investments over long periods of time, such as AMI.

In order to accomplish this, the utility must understand how public requirements will evolve and how technologies will evolve.

Public Requirements

Public requirements are the primary drivers behind AMI. These primarily find their expression in regulatory pronouncements. The Energy Act of 2005 and proposed legislation on energy efficiency and the Smart Grid are influences on the environment that surrounds AMI.

Public requirements are known to utilities themselves as part of their normal customer service programs. Operational efficiencies and cost savings for the utility itself are important public requirements that are often overlooked. The increase in profits and cash flow are important for the financial health of utilities and are cushions for the risk inherent in investments such as AMI. The challenge to those considering AMI is to determine whether the technology mix delivers the most value, given social and economic realities.

Predicting Technological Change

In the language of technology innovation and obsolescence, predicting the evolution of technology is part of crossing the chasm from AMR to AMI and beyond. Some comfort can be taken from using "future proof" architecture.

The path of technological change cannot be forecast with any precision. However, there are certain forecasting methodologies that can point the way. Among these are:

- Trend analysis
- Delphi models
- Foresighting

Trend Analysis

Trend analysis is the most common forecasting tool, but it is not well suited to forecasting technological change. Trend analysis is most helpful when statistics are abundant and models are well developed around solutions that are reasonably well defined.[33]

Trend analysis is rooted in the belief that the future is often much like the past, only more so. This may or may not be true with AMI and is certainly not true for "disruptive" technologies, such as computers. Trend analysis is most helpful when a technology is evolving on a particular path, such as microprocessors. It is relatively easy to predict the parameters to forecast and measure the advance of technology over time and the results in the marketplace.

Trend analysis for AMI as a solution is not practical at the moment, because there are too few large-scale installations. Extrapolating on lessons learned in pilot projects may be helpful nonetheless. Trend analysis is possible for the major components of AMI, metering, data management software, and telecommunications.

[33] Neither of these fit AMI technology or solutions well.

It is important to note that AMI architecture and standards themselves are evolving. The direction of this evolution can be discerned and views formed as to the implications for deployment.[34]

Delphi Models

Delphi models can be any of the following:

- **Panels or committees of experts**
  These are field experts who are often years ahead of day-to-day practice. However, they sometimes have little knowledge of applications. This risks missing a new S-curve.
- **Structured questionnaires/surveys**
  These are means of collecting data and insights on new technology in areas of specific interest to program managers. They can be informal, such as contacting colleagues for the "lay of the land." Or they can be highly structured and targeted surveys designed to collect specific data.
- **Scientific reviews**
  Literature search is helpful for background. Scientific reviews are particularly helpful in developing a conceptual framework and for technological forecasting.[35]
- **Technological forecasting consultants and "think-tanks"**
  Studies and models prepared by interested parties provide insights and guidelines for evaluating and deploying new technologies and solutions.[36]
- **Request for interest (RFI)**
  RFIs are helpful to evaluate the cost, technical merits, and ability to meet schedule of prospective vendors and system integrators.

  The creation of a technology advisory board is highly recommended as a source of information and guidance when launching a serious AMI program. A good example is the technology advisory board set up by Southern California Edison (see the case study in Section 4).

Foresighting[37]

Foresighting is a useful tool for assessing the evolution of AMI technology with respect to innovation and obsolescence. However, it should be used with some caveats and within a set of scenarios that are specifically grounded in the regulatory and economic environment in which utilities are strategizing and making decisions. The definition of *foresighting* in the insert below is helpful to understanding its role in any process to minimize the impact of obsolescence on AMI.

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[34] The most evident lesson from the evolution of the architecture for AMI and its component technologies is summed up in one word: openness – Open Architecture.
[35] With respect to AMI, scientific reviews on the smart grid, standards, nanotechnology, lasers, satellites, and next generation telecommunications are particularly important.
[36] With respect to AMI, the work of EPRI with the IntelliGrid and the DOE with GridWise™ are good examples.
[37] Foresighting is a term used more overseas than in the U.S. However, it has much to offer as a tool for understanding technology obsolescence for AMI technologies and solutions.

Foresighting Definitions

Foresighting is the effort to assess future conditions based on current conditions and trends. Implicit in the term *foresighting* is the notion that the future is uncertain and not directly predictable, so the focus is more on general conditions rather than specific events.

According to one definition, *foresighting* is "a process by which one comes to a fuller understanding of the forces shaping the long-term future which should be taken into account in policy formulation, planning and decision making.… Foresight involves qualitative and quantitative means for monitoring clues and indicators of evolving trends and developments and is best and most useful when directly linked to the analysis of policy implications …".[38]

Foresighting can be used to refer to very different kinds of analyses ranging from short-term, focused analyses of specific sectors to longer-term, broader assessments of social, economic, or technological change. Foresighting can also include more "normative" assessments of how to reach a future state that is considered desirable (for example, what will have to happen to allow a certain future state to occur).

Source: "Background on Foresighting Methods" (Chapter 2), *Foresighting Around the World: A Review of Seven Best-In-Kind Programs,* Marina Skumanich & Michelle Silbernagel, Battelle Seattle Research Center. January 1997.

Thus, it may be seen that foresighting is basically of no use the development of a snapshot to support a one-time strategy for technology selection, let alone deployment. Foresight needs to be the input for generating multiple scenarios. One scenario may be chosen as the leading one, based on the strategy adopted, but all of them need to be kept handy, and a continuous evaluation should take place to reevaluate assumptions. This is seldom done. Scenarios are considered as starting points for decision making, and then they are abandoned and forgotten. Scenarios are often based on technology timelines and market expectations. New technologies can arise and change significantly the assumptions. Any new technology should cause a re-evaluation of the scenarios. Monitoring of technology timelines and market reaction may lead to retuning of scenarios and to a change of strategy. Scenarios may also have certain milestones, go/no go checkpoints. For this reason they need to be monitored and acted upon.

Foresighting needs to be part of the implementation processes. In this way, the benefits of scenario activity can be realized and in turn improve the predictive power of the foresight activity.

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[38] B. R. Martin and J. Irvine, *Research Foresight: Priority Setting in Science.* London: Pinter Publications, 1989.

Foresighting and Technological Disruptions in the Telecommunications Sector

Technological disruptions will happen and most of them are unexpected. Looking at the technology trajectories and at the market, however, it is possible to make some guesses about possible disruptions that may happen in the next fifteen years. With such a long horizon one can anticipate what might happen at a global level, which is where disruptions occur. Several such disruptions with respect to the telecommunications sector have been identified in the FISTERA[39] project, and those are discussed in the context of foresighting. This disruption, based on the assumption of unlimited bandwidth in wireless access, is an example of the type of reasoning that leads to the identification of technological disruptions that are applicable to the telecommunications industry, the communications component of AMI, and AMI solutions overall..

Foresighting of disruptions in the telecommunications sector that influence technological obsolescence are particularly pertinent to AMI. These disruptions are shown in Table 3-1.[40]

Table 3-1
Foresighting of Disruptions in the Telecommunications Sector

Disruption	Technology Enabling Factors	Market Pull Factors	Impact on the Industry
Transformation of Products Into Services	Embedding communications capabilities into any product; competitive advantage derives from profiling, cheaper manufacturing	Products become commodities; loss of differentiation capabilities, increased copycat possibilities	Enterprises become service companies; shortening of product's lifecycle, strong increase of call center; restructuring of the value chain
The Disappearance of The Computer	Diminished processing cost; system on chip; wearable computers; increased connectivity and ubiquitous access	Need to increase volumes; need to increase flexibility; need to provide easier access to functions	Skill to exploit increased processing capabilities in any object; new level of competence required; new actors and competitors in the value chain
Ubiquitous Seamless Connectivity	Increased connection capabilities for any object as result of object capabilities and access points availability; variety of infrastructures; WPAN; software radio	Mature market drifting toward flat rate; demand for transparency; drive to decrease cost; bundling communications into services and goods	Shift from connectivity to service; bundling of services; seamless service hopping; crucial importance of profiling; embedded connectivity demand; increasing opportunity to offer new services

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[39] FISTERA (Foresight on Information Society Technologies in the European Research Area) is a thematic network funded by the European IST (Information Society Technologies) program of DG Information Society (Ref.: IST-2001-37627) to develop cross-national visions of the future of technologies on a per-sector basis. See: http://fistera.jrc.es/

[40] Roberto Saracco, "Technology Evolution in Information and Telecommunications: Challenges and Opportunities Ahead for Developed and Developing Countries," TILAB Telecom Italia, Bucharest Fistera, Workshop in Fall 2004.

Table 3-1 (continued)
Foresighting of Disruptions in the Telecommunications Sector

Disruption	Technology Enabling Factors	Market Pull Factors	Impact on the Industry
Changing Traffic Pattern	Huge amount of local storage; Sensors, tags; digital camera, camcorder; agent communications	Growth of peer to peer as content production is more and more dispersed and shared; flat rate and always-on tariffs	Push towards optical access; always on, ubiquitous wireless access and seamless connectivity across access points
Unlimited Bandwidth	Advances in propagation studies; terminals as network nodes; cognitive radio; software radio; mesh Networks	Need for ubiquitous connectivity; variety of local access operators; great variety in traffic demand	Incumbent mobile operators; new mobile operators; service and product industry; regulatory framework
Disposable Products	Diminishing cost of production "per item"; increased flexibility and customization; long-lasting batteries; on-site production; short-range embedded connectivity	Faster pace of evolution for fashion and design; shift from products to services; function oriented interface	Evolution in the value chain; faster evolution lifecycle; evolution in customer care; recycling as a problem: as part of production and as a service
Autonomous Systems	Increased processing power in objects; increased flexibility in terminals; agent technologies; ad hoc networks; local world mirroring	Sensors and sensors networks; overall increased complexity; heterogeneous systems; fast asynchronous evolution	Network operators dilemma: as network users or as part of their offering; virtual networks providers; service providers; engineering challenges
From Content To Packaging	Diminished cost of content production; consumers' based content production; information as a "by product"; multimedia and multimode; profiling	Abundance of information; need to get rid of information; difficulty in controlling the ownership of content	Reshaping of content industry; shifting towards content bundled into services; rise of the packaging industry; ambiguity in the telecommunications industry biz to be resolved
The Emergence Of Virtual Infrastructures	Ubiquitous, seamless communications infrastructures leveraging on WiFi, UWB, multimode terminals, WPAN; wireless broadband; increased local storage; agents technology; intelligent ambient; mixed virtual reality	Globalization of business; increased circulation of people; leveraging global investment	Telecom operators see a growth of competition with a growing loss of the network ownership advantage; emergence of virtual telecom operators; consumer electronics opportunity; computer industry used as underlying platform

S-Curve as a Prescriptive Tool

Engineers can use data on the deployment and performance of technologies and solutions in their own utility or data in the overall industry to map S-curves. Although mapping the technology's S-curve may be useful for gaining a deeper understanding of its rate of improvement or limits, its use as a prescriptive tool is limited. The true limits of technology may be unknown. The shape of S-curve can be influenced by changes in the market, component technologies, or complementary technologies. Utilities that follow an S-curve model too closely could end up switching technologies too soon or too late. The S-curve is useful for the conceptual understanding of technology innovation and technology obsolescence. It is not a forecasting tool.

The Technology Assessment Method

The three pillars of technology assessment are:

- Use cases, which capture the requirements
- Technology assessment methodology, which maps those requirements to available technology
- Systems engineering, which translates the findings from the first two steps into a design for the entire system

The Technology Assessment Method was used by Southern California Edison (see the case study in Section 4) and Alliant Energy during their AMI projects.

Alliant Energy Example

The Technology Assessment Method was used by Alliant Energy to evaluate communications technologies as part of its AMI planning.[41] It included references and links to specifications and other information. Technologies were measured against criteria defined by the IntelliGrid Architecture, including:

- Level of standardization
- Level of openness
- Level of adoption
- Level of users' group support
- Security
- Manageability
- Scalability
- Use of object modeling
- Use of self-description and metadata

[41] "Methodology Without Madness," A Smart Grid Newsletter, Case Study, February 2007.

- Applicability to the power industry

A matrix was generated from the results from applying these criteria to various telecommunications technologies. The criteria were not weighted for importance, and the resulting ratings were not intended as recommendations. The scores merely represented how well each technology matches up against each criterion.

Scoring Matrix

A generic scoring matrix is shown in Figure 3-2.

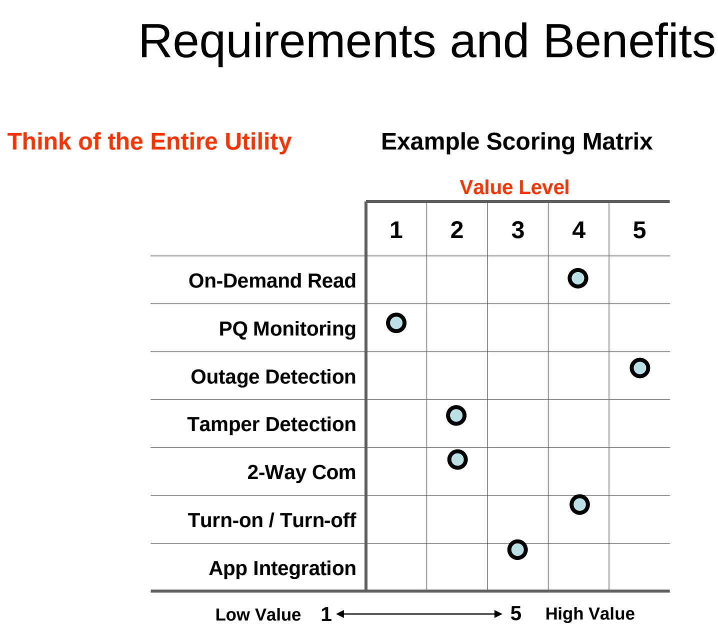

Figure 3-2
A Generic Scoring Matrix

Technology Assessment Methodology – U.S. Department of Defense

Many weapon system failures are attributed to premature transfer of technology to operational systems. Insufficient measures of assessing technology readiness are major contributors to such failures.

The development of new defense technologies within the U.S. Department of Defense (DoD) is a multi-dimensional problem. First, the DoD must resolve issues that result from immature technologies transition. Immature technology transition is the leading cause of weapon system problems. An important factor in the success of a new weapon system is ensuring that technologies are mature prior to being integrated. Second, the creation of parallel paths for the development of technology and the development of an acquisition weapon system has diluted the link between technology and system performance requirements. The technologist has responsibility for managing the development of the technology, while the weapon system acquisitionist has responsibility for the development of the weapon system. Unfortunately, the technologist has different goals, environments, and perspectives than the system acquisitionist. The original reasoning behind this deliberate separation is that it allows the acquisitionist to focus on meeting requirements for the system development, while providing the technologist an environment to explore capabilities of the technology. An unforeseen result of this separation is that two conflicting drives of motivation are generated.

The technologist is motivated to transition technologies into weapon systems. Thus, technologists are optimistic on the maturity assessment of their technology. The acquisitionist is motivated to meet system requirements, and often uses a risk-adverse approach for the design process. Consequently, the acquisitionist is more likely to underestimate the maturity of new technologies. This forces the technologist to focus on risk mitigation. These conflicting motivations justify the need for an objective methodology to assess a technology's fit with system performance requirements. As a technology's maturity increases, the criticality for decision support tools to determine transition readiness is also increased. Hence, a common understanding, between the technologist and the acquisitionist, is needed.

In response to this predicament, the DoD has developed a methodology to measure the performance risk of technology in order to determine its transition readiness. This methodology is referred to as Technology Performance Risk Index (TPRI). The TPRI can track technology readiness through a lifecycle, or it can be used at a specific time to support a particular system milestone decision. The TPRI is computed using the performance requirements, the degree of difficulty, and the unmet performance. These components are combined in a closed loop feedback manner to analytically calculate the performance risk.

The approach to develop a common understanding of technology readiness was to utilize a modified version of Garvey's system performance risk index[42]. The threshold value of a Technical Performance Measure (TPM) divides performance into acceptable and unacceptable risk regions. In this manner, it is the goal of a system developer to reach the acceptable performance risk region. To get into the acceptable performance risk region, the technology must meet or exceed the identified TPM threshold.

Source: "A Performance-based Technology Assessment Methodology to Support DOD Acquisition," Dr. Sherry Mahafza, Dr. Paol Componation, and Dr. Donald Tippett. *Defense Acquisition Review Journal.* January 2005.

Importance of Open Architecture

Open architecture is the standardization, documentation, and publication of system parameters that are critical for third party implementation of selected system functions. Open architecture has often been presented as a solution for all of the incompatibility issues that exist in metering infrastructures. In order to address the potential benefits and drawbacks offered by this approach to incompatibility, definitions for open architecture must be applied to the metering infrastructure, issues examined, and recommendations made concerning the application of open architecture principles to that infrastructure.

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[42] P. R. Garvey and C. Cho, C. "An Index to Measure a System's Performance Risk," *Acquisition Review Quarterly,* 33 (Spring 2003).

Open architecture is operative only when its operating parameters are defined in the public domain. Public domain definitions are the publication of standards describing the operating parameters that will provide sufficient information to allow a third party to interface with the system. Communication protocols, data structures, physical interfaces, and electrical interfaces are examples of operating parameters.

Fully open systems require total standardization and documentation of all system parameters. Standards frequently do not exist for all system parameters. Development of standards is expensive and slows product development, which can serve as a disincentive to developing totally open architecture.

Applicability of Open Architecture to AMI

There are three critical functions in the open architecture that are applicable to AMI:

- Meter reading
- Meter data communication
- Meter data processing

The Smart Grid architectures are designed as open architecture for AMI. Standards need to be developed for each of the functions of AMI regardless of the open architecture that is followed.

Standardization of the functionality of the elements is required to ensure overall system performance. The standardization of interfaces to each element is required in order to ensure compatibility and communication with other elements. Complete standardization eliminates system redundancy and simplifies the design of interfaces between system elements. This is especially important when there are many alternative technologies with similar functionality that have to be brought together in a common functional framework.

A segregated system that does not incorporate fully open architecture may have redundancy of function and unnecessarily complex interfaces between elements. The full benefit of open architecture can be gained only when system parameters are available and all implementations of the same system functions use the same sets of standards. In metering systems, multiple standards exist for both communications and metering functions. If every function and system interface utilizes the same standards, then full benefit of an open architecture will be achieved.

Smart Grid Programs

There are a number of programs the share the goal of transforming the electric power delivery system into an intelligent grid. These all contribute towards the development and acceptance of an open architecture for the Smart Grid and thereby AMI. There are substantial commonalities and differences between the programs. However, all relate to AMI. These programs were profiled and mapped by EPRI;[43] a summary description of these programs is found in the next section.

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[43] *Profiling and Mapping of Intelligent Grid R&D Programs,* EPRI, Palo Alto, CA: 2006. 1014600.

Smart Grid Programs

IntelliGrid Consortium
Founded by EPRI in 2001, IntelliGrid seeks to create a new electric power delivery infrastructure that integrates advances in communications, computing, and electronics to meet the energy needs of the future. Its mission is to enable the development, integration, and application of technologies to facilitate the transformation of the electric infrastructure to cost-effectively provide secure, high-quality, reliable electricity products and services

The Modern Grid Initiative
Established by the U.S. Department of Energy in 2005 through the Office of Electricity Delivery and Energy Reliability and the National Energy Technology Laboratory, this program focuses on the modern grid as a new model of electricity delivery that will bring a new era of energy prosperity. It sees the modern grid not as a patchwork of efforts to bring power to the consumer but as a total system that utilizes the most innovative technologies in the most useful manner.

GridWise™
Funded by the Distribution Area Program of the DoE Office of Electricity Delivery and Energy Reliability, this organization includes the GridWise Alliance, a group of power industry representatives who support the vision of the intelligent grid, and the GridWise Architecture Council, an association of experts who seek to articulate guiding principles for an information architecture.

Advanced Grid Applications Consortium (GridApp™)
Formed by Concurrent Technologies Corporation in 2005 and sponsored by DOE, GridApp™ applies best utility technologies and practices to modernize electric transmission and distribution operations.

Consortium for Electric Reliability Technology Solutions (CERTS)
Created in 1999 and funded by DoE and the California Energy Commission, CERTS researches, develops, and disseminates new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system and the functioning of a competitive electricity market.

European Union 5th and 6th Framework Programs
Sustainable Energy Systems and Electricity Networks of the Future —The European Commission funds R&D activities on sustainable energy systems through its Framework Programs. In 2006, the Commission launched the SmartGrids Technology Platform to: 1) increase the efficiency, safety, and reliability of the European electricity transmission and distribution system by transforming the current electricity grids into an interactive service network and 2) remove obstacles to the large-scale deployment and effective integration of distributed and renewable energy sources.

Galvin Electricity Initiative
Founded in 2005 by the former CEO of Motorola, this program applies the concepts of total quality management to the electric power industry, with the goal of developing one or more configurations of a "perfect" power delivery system to meet the needs of the rapidly evolving digital economy and society.

Source: Profiling and Mapping of Intelligent Grid R&D Programs, EPRI 1014600, Final Report, December 2006.

Importance of Standards

Standards are established when a critical mass of consumers has adopted them, or when a critical mass of key players believes that the standard will be adopted. Standards for technical performance of meters are required to ensure accuracy and reliability of meter data, as well as the safety of personnel and customers. Standards are central to the implementation of new technology and avoiding technological obsolescence, especially where technologies need to be integrated and interoperable, such as AMI.

Standards impact technology obsolescence through:

- Expanded network externalities
- Reduced uncertainty and risk in technology decisions
- Reduced customer lock-in to particular components
- Innovation in the market vs. innovation for the market
- Innovation on value vs. features
- Component vs. systems innovation

Standards shift the locus of competition from systems development to component development. Specialists tend to thrive in the mix-and-match environment created by interface standards. Generalists and system developers tend to thrive in the absence of standards. In the absence of standards, a) there is no architectural innovation (no mix-and-match) and b) the organization can not benefit from component innovation.

Once a standard has been agreed on (selected), the utility benefits from component innovation and architectural innovation. The longer the industry takes to determine a standard, the more costly it will be for utilities making investments in the technologies. At the outset of deploying a new technology, it is difficult for individual utilities to determine cost trends or how long it will take the industry to determine the dominant standard.

There are two main standards groups for AMI technologies: ANSI and the IEEE. ANSI has developed standards for meters; the IEEE has developed standards for AMR and communications.

ANSI Standards

Meters should meet the following ANSI standards that apply to the specific type of meter, generally adhering to the ANSI C12 family of standards:

- ANSI C12.1 Code for Electricity Metering
- ANSI C12.6 Marking and Arrangement of Terminals for Phase-Shifting Devices Used in Metering
- ANSI C12.7 Requirements For Watt-hour Meter Sockets
- ANSI C12.10 Electromechanical Watt-hour Meters
- ANSI C12.11 Instrument Transformers for Revenue Metering, 10 kV BIL through 350 kV BIL (0.6 kV NSV through 69 kV NSV)
- ANSI C.12.13 Electronic Time-of-Use Registers for Electricity Meters
- ANSI C12.20 0.2% and 0.5% Accuracy Classes

Where existing certified meters are used, they may be retrofitted with devices for communications purposes. Any such retrofits should adhere to all appropriate published standards.

ANSI is expected to publish a new standard (C.12-22.20XX) that provides an application layer standard for network communications, designed to transport C.12.19 standard data tables in electric metering over any physical medium.

IEEE Standards – AMR

The IEEE established a standard for AMR that is applicable by reference to AMI. The purpose of the IEEE standards process was mainly to establish the communications links between meters and billing systems for AMR. The standards were predicated on the fact that devices were not standardized; services and interfaces were standardized; and that new technologies were connected to old interfaces.

The result of the IEEE standards process for AMR was IEEE 1397. It is the national standard reference model. It is the beginning of an open standards process for AMR and AMI, and is the start for developing interface standards.[44]

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[44] "The IEEE Reference Model Gives California Better Standards," A Presentation to the Permanent Standards Working Group, Bill Rush, Chairman, IEEE SCC31. June 11, 1998

IEEE Standards – Communications

There has been considerable discussion regarding the applicability of the newer IEEE wireless specification and their technologies for AMR systems. IEEE specification 802.11, better known as "WiFi," has limited capability for AMR because of its limited range. However, IEEE specification 802.15.4 or ZigBee could have more potential for AMR systems. ZigBee's operational range is slightly better than Wi-Fi so that it might work effectively in densely populated areas. It is much more likely that these technologies will be utilized in future demand response and home automation applications as AMR and demand response systems unite and evolve. Open standards in general (and the Zigbee wireless standard in particular) will disrupt business as usual.[45]

Integrated Energy and Communications System Architecture

Integrated Energy and Communications System Architecture (IECSA) is an open, standards-based systems architecture for the data communications networks and intelligent equipment necessary to support the power delivery infrastructure of the future.

IECSA is being designed as a complete set of systems requirements and documentation to support industry-wide enterprise architecture for a self-healing grid and integrated consumer communications interface. It contributes to relevant standards development organizations and industry consortia to effectively move the development of key open standards forward. Among the contributions are the elicitation and management of system requirements, analysis of requirements and development of proposed architectural designs, evaluation of architectural designs, and the use of standardized industry notation for documentation of architectural views.

IECSA is a valuable resource for identifying the potential for infrastructure sharing and synergy between power engineering operations and other application domains.

Soft Standards

A "soft" standard is a specification that is completely compatible with current public standards but offers *enhanced functionality and performance*. It offers customers the security of knowing that they have avoided being "locked in" and an upgrade path to the public standard. Plus, it offers the functionality and performance of a more finely "tuned" technology.

A "soft" standard must be better than the public standard, compatible with the current version, and compatible with future versions. Ensuring that the "soft" technology is embodied in future generations of the technology may be a central strategic goal. In looking at AMI solutions it is prudent to look for soft standards.

[45] "Disruption" understood in the context of technological obsolescence theory.

OpenAMI[46]

OpenAMI has taken on the task of developing AMI standards and promoting rapid adoption of AMI technologies. Through development of various design principles and use cases, the OpenAMI Task Force has tried to develop standards to accelerate AMI implementation. Implementing such standards is necessary to reduce smart metering equipment costs and accelerate AMI implementation.

Working with the California Energy Commission, California Public Utility Commission, and various standards groups, OpenAMI has taken on the challenge of reconciling a divergence of views involving the technical sophistication of AMI systems, required vs. optional features, communications options, and other issues potentially having a significant impact on the costs and benefits of AMI implementation.

Standards Uniformity

Needless to say, there is a decided lack of uniform standards. This state of affairs for standards for the smart grid are shown dramatically in Figure 3-4. There are six to nine standards for communications, monitoring, and software interfaces—each. Together this means that there are up to 729 potential choices of Smart Grid basic design.[47] The standards situation for AMI is similar in magnitude, indeed inextricably intertwined with the predicament facing the Smart Grid.

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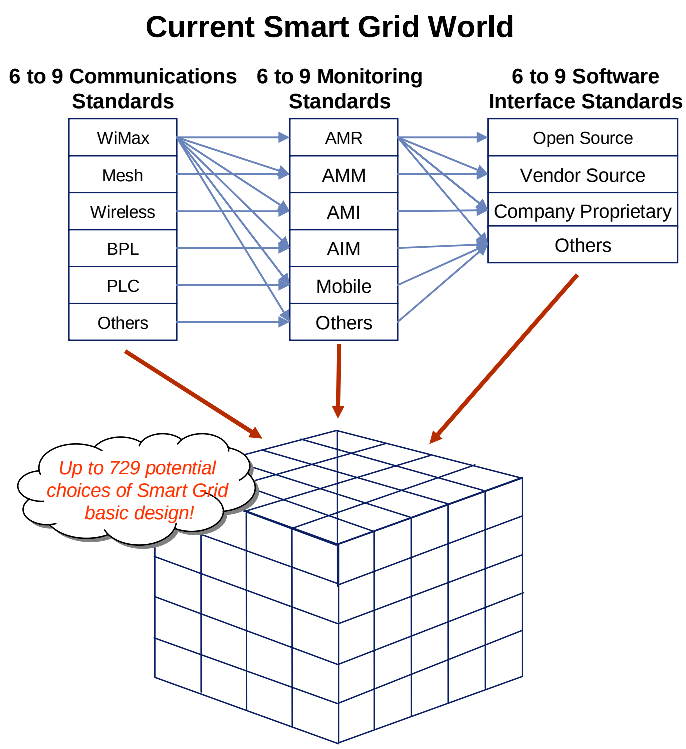
[46] Open AMI Collaboration web site: http://sharepoint.ucausersgroup.org/OpenAMI/default.aspx.
[47] BAH



Source: *Smart Grid – Opportunity Meets Necessity*, EEI Strategic Issues Forum, Booz, Allen, Hamilton, Miami, FL. February 7, 2007

Figure 3-3
Lack of Uniform Standards

Risk Assessment and Criteria

Technological alternatives should be evaluated for risks. These risks fall into five main categories, only one of which is technological risk. However, it must be kept in mind that technological risk, the risk of obsolescence in particular, impacts the full spectrum of risks.

Business Risks

- Appropriateness for all customer classes (commercial, industrial, and residential)
- End-user acceptance of intrusive technology (i.e. shared phone lines vs. dedicated phone lines)
- Accommodates innovation and introduction of new technologies
- Network operational stability
- Accommodates increasing demands in the quantity and quality of data

Financial Risks

- Customers or capital investors to provide network infrastructure investment (certain network costs are passed down to customers in rate base)
- Financial stability of network carrier
- Total costs of ownership
  - Initial investment costs (hardware and software costs)
  - Network deployment costs
  - Meter installation costs
  - Recurring operational and maintenance costs
  - Economic parameters
  - Risk increases as payback or lease period increases
  - Dedicated or shared network investments
  - Buy network vs. lease network services

Technological Risks

- Limits of single or multiple technologies
- Network data capacity
- Potential for technology obsolescence
- Limits of single or multiple technologies

Performance Risks

- Ability to obtain consistently accurate data

Regulatory Risks

It is important to get a clear statement of public policy with respect to demand management, conservation, and, most importantly, cost recovery.

Vendor Bottlenecks

There are a number of different factors that might impact the costs and benefits of AMI. One of the risks considered is due ironically to significant growth in AMI from sales to other large utilities in North America. AMI providers may have difficulty meeting the production volume for DTE Energy while maintaining product quality due to other large utilities possibly ordering the same products (AMI endpoints and network infrastructure equipment) within the same time frame as DTE. DTE has seen some evidence of this already in the feedback received from its six AMI vendors responding to the RFP for AMI. Expectations for this year are:

- SCE is expected to select an AMI supplier for 5 million endpoints, SDG&E for 2.1 million, Ontario utilities for additional 3 million, Consumers Energy for 3.4 million, and DTE for its 4 million.

- Announcements for large (over 100,000) AMI deployments for electric, gas, and water endpoints have increased by over 200 percent in 2006 over 2005 levels. In 2007, it is likely we will see another increase of 25 percent over 2006 levels. As these announcements result in actual production activity in coming years, AMI providers will enjoy record sales and will need to increase production levels over and above anything seen before.

Source: DTE Energy: "MDM Must Come Before AMI," Patti Harper-Slaboszewicz, Utilipoint Daily IssueAlert. February 21, 2007.

Serviceability and Interoperability

Serviceability is the ability to remotely upgrade, change, or reconfigure the firmware, software, or other programming that resides in the meter or communications network. This is an important maintenance consideration because the cost of any physical upgrade that would be required to change the embedded software will likely cost as much as the original installation.

Interoperability is important for many utilities, particularly those that face the prospect of having a single technology solution built upon proprietary scheme for deployment over millions of meters. This presents very large procurement and operating risks. However, there is an opportunity to include communication interfaces with smart demand technologies like communicating thermostats. There are existing technology models/standards in other industries, telecommunications and computing systems that can be readily applied to resolve these interoperability issues.

Mitigation – Minimizing Risk and the Impact of Technology Obsolescence

If a product requires a long application life, then an open architecture that includes an obsolescence management strategy may be required. Many obsolescence mitigation approaches have been proposed and are being used. These approaches include lifetime or last time buys (buying and storing enough parts to meet the system's forecasted lifetime requirements or requirements until a redesign is possible), part substitution (using a different part with identical or similar form fit and function), and redesign (upgrading the system to make use of newer parts).[48] Several other mitigation approaches are also practical in some situations: aftermarket sources (third parties that continue to provide the part after its manufacturer has discontinued it), emulation (using parts with identical form fit and function that are fabricated using newer technologies), and reclaim (using parts salvaged from other products).

The prediction of obsolescence enables engineers to more effectively manage the introduction and on-going use of long field-life products based on the projected lifecycle of the parts. The obsolescence prediction methodology is a critical element within risk-informed parts selection and management processes.[49]

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[48] R. C. Stogdill, "Dealing with Obsolete Parts," *IEEE Design & Test of Computers*, vol. 16, no. 2, pp. 17- 25, April-June 1999.

[49] M. Jackson, P. Sandborn, M. Pecht, C. Hemens-Davis, and P. Audette, "A Risk-Informed Methodology for Parts Selection and Management," *Quality and Reliability Engineering International*, vol. 15, pp. 261-271, 1999.

Continuous Technology Refreshment and Obsolescence

Program engineers at utilities and regulatory agencies and vendors must continuously review AMI system architecture and establish a rigorous change management process for life-cycle support. Systems that integrate multiple commercial items can require extensive engineering to facilitate the insertion of planned new commercial technology. This is not a "one time" activity at the beginning of the technology selection process; it is an on-going necessity. Unanticipated changes may drive reconsideration of engineering decisions throughout the life of the program.

Successful parts management addresses diminishing manufacturing sources and material shortages in the proposal, design, and maintenance phases of a product—that is, throughout the product's lifecycle. Performance-based logistics support arrangements can be used to manage technology refreshment. A "product support integration" team can provide continuous engineering support for the AMI system. This team should have responsibility for performance outcomes and be incentivized to maintain currency with state-of- the-art technology, maximize the use of commercial off-the-shelf items, and generally use readily available items to avoid the high cost of diminishing manufacturing sources and material shortages/obsolescence over the life of the system.

An effective approach to such a pervasive problem hinges on the program manager being proactive. This approach provides the program manager with an opportunity to resolve obsolescence problems before they have an adverse impact on the total ownership cost, reliability, and availability of spare parts and maintenance services.

Forecasting Electronic Part Obsolescence

Research into forecasting electronic part obsolescence largely focuses on the development of an electronic part lifecycle methodology for predicting part obsolescence dates.[50] Part obsolescence dates (the date on which the part is no longer procurable from its original source) are important inputs during design planning. Studies indicate that most electronic parts pass through several lifecycle stages corresponding to changes in part sales: introduction, growth, maturity (saturation), decline, and phase-out. Most electronic part obsolescence forecasting is based on the development of models for the part's lifecycle. Traditional methods of lifecycle forecasting utilized in commercially available tools and services are based "scorecard" or ordinal scale based approaches, in which the lifecycle stage of the part is determined from an array of technological attributes. More general models based on technology trends have also appeared, including a methodology based on forecasting part sales curves and leading-indicator approaches.

Design Refresh Planning

A methodology should be developed for determining the part obsolescence impact on lifecycle sustainment costs for the long field life electronic systems based on future production projections, maintenance requirements, and part obsolescence forecasts. The methodology determines the optimal design refresh plan during the field-support-life of the product. The design refresh plan consists of the number of design refresh activities, their respective calendar dates, and content to minimize the lifecycle sustainment cost of the product. The methodology

[50] R. Solomon, P. Sandborn, and M. Pecht, "Electronic Part Life Cycle Concepts and Obsolescence Forecasting," *IEEE Trans. on Components and Packaging Technologies,* December 2000, pp. 707-713.

supports user determined short- and long-term obsolescence mitigation approaches on a per-part basis and variable look-ahead times associated with design refreshes.

Design refresh planning is one of the only proactive design/cost tools in the technology obsolescence area. It provides planning knowledge that can be used for business case development, return on investment (ROI) analysis, risk analysis, and future budget planning.

Electronic Part Life Cycle Concepts and Obsolescence Forecasting

Obsolescence of electronic parts is a major contributor to the lifecycle cost of long-field life systems such as AMR and AMI. A methodology to forecast lifecycles of electronic parts is necessary, in which both years to obsolescence and lifecycle stages are predicted.[51] The methodology embeds both market and technology factors based on the dynamic assessment of sales data. The predictions enable engineers to effectively manage the introduction and on-going use of long field-life products based on the projected lifecycle of the parts incorporated into the products. Application of the methodology to integrated circuits is paramount.

Vendor Obsolescence

Mergers and acquisitions of companies assume greater importance in the products and services offered in the metering industry. The history of meters shows this. The refrain today is the same. Companies with mature technology become subject to increased competition by those who have lower production costs, lower labor rates, or lower overheads. Mature technology is continuously threatened by substitution of newer technology. Utility engineers should watch for these changes while selecting technology and continuously maintain a system development mode. Vendors are alert to emerging or competing technologies, and a company that leads with product innovation, establishes the industry standards, and follows through with incremental and process innovation can sustain success.

It is also important to take a proactive approach to developing or dealing with technological disturbances. Migrating to an emerging technology in a timely manner keeps the level of service high and meets changing requirements.

Vendor Obsolescence

"In fact, obsolescence over the past 30 years is not really about technology obsolescence as much as it is vendor obsolescence. Take notice of the new technology claims many vendors make to see what actually often occurs—vendors' own obsolescence of their previous technology. One of the clearest indications is when someone claims the new technology is the 'new replacement for ______' (fill in the blank with the measurement and automation platform of your choice).

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[51] R. Solomon, P. A. Sandborn, and M. G. Pecht, "Electronic Part Lifecycle Concepts and Obsolescence Forecasting," *Components and Packaging Technologies, IEEE Transactions.* Volume 23, Issue 4, Dec 2000, Page(s): 707 – 717.

"We are not implying that there are not obsolete products. All companies face issues with end-of-life parts, among other things, which affect a particular product's lifespan. Nonetheless, it is important to look at a vendor's track record of continuity, scalability, and support for platforms. In fact, where possible, it is preferable to be platform agnostic, meaning do not "bet it all" on one platform as the answer for all requirements, while still meeting the current application needs."

Source: Technology Obsolescence – A 30-Year View, John Graff, VP Marketing, National Instrument.

Guidance to Minimize the Impact of Obsolescence on AMI

This section offers guidance to minimize the impact of obsolescence on AMI in the following areas:

- Open-source architecture
- Platform-independent component architecture
- Warranties
- Component replacement strategy
- Clear understanding of functionality and benefits
- Financial considerations
- Regulatory

Open-Source, Standards-Based Architecture

As noted throughout this discussion, open-source architecture and standards are major defenses against technology obsolescence. Utilities considering AMI deployment would be well advised to pay close attention to IntelliGrid, GridWise™, and OpenAMI.

Platform-Independent Component Architecture

The SmartGrid architectures have layered networks and take advantage of the constantly evolving communications landscape. Another characteristic advantage of layering is technology interoperability and platform for enhancements. With respect to software, it is important to ensure that it is upgradeable and has the capability for remote reconfiguration and reprogramming.

Warranties

Warranties from vendors over the lifetime of the components are important in order to ensure the expected functionality and serviceability of components over the lifetime of the AMI system deployment. Further protection may be obtained from having multiple vendors for a component.

Component Replacement Strategy

As components and vendors discontinue products over time (and AMI is a long-term investment), it is important for the utility to have a replacement strategy. This includes a "last-time" buy provision, redesign (preferably as part of a technology innovation program), and a contingency plan for substitute components.

Clear Understanding of Functions and Benefits

The functions and benefits are ultimately subject to regulatory approval. This is what impacts cost recovery and return on investment. It also determines whether the utility will get a return on its investment before the technology might become obsolete. Regulatory certainty and prudence is an unavoidable determinant in this area.

It is important to keep in mind that regulatory objectives related to AMI development and deployment, such as demand management and conservation. The utility must get agreement from regulators on the defined functionality over a limited timeframe, such as data retention, real-time, and two-way communications. This protects the investment and ensures that technology obsolescence will not become a reality until the investment has generated the expected return.

Financial Considerations

It is paramount to understand the financial considerations over and above any business case specific to AMR/AMI. This is necessary for the long-term financial health and survivability of the company. These include:

- Cost of investment
- Incremental network costs
- Cost recovery
- Return on investment
- Competing infrastructure investment needs
- Utility finances

Financial Incentives

Current tax law treats much smart metering equipment as long-lived assets requiring depreciation over 20- years. A preferable approach would be to classify smart grid technology as "qualified technological property," which has a five-year depreciation life. This would allow for cost recovery on obsolete meters prematurely retired from service when smart meters are installed.

The Cantwell bill also incentivizes utilities to install smart grid technologies by allowing enhanced returns, as much as 30% over the normal (regulated) return on capital. The Cantwell bill provides for 20% of the cost of smart grid components to be taken as federal income tax credits.

Source: Overview of the "Reducing Demand through Electricity Grid Intelligence" Act, Sen. Maria Cantwell. April 25, 2007.

Cost Recovery

Observations on Cost Recovery, Return on Investment, and Obsolete Equipment

Cost Recovery – Utilities should have the certainty of knowing that they can include in their rates the actual costs of investing in AMI systems.

Enhanced Return – Utilities should be permitted to earn an enhanced return on their investment in AMI, including a return on a portion of their operating and maintenance expenses, to induce utilities to spend on AMI investments.

Retained Savings – As an alternative to an actual return on operating and maintenance expenses, utilities should be permitted to retain a meaningful portion of the savings resulting from such expenses to the extent they result in efficiencies that otherwise would be passed on to end users (thereby producing a return on the utility's expenditure).

Obsolete Equipment – A utility should be able to recover the costs of equipment rendered obsolete by its deployment of an AMI system, based on the remaining depreciable life of the obsolete equipment.

Rate Recovery

Utilities planning or developing AMI System/SmartGrid initiatives are generally seeking to recover the difference between total AMI infrastructure cost and the operational savings it generates. Utilities are typically pursuing two regulatory strategies with regard to rate recovery: (1) build AMI cost into rates in incremental increases over the deployment lifespan or (2) add a special surcharge to cover utility costs.

Most utilities are inherently risk averse and pursue only large capital investments likely to receive cost recovery approval from regulators. In some states, it is necessary for the meter to have certain functionality to qualify for cost recovery through a surcharge mechanism.

Protection of Existing Investment

With fast-changing technologies, it is important to consider not only savings in time and money but also the protection of existing investment and the avoidance of stranded costs. Another major consideration in protecting existing investment is in the telecommunications infrastructure, where cross-platform (AMI + communications) issues come into play. Interoperability and standard interfaces are critical. Network capacity sufficient to support enhanced and additional applications are other important considerations in order to avoid obsolescence.

Depreciation

Company-specific depreciation studies are necessary in order to fully recognize the functional obsolescence of AMI systems and avoid "stranded costs." Public utility commissions recognize that the capital costs for AMI systems are subject to obsolescence and have adjusted the life over which the capital costs are depreciated. However, in many cases these adjusted rates are not sufficient to prevent "stranded costs" because asset replacements are necessary with the advance of technology, especially microprocessors and telecommunications infrastructure.

Typically, depreciation for capital costs for meters and data transmission systems is based on a twenty-year life, unless the commission approves a different life based on a company-specific depreciation study; Typically, depreciation for capital costs for data management infrastructure and software is based on a seven-year life, unless the commission approves a different life parameter supported by company-specific depreciation study;

Depreciation and Deployment

AMI systems are deployed over extended periods of time. Most often, it takes five years from the acceptance of the technology solution to fully deploy within the utility's foot print. Technology is changing throughout this time period, and the process of technological obsolescence is underway. Time is moving forward. By the time the technological solution that was originally selected is fully deployed, the technology is already five years or more on its way to obsolescence. For this reason, the depreciation life for the capital costs should be adjusted to the date at which the technology was proven and selected. A suggested adjustment is shown in the example below.

Comment on Depreciation Rates

Traditionally, meters were depreciated over 30 years. In recognition of the shorter lifetimes of electronic devices in harsh environments and the implications for functional obsolescence, regulatory authorities are recently open to considering 15 to 20 years for AMI.

Communications equipment has an even shorter life, closer to seven years. This should be the maximum number of years for depreciation purposes for telecommunication equipment installed specifically for AMI.

Information technology products, especially data management software, is constantly upgraded. The depreciation period should be no longer than three years; preferably it should be written off.

In order to encourage investment in AMI, "stranded" assets should be accounted for in the most advantageous manner.

Accounting for utilities is an arcane world. It is beyond the purview of this discussion to comment on the specifics of the depreciation policies and account practices. Suffice it to say, whatever the methods are applied, they must take technology obsolescence into serious account. In many ways, the accounting method is the deciding factor in the decisions with respect to AMI.

Regulatory Authorities

Regulatory certainty and support is a deciding factor in most deliberations within the AMI decision-making process. The regulatory environment can both foster and hinder technology choices. It can encourage the timely deployment of solutions with technology solutions that fit the current and future needs; or it can prematurely mandate (or approve) the deployment of systems that are destined for technological obsolescence.

Technology obsolescence is recognized by regulators, but it is of secondary importance when considering technologies that can deliver the functionality for demand management in today's environment. While encouraging utilities to facilitate deployment of AMI technologies, regulatory authorities[52] are cognizant that regulatory options must be allowed to recognize technology obsolescence as impacts capital costs, namely to:

- Provide for timely cost recovery of prudently incurred AMI expenditures, including accelerated recovery of investment in existing metering infrastructure, in order to provide cash flow to help finance new AMI deployment.
- Provide depreciation lives for AMI that take into account the speed and nature of change in metering technology.

Regulatory authorities further recognize that:

- The Federal tax code with regard to depreciable lives for AMI investments should be amended to reflect the speed and nature of change in metering technology.
- Open architecture and interoperability of AMI will help enable cost-effective investments, avoid obsolescence, and increase innovations in technology products.

Experiences with AMR /AMI

Year	Vendor/Party	Technology	Scope	Notes / Key Lessons Learned
Pre-2000	• Hexagram	• Pulse encoders – read by handhelds	• 600,000 inside gas meters currently in service	• Still in use • Some maintenance issues with batteries and access
	• Itron	• RF handheld radio technology	• 130,000 point solutions for company/ access issues	• In use today with very limited manpower
	• Echelon, Comcast, HP	• Custom 2 way technology	• 160 point solutions • Appliance Control • TOU Special Rates	• High Cost, Technology ahead of its time • Complex for customer
2001	• Hexagram	• STAR fixed network licensed 450 MHz	• 50 homes Hamtramck – electric gas & water – 2 data collectors • 1,000 gas meters, rural deployment – 8 data collectors • Hourly data downloads	• Deactivated – Never expanded due to cost • Retrofit electromechanical meters is expensive • Collectors on pole expensive to maintain (requires line crews/bucket trucks)
2002	• Itron	• Fixed network licensed 960 MHz & 1 GHz	• Pilot for 1127 residential electromechanical meters retrofitted with ERT-45 modules • 43 cell control units • 1 network control node • 3 servers • 15 minute interval data	• Software update issues created problems • Collectors on poles – some outages

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[52] Source: Committee on Energy Resources and Environment, NARUC. February 2007.

Year	Vendor/Party	Technology	Scope	Notes / Key Lessons Learned
2001	• DTE Load Research	• Wireless analog	• 1,800 units retrofitted • Residential (single phase) and commercial interval meters for load research and hard-to-read meters	• Still in use • DTE owned technology, non-commercial • High maintenance and infrastructure costs
2001	• MUNET	• Cable/DSL broadband	• 12 locations (DTE volunteers)	• Multiple upgrades required at meter – hard on customers • Power supply issues force need to pull meters often
2001-2005	• Innovatec • Nertec • Smart Synch • Elster REX • Transdata • Comverge • Telenetics • Metrum	• Various technologies	• Small lab tests ranging from 1 to 20 meters for multiple technologies and vendors – primarily done in conjunction with MV-90 and choice meters, but technologies can be used in larger AMR deployments	• Lab testing only • Learning about technologies, but no technology accepted for larger pilot • General improvements over time especially in deployment (vs. technology)

Source: Automated Meter Reading Overview, 21st Century Energy Plan Discussion Forum, June 29, 2006

Timing of Deployment – Fear of Obsolescence

The decision to deploy should not be unnecessarily delayed due to fear of obsolescence. This can result in either a failure to realize the full benefits of a solution that meets a real need of the utility. Further, waiting for a technology to be mature and proven as evidenced by wide-scale deployment increases the risk of obsolescence and stranded assets and over investment. There is risk of obsolescence in the metering and communications side of the equation. But communications is by far the greatest. The message here is to avoid fear of obsolescence inertia and proceed with deployment on an accelerated basis when the technology solution that meets the utilities requirements is proven and ready. However, the utility should be forecasting technology as part of the decision process in determining the solution. Unnecessary delay can lead to technological obsolescence and possibly stranded investments and leave the utility with a large opportunity cost for benefits foregone.

Some technologies could be obsolete before they are installed if they do not meet the needs of the utility and its customers over the expected lifetime—at least five years. However, when technologies and solutions are identified and proven that meet those needs, they should be deployed as soon as practicable. In this way, the maximum benefits over time will be realized, and the cost of technological obsolescence minimized, especially when a "disruptive"' technology may intervene following long installation periods. Circumspection in deployment is more acceptable when it is driven by "future proofing" the proposed solution and adoption to an architecture and enterprise communication infrastructure.

Business Case

"Despite the confusion, I do not advocate waiting. Advanced metering is too important and too empowering."

"There is no shortage of AMI solutions."

Source: The Dangers of Advanced Metering, Jesse Berst, Grid Automation. Feb 12, 2006.

AMI should be approached in the context of its contribution to an electric utility as a business. The business case for AMI and AMR depends on much more than technology alone. In order to have a global view, one must look to the regulatory environment and the business side of the utility. The utility is the owner and decision maker whose primary concerns are service and financial strength.

Corporate and business goals are driving the strategy for future distribution automation investment, not the latest technology or IT and communications infrastructure per se, or regulatory mandates for that matter. Different generations of IT systems over the past 20 years are merging to create "intelligent grids" and "intelligent enterprises." Convergence of IT/hardware for real-time asset management and operations allows business processes to be integrated with real-time applications to deliver benefits across the enterprise. It is only logical that AMI would be the logical extension of these developments.

AMI bridges the gap between real-time operations and business enterprise systems. The business functions that are impacted by AMI are as follows:

- Outage and restoration
- Safety
- Demand response/ load management
- Forecasting
- Customer services and billing
- System planning and engineering
- Collection and revenue protection

The utility as a business must be constantly aware of the operational efficiencies and savings that can be realized from AMI technologies and solutions. This is necessary not only to receive the highest return on investment but also to avoid technology obsolescence that might arise from deploying systems that are not open to enhancements that will contribute positively to the utility as an enterprise or business.

New Services and Revenues

As noted earlier the current motivation for pursuing AMI is rooted in demand management. However, once the telecommunications links are established, the utility has several opportunities to offer new services.

Additional services that utilities may offer in the future through AMI systems include:

- Home safety (flooding and medical alarms)
- Home security (forced entry alarms)
- Fire detection
- Appliance energy management
- Entertainment
- Telco, Internet

These additional services may require additional infrastructure that to some extent may render the existing infrastructure obsolete, most likely with respect to the communications gateway and backbone.

While traditional AMI functions such as load control continue to be viewed as largely utility-centric features, other benefits such as energy management and appliance monitoring could be supported that would provide real added value for the customer if implemented and priced properly. Utilities must do a better job of articulating the energy saving benefits to be gained through the introduction of AMI alternatives that use energy management gateways, home energy management systems, and in-home displays. "Attractive" time-of-use rates should be implemented that adequately reflect the real value customers place on modifying living habits and cutting back on energy usage. After all, improving energy efficiency and reducing energy waste are objectives that are as important to effective energy planning as shifting the time when that energy is used.

In many cases, technological obsolescence will derive more from failing to realize the potential for building on initial AMI installations to realize the cost savings from operational efficiencies and new revenues from enhanced customer services. Therefore, it is essential that the initial AMI solution be designed according to an open architecture and with continuous technological development a part of program management.

Technological Life

Finally, there is a "technological" life. That is the period where we consider the AMI system to be fairly modern and possessing most but not necessarily all features and efficiencies of newer systems. PG&E's AMI system could still be used and useful but quickly become technologically obsolete.

Before the introduction of the personal computer, it would have been hard to seriously project the impact and the rate of change that we have seen in that tool on our personal and business lives. We lack the same vision of how metering, and communications technology may change over the useful life of the AMI system.

PG&E’s current metering system with manual meter reading is functional; it also is used and useful, but it is technologically obsolete—once we accept that the proposed AMI technology works. But technological obsolescence alone is not sufficient to warrant replacing the system. That is why we apply an economic test: whether or not the present value of all benefits is greater than the present value of the revenue requirement paid by customers for new system for the useful life of the system. Although PG&E expects the system to remain in service for 20 years, only time will tell whether there will be significant unforeseen developments—good or bad—that may lead to an earlier or later replacement of the AMI system.

Source: D0607027 Authorized PG&E to Deploy Advanced Metering Infrastructure, California CPUC Monday, June 25, 2007

Importance of “Future-Proofing” Technology/Investment

“Metering for utilities will change more in the next three years than in the past twenty. In this environment, “future-proofing” is essential to success.”

Source: The Dangers of Advanced Metering, Jesse Berst, Grid Automation. Feb 12, 2006.

Future-Proofing

Utilities must make every effort to “future-proof” their investments in AMI. The first step is to be aware of current solutions on the market that are not “future-proof.” Indications of not being “future-proof” are:

Future-proofing is necessary to remain open to new advances – new applications, new communications, enhancements – as they become available.

Future-proofing is also necessary to avoid stranded costs in the future due to technology obsolescence

Source: The Dangers of Advanced Metering, Jesse Berst, Grid Automation. Feb 12, 2006.

Importance of Innovation Management

The role of individuals within the firm who can be "champions" of AMI throughout the technology selection process and beyond deployment is critical to minimizing the impact of technology obsolescence. Among the roles that need to be fulfilled are:[53]

- Idea generators: finders of "ideas"
- Gatekeepers and boundary spanners: communication facilitator between inside organization and outside
- Champions: entrepreneurs, do what they can to ensure success of the innovation, visionaries with communication skills
- Sponsors: coach or mentor, often a senior-level manager that provides "behind-the-scenes support"
- Project managers: planners, coordinators, "rationalizers"

Just as successful innovation requires the commitment of inventors and entrepreneurs, successful deployments of AMI depend on certain "roles to be played throughout the process, indeed throughout the lifetime of the technology.

In order to minimize the impact of technological obsolescence, AMI programs must continue to evolve with technology and leverage existing technology with "disruptive" technology that realizes the vision of the Smart Grid.

[53] W. J. Abernathy and K. B. Clark, "Innovation: Mapping the Winds of Creative Destruction," *Research Policy,* Vol. 14, 1985.

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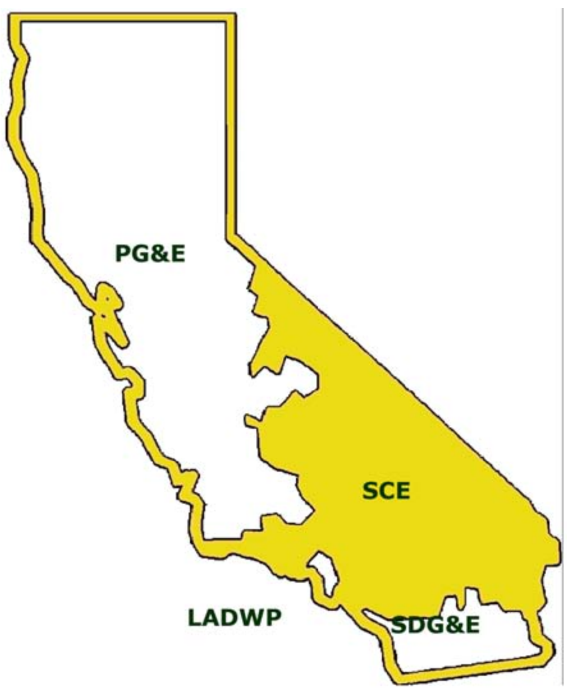
SOUTHERN CALIFORNIA EDISON ADVANCED METERING INFRASTRUCTURE PROGRAM: EDISON SMARTCONNECT™

This case study describes Southern California Edison's approach to Advanced Metering Infrastructure (AMI) and its recognition of the importance of technological obsolescence. The AMI Program at Southern California Edison (SCE) was born of the energy crises of California, starting the state of emergency in 2001.[54] California's regulatory bodies were concerned about shortages and looked to demand response programs and time-of-use pricing for solutions. Demand response programs were instituted for large, industrial customers, but new metering and communications infrastructure—Automatic Metering Infrastructure—would be needed to extend those programs to the entire user base.

The Real-Time Energy Metering (RTEM) program was launched by emergency legislation on April 11, 2001. The program scope was for the purchase and installation of advanced interval metering and related metering communications and end-user communication systems for all commercial end-user accounts with peak demands exceeding 200 kW.



- Operating for over 120 years
  13,500 employees
- Service Area
  50,000 square miles (430 communities in 11 counties)
- Population served
  More than 13 million
  Over 4.6 million meters
- $8 billion operating revenues
- 82 billion kilowatt-hour Sales (Bundled Service + Direct Access)
- Demand response programs
  More than 1,200 MW of peak demand response resources
  300+ MW alone from SCE air conditioner cycling program

[54] On January 17, 2001, the Governor proclaimed a state of emergency to exist under the California Emergency Services Act; it ended on November 13, 2003.

SCE Real-Time Energy Metering Program

SCE complied with a RTEM project to install 12,000 meters. Prior to the start of the project, SCE had virtually no infrastructure to remotely collect meter data and communicate this back to the customer. All 12,000 meters had to be replaced, and a communications infrastructure had to be built and integrated into the SCE existing manual customer data-acquisition system.

Despite conducting a 50-meter proof-of-concept test of metering technology prior to deployment, start-up issues arose with both hardware and software, including a manufacturer recall of the first shipments of meters and system problems at a couple of distance thresholds (3000 and 10,000 meters), requiring extensive troubleshooting of both internal and external systems and processes.

Multiple communications solutions were used. A paging solution was the most cost-effective; it was used in about 85% of the installations. Where paging service was not adequate, landline telephones or radio communications were used. About 10% of the RTEM meters were installed with telephone-based communications. A third alternative communications solution, used for 5% of the project scope, was the SCE existing private radio network.

The majority of the project was completed in 2002.

At the time of the RTEM program, SCE foresaw the opportunity for demand response to address the cost-effectiveness of advanced meter deployment based on demand response results developed through the RTEM project. "SCE believes that more load-management and demand-response programs will be a strategic component of SCE's future. The RTEM project was a significant step toward that future."[55]

From this point forward, SCE started thinking about new and innovative ways to deliver demand response. All the while it pondered the threshold question: "Do operational benefits of AMI (with demand response) outweigh costs?"

In July 2004, the California Public Utilities Commission (CPUC) issued a ruling ordering the three large investor-owned utilities in California to submit business cases and plans for deployment of an Advanced Metering Infrastructure.[56] The ruling established December 15, 2004 as the date by which each utility was to file an application for a particular advanced metering infrastructure deployment strategy and the associated justification, timing, costs, and cost recovery based on the results of their analysis.

SCE's initial response to the ruling was in March 2005[57] in the form of testimony before the CPUC. The Executive Summary of this testimony, shown in the insert below, clearly articulates the SCE approach to the ruling and the challenge of deploying AMI technology.

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[55] Kevin Wood, Manager of Meter Technology Deployment, Customer Service Business Unit at Southern California Edison. October 1, 2003.

[56] *Administrative Law Judge And Assigned Commissioner's Ruling Adopting A Business Case Analysis Framework For Advanced Metering Infrastructure*, Public Utilities Commission of the State of California, July 21, 2004.

[57] Assigned Commissioner and Administrative Law Judge's Ruling Calling for a Technical Conference to Begin Development of a Reference Design and Delaying Filing Date of Utility Advanced Metering Infrastructure Applications, issued November 24, 2004.

Business Vision, Management Philosophy, and Summary of Business Case Analysis[58]

"Southern California Edison Company (SCE) has completed an extremely rigorous business case analysis of Advanced Metering Infrastructure (AMI). SCE's findings indicate that an integrated AMI solution that leverages additional commercially-available technologies has the potential to provide an effective platform for enhancing routine customer services, providing more sophisticated alternatives for load management and demand response, and increasing operational efficiencies and benefits. However, these enabling technologies have yet to be cost effectively packaged or integrated into a streamlined meter for application in the United States. Therefore, SCE has concluded that given its operational starting point, an investment in currently-available AMI technology is not cost effective for SCE's customers. Instead, SCE proposes to achieve significant increased operational and demand response benefits through a concerted and aggressive effort to develop an "advanced integrated meter" (AIM) that integrates additional technologies into the next generation of meters.

"SCE's business vision for AMI seeks to undertake a deliberate, yet fast-paced effort to design and develop a new AIM platform that will better meet SCE's and its customers' needs by integrating additional proven technologies. The goal of the AIM project will be to add significantly more functionality at the same or lower cost as today's solutions, in order to significantly increase benefits over the current AMI business case.

"The AIM development will take a "clean sheet" approach to design a meter that provides additional functional capabilities not available in currently-available metering solutions, including the possible integration of load control, demand limiting, two-way communications, customer information displays, data storage, and/or other proven stand-alone technologies. SCE seeks to significantly increase overall durability and versatility of AMI by using open, extensible and multifunctional meter and communications platforms. The AIM project is expected to leverage commercially-available components through an open design for both the meter device and communications to provide a flexible and sustainable technology platform during its long lifecycle. This is essential given recent and anticipated future technology developments in home connectivity, distribution grid intelligence, distributed generation, and broadband over power lines, all of which may interface with the AIM technology SCE has developed a detailed strategy and aggressive timeline for the AIM development project that allows for integrated meter design, prototype development, beta production, and pilot test before a new business case would be prepared for Commission approval of full deployment. If there are no major obstacles and the AIM technology delivers its promised improvements to the business case analysis, SCE envisions completing full deployment of the new AIM system no later than one to two years after the time that full deployment of today's AMI technology could be completed. SCE's customers would nevertheless be advantaged, despite this slight delay, given the superior attributes of the proposed AIM technology, including more durability, versatility and the ability to deliver significant improvements in system reliability, customer billing and service options, outage management and operational efficiencies. Thus, it is critical that SCE's ultimate investment in AMI focus on "getting it right" instead of rushing to "get it done." "

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[58] *Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism, Volume 1 – Business Vision, Management Philosophy, and Summary of Business Case Analysis,* Before the Public Utilities Commission of the State of California, March 30, 2005.

Simply put, SCE's preliminary business case showed that existing technology was not cost-effective. Using existing technologies and applications, the SCE preliminary business case showed a large cost benefit deficit. The most favorable scenario had a negative present value revenue requirement impact of more than $871.2 million (2004 present value).[59]

The technology, or at least the integrated applications, had not evolved to the point where deployment was economically feasible. The technology had to extend well beyond automated meter reading (AMR).

To gain enough benefits to justify the cost, SCE needed a system with (1) the latest meter designs, (2) a communication and network system, and (3) networked devices in customer homes. However, the preliminary analysis did not find the technologies or systems available in the marketplace. SCE looked at "next generation technology that could create a positive business case."[60]

SCE revisited the process. SCE essentially took control of the technological development process and brought the technology forward. The SCE initiatives are well recognized in the industry, resulting in numerous awards.[61]

Advanced Metering Infrastructure Program

The primary challenge to SCE in developing its AMI Program was to address the fundamental cost drivers from preliminary business cases by adding functionality, and thus value, to the system. This could be done by maximizing the potential value from load control for both grid reliability and demand response; increasing field automation and efficiency; and identifying additional uses for the system based on tangible customer and SCE business value. Further, SCE took a long view towards developing requirements that anticipated customer needs and supported policy objectives through 2012.

Given the varied pace of technology advancement in the meter and communications industry, the risk of technology obsolesce to AMI is high. In order to manage this risk, the AMI program focused on understanding the market and vendor solutions and technologies; developing a layered architecture necessary to meet its requirements, assess vendor offerings, and understand any gaps; and developing strategies and technical points of view with an emphasis on future-proofing SCE's AMI solution against the risk of rapid technical obsolescence.

SCE was diligent in communicating with industry—electric utility and telecommunications—to help encourage the pace of innovation and ensure the basic architecture elements necessary for future-proofing would be available at the time of implementation.

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[59] Southern California Edison Company's (U 338-E) *Revised Preliminary Analysis of Advanced Metering Infrastructure Business Case.* January 12, 2005.

[60] Paul De Martini, Director, Advanced Metering Infrastructure Program, SCE.

[61] The Electric Power Research Institute (EPRI) has recognized SCE as an industry leader for its approach to advanced metering (Department of Energy's 2007 Smart Grid Implementation and Deployment Leadership Award). SCE's AMI Phase I was selected by The Utility Peer Network as the 2005/06 Best AMR Initiative in a North American Investor Owned Utility. The Project Management Institute – Orange County named the Edison SmartConnect™ Advanced Metering Infrastructure the PMI-OC 2006 Project of the Year.

Technology Advisory Board

One of the ways in which SCE kept abreast of technological development and future-proofed the process was through a Technology Advisory Board (TAB). The Technology Advisory Board is a "Blue Ribbon" panel of experts with diverse backgrounds and areas of expertise and "know-how" relevant to AMI technology development. Board members are chosen to advise SCE on the selection of technology for Edison SmartConnect™. The panel will rely on its experience and expert judgment to advise SCE on issues involving technology requirements, reference architecture, and interface with standards organizations.

The TAB comprises members who represent key organizations involved in advanced metering development or share a keen interest in the future of metering and demand response from an international perspective.[62] The TAB held its first meeting on September 15, 2005. Meetings were held every one or two months throughout the development phase of the program. The TAB was instrumental in maintaining a high profile for issues related to technological obsolescence. An example of their contribution can be seen in Figure 4-1, which describes the SCE Technology Adoption Zone in relationship to second- and third-generation "smart meter" technology.

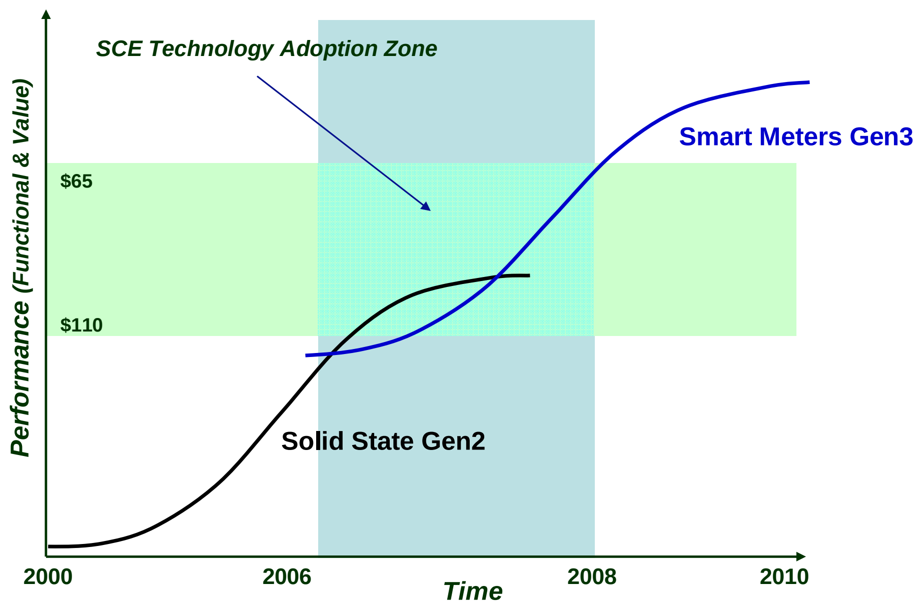

Figure 4-1
Second Generation vs. Third Generation Difference in Adoption of Architecture-Based Designed

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[62] Members: Carnegie Mellon University: Dr. Rahul Tongia; Gridwise Architecture Council: Mr. Steve Widergren; IntelliGrid: Mr. Joe Hughes; International Electrotechnical Commission (IEC): Mr. Richard Schomberg; CEC Demand Response Research Center: TBD; OpenAMI: Mr. Ray Bell.

Three-Phase Approach

SCE took a three-phase approach to developing its AMI program. Phase I involved developing the specifications for the next generation of meters and support systems, working with meter manufacturers and communications technology suppliers to develop the required technology, assessing technology and performing cost-benefit analyses.

Phase II includes extensive lab and field testing of the new products, procuring the new technologies, selecting a deployment contractor, and verifying the costs and benefits of the full deployment business case.

Phase III will commence in 2008 and will involve installing Edison SmartConnect™ meters for all SCE customers located in 5.3 million households and small businesses throughout the 50,000-square-mile service territory during a five-year period.

Phase I: Three-Phase Approach
Completed in December 2006

In this phase the preliminary requirements, conceptual architecture and conceptual feasibility, reference architecture, beta product testing was completed; regulatory applications were filed; and the RFP for meter and telecommunications was issued.

Phase II: Pre-Deployment
January 2007 through December 2007

Scope includes field tests for meters and telecommunications and meter data-management system installation. SCE filed its final Edison SmartConnect™ business case for Deployment in July 2007; final approval expected in Q1 2008.

Phase III: Deployment
January 2008 through June 2012

Deployment will start with logistics setup, telecom network installation, and new meter sets. Large-scale meter installations begin in January 2009 thru June 2012. The multi-phased approach to the development and deployment of next generation AMI was scheduled over a 7 1/2 year period. The phases and timeline are shown in Figure 4-2.

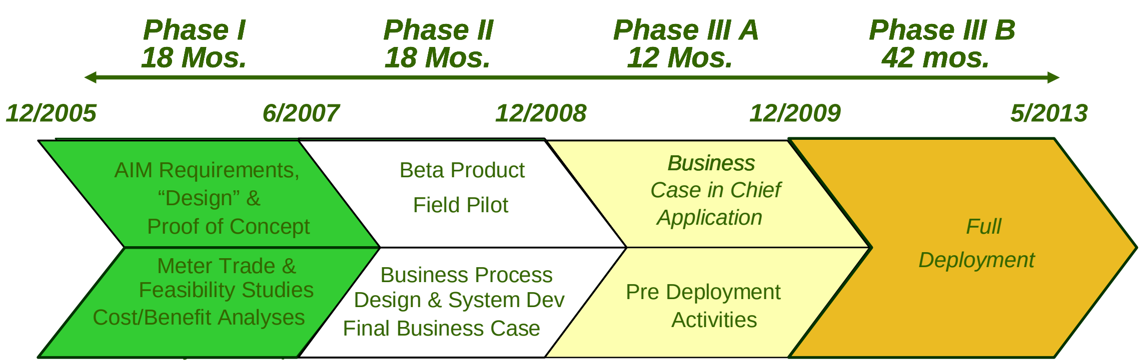

Figure 4-2
SCE Multi-Phased Approach

Systems Engineering

SCE approached the process using a systems engineering model that developed requirements, assessed technology, and delivered AMI solutions that had a positive cost benefit. It included tradeoff analysis focused on the value of enabling scenarios in the AMI business case.

SCE contracted with consulting system engineers to help define the requirements and identify needed technologies.[63] SCE examined the IntelliGrid to define requirements through use cases to determine functional and non-functional requirements and identify the business case for each. SCE's systems engineering process provided a disciplined approach to designing, deploying and operating an advanced metering infrastructure that meets the needs of its users within a predictable budget and schedule.

Technology Assessment – Use Cases

One of the pillars of technology assessment[64] is the development of use cases to capture requirements.[65] The use cases served as the basis for allocating functionality to components and architecture elements within the AMI solution to help SCE communicate its vision of the AMI system implementation.

SCE conducted over 44 workshops and developed 99 scenarios involving over 140 subject-matter experts. In all, eighteen separate use cases were analyzed in six categories, representing ninety-nine separate potential scenarios of how AMI might be utilized to either improve service levels, lower cost, or both. Descriptions of the use-case series are presented in Table 4-1.

Table 4-1
Descriptions of the Use-Case Series

Billing and Customer Service	Customer Interface	Delivery	Energy Procurement	Field Services & System Recovery	Installation & Maintenance
B1 Multiple clients read demand and energy data.	C1 Customer reduces demand in response to pricing and/or grid event.	D1 Distribution operator curtails/limits customer load for grid management.	E1 Real-time operation curtails/limits load for economic dispatch.	S1 AMI system recovers after power outage or communications or equipment failure.	I1 Utility installs, provisions, and configures AMI system.

[63] EPRI, EnerNex, IBM.
[64] SCE leveraged the prior efforts of EPRI's IntelliGrid project and the OpenAMI Task Force.
[65] Use cases are a proven method for the collection and documentation of both functional and non-functional system requirements. The use-case approach represents a methodology for identifying necessary functionality and vendor product requirements. Use cases place particular emphasis on how metering systems will be used when deployed. The process focuses on usage-based requirements to achieve a functional goal, rather than being constrained by existing product design. The intent is to clearly define the desired requirements, leaving vendors as free as possible to come up with innovative solutions.

Table 4-1 (continued)
Descriptions of the Use-Case Series

Billing and Customer Service	Customer Interface	Delivery	Energy Procurement	Field Services & System Recovery	Installation & Maintenance
B2 Utility remotely limits or connects / disconnects customer.	C2 Customer has access to and reads recent energy usage and cost at his or her site.	D2 Distribution operators optimize network based on data collected by the AMI system.	E2 Utility procures energy and settles wholesale transactions using AMI system data.		I2 Utility manages end-to-end lifecycle of the meter system.
B3 Utility detects tampering or theft at customer site.	C3 Customer uses prepayment services.	D3 Customer provides distributed generation.			I3 Utility upgrades AMI system to address future requirements.
B4 Contract meter reading for other utilities.	C4 External clients use the AMI system to interact with customer devices.	D4 Distribution operator locates outage using AMI data and restores service.			

Once the use cases were finalized, SCE conducted a process to consolidate the use-case requirements by eliminating duplicates, combining similar compatible requirements, and resolving any remaining conflicting requirements across use cases. This process also sought to ensure consistency of terminology and language across each of the requirements. The resulting consolidated set of requirements was then prioritized and mapped to architectural components and functional areas to generate SCE's Preliminary Requirements for AMI that were published on June 30, 2006. Because of this consolidation process, the requirements included within the use-case documents in some cases differ from those included in the Preliminary System Requirements for AMI.[66]

SCE prepared a use-case test report that highlighted gaps and challenges of the AMI architecture as it relates to the requirements derived from SCE's AMI use cases. The methodology used to perform the analysis was to review the use case documents, sequence diagrams, activity diagrams, and system interface diagram and determine whether the architecture meets the stated requirements. The report was used to identify areas of focus in the development of the platform-specific model in Phase II.

[66] Technology Development, SCE.

IntelliGrid[67]

To make sure that the result would be "future-proof," SCE sought consulting partners familiar with the systems engineering approach and with the Electric Power Research Institute's IntelliGrid architecture. Using IntelliGrid principles, SCE stepped through a rigorous process of specifying what it needed, then evaluated the technology.

SCE leveraged the prior efforts of the IntelliGrid Architecture to provide an initial guiding framework and scope for the requirements-gathering process for the SCE AMI project. The IntelliGrid Project utilized use cases as a means of gathering system requirements and provided the initial set of uses that SCE adopted for its AMI requirements gathering process. Once the use cases were completed by the SCE teams, SCE contracted with EPRI to take SCE's use case content and integrate it back into the IntelliGrid model for widespread use by the electric energy industry. This modeling effort was the first attempt to integrate the work of many users and to convert it from an independent requirements-gathering activity into a common industry model that could be used to document, specify and ultimately construct and manage AMI systems for electric energy companies. The model can also be used to assist with EPRI's standards integration and harmonization work to bring the industry together on open systems development.

Because of their careful application of IntelliGrid principles, the planning stage was completed months ahead of schedule. And because SCE worked with vendors throughout the process, the products that they needed were developed for the market.

"The IntelliGrid use cases really helped jump-start our process. If we had not used the IntelliGrid model, it would have added six to nine months to our process."[68]

Technology Assessment Method

The Technology Assessment Method was used by SCE to provide an initial guiding framework and scope for the requirements-gathering process for the AMI Program.[69] SCE was keenly aware of the need to select designs and technologies that mitigate the risk of rapid technology and functional obsolescence.

Technology Capability Maturity (TCM)

SCE was pursuing technology known to be feasible, but no available products met all the needs. It was apparent that there was considerable diversity in not only the capabilities but in the basic approach and stated strategic directions of the technology vendors. In order to objectively understand the capabilities of various solution components as well as communicate desired features to support its requirements, SCE adopted an abbreviated form of the Technology Capabilities Maturity methodology (TCM).[70] Each TCM summary consists of a matrix that lists business, system, and architecture requirements along the horizontal access. Each TCM summary assigns a maturity level from 0 to 5 on the vertical axis. A TCM matrix for a given device might have a lot of boxes checked off for requirements but might also score a low maturity level, or

[67] SCE is the first U.S. utility to adopt EPRI's IntelliGrid Architecture for a system-wide advanced metering deployment.
[68] Paul De Martini, Director, Advanced Metering Infrastructure Program, SCE.
[69] Technology Development, SCE.
[70] Based on CFTP developed by J. Paap, MIT.

vice-versa. A TCM matrix, shown in Figure 4-3, shows the tradeoffs of a particular technology at a glance.[71]

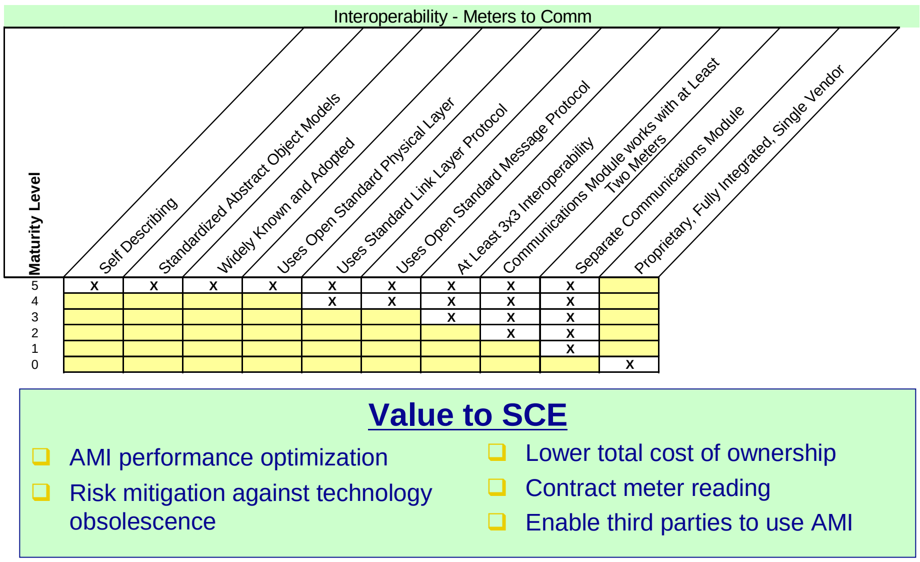

Figure 4-3
A TCM Matrix

Technology Capability Maturity Matrix was effectively the screening process that SCE used to describe the state of the art of specific technological components of the AMI system. The cycles of AMI technology development and maturity are evident in this analytical framework. It is evident that the current state of advanced meter and telecommunications technology development is following typical "S" curve paths.[72]

AMI Technology Roadmap

The AMI Technology Roadmap identified entities, organizations, standards, and milestones to be considered throughout the technological development of the SCE AMI. The AMI Technology Roadmap contains:

- A description of the goals of an ideal AMI system from an open systems perspective
- A list of obstacles in the way of achieving those goals
- A list of milestones toward achieving those goals and a diagram illustrating dependencies between the milestones.

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[71] The TCM scales represent a superset of the requirements identified in the Requirements Report and are used to understand the suppliers' capabilities and the direction in which the industry is evolving AMI products and solutions.
[72] Meeting Minutes, SCE AMI Technology Advisory Board, April 20, 2006.

This document was used to communicate SCE's system design goals and principles to new AMI team members and suppliers and as a mechanism to maintain focus on our design goals.

Vendor Collaboration

At the beginning of the technology-evaluation process, there were no products that could meet the metering requirements. "Once the vendors realized that SCE and the other UtilityAMI members were serious about their requirements, they began to react. Now there are at least two meter vendors who meet a large percentage of the common requirements defined by UtilityAMI and the specific requirements published by SCE."[73]

SCE's approach to vendor collaboration began in 2005. SCE's requirements called for suppliers to go beyond basic advanced meter features— measuring usage hourly rather than monthly, and using a two-way wireless network to communicate usage information—and to develop a suite of new technical capabilities and functionality.

Phase I

The AMI system design work created during Phase I of the project included the development of the 18 use cases for the AMI technology. As SCE's system design team worked with the supplier community through the Technology Capability Maturity (TCM) framework to understand the capabilities of each offering, it was clear that the technology existed to satisfy SCE's requirements. However, some aspects of end-to-end system design and architecture needed more focus to ensure that SCE understood how each supplier's solution would be integrated into SCE's entire AMI system. Hence, the system design team used the Conceptual Architecture,[74] completed in the first half of Phase I.

The goal of reference architecture is to develop a set of architecture models that describe how AMI will satisfy specific scenarios and requirements in each use case. The system engineering approach adopted by SCE is not only designed to yield a business-aligned architecture but also to ensure the performance requirements of the system are well understood and can be satisfied by the candidate solutions. The following is a summary of the analysis undertaken in each of the architecture areas of the Reference Architecture.

Market Survey RFI

SCE had received encouraging feedback from its market survey solicitation initiated in December 2005. The market survey was conducted through a request for information (RFI) process and was developed to acquire information surrounding the level and extent of product development activities among suppliers, the possible alignment with SCE's conceptual core requirements, and desired product capabilities. The information obtained also revealed that significant technology development activities were underway with a large number of industry suppliers.

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[73] Don Von Dollen, IntelliGrid Program Manager.
[74] As described in the CFR.

Meter and Telecommunications RFP

SCE issued the Meter and Telecommunications RFP on December 13, 2006. The proposals were evaluated in Phase II. The RFP results provided the basis for contract negotiations and awards for the execution of the field test in Phase II.

The main objectives of SCE's Meter and Telecommunications RFP were to:

- Meet AMI business and technical requirements by selecting up to two communications suppliers and two meter suppliers.
- Minimize the total cost of ownership by considering and balancing multiple cost drivers, such as functionality, performance, and future upgrades.
- Shift performance risk to the supplier by developing contract terms and conditions that support key business benefits and cost drivers.

Meter Management System (MMS) RFI

SCE proceeded with development of preliminary high-level business requirements for an MDMS COTS application and issued a request for information in June 2006 to seven MDMS suppliers. The RFI was structured to provide SCE with a comprehensive view of current MDMS COTS product capabilities and test the assumption that MDMS suppliers will provide enhancements to their COTS applications in terms of functionality and timeframes that were consistent with, and aligned with, SCE's AMI program needs.

Home Area Network

As a central element of SCE's customer experience and intelligent grid initiatives, the home area network component picture came into sharper focus during Phase I. SCE continued to monitor the technology landscape and confirmed the broader industry's move to support the ZigBee™ wireless communications IEEE 802.15.4 standard for home automation and systems control. Discussions with major appliance and programmable communicating thermostat (PCT) manufacturers informed SCE that commercially available products would be available in 2007. Due to this wide support from home appliance and control companies, SCE decided to join the ZigBee Alliance in October 2006 to actively participate in the dialogue shaping the direction of the standard and keep abreast of products in development.[75]

Testing

SCE's testing activities in Phase I focused on verifying the functionality of currently available and emerging technology with the goal of determining whether technology will be able to meet SCE's stated AMI functionality objectives. SCE also tested a number of AMI components from several suppliers, including standalone and integrated service switches, radio frequency (RF) neighborhood-area-network (NAN) communications, and home-area network (HAN) communications.

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[75] It appears that ZigBee™ is emerging as the industry's leading choice for a HAN communications protocol for residential applications.

SCE conducted product testing activities, including component-level testing and product qualification testing of the candidate AMI meters in advance of planned field tests. It utilized laboratory environment testing results to help shape the development of the Field Test plan that was implemented in Phase II.

Testing

Meters – Westminster Meter Testing Facility

A well-known meter testing facility managed by SCE.

Telecommunications – Alhambra Telecom Test Bed

SCE constructed 40 structures at a facility located in Alhambra, CA[76]

Home Area Network – Zigbee Test House

One of SCE's communications engineers set up initial testing of the Zigbee protocol in his 1,600 sq. ft. home in Torrance, CA.

Phase I Results: AMI Technology and Business Case

SCE made significant progress in the development of next-generation AMI products that met its AMI requirements for functionality and project timing. SCE is now able to take advantage of the developing market. SCE is confident that these next-generation AMI products will provide the added functionality and capabilities that it requires.

Technology Improvement[77]

Based on SCE's research and continued dialogue with product manufacturers and industry leaders, it has become evident that significant changes are coming to the meter marketplace. Within the next six months, most of the major North American meter manufacturers and some new market entrants are expected to offer a new generation of meters that will include many of the advanced features and capabilities that SCE has been advocating, including an integrated service switch that enables remote connect and disconnect and will be located under the cover of the meter itself. This feature is slated to be offered at a fraction of the price historically charged for these devices.

Some of the additional features expected to be available in this new generation of meters include remote upgradeability, more memory, and some limited power quality reporting capabilities. SCE has also seen evidence that the meter manufacturers have been working more openly with multiple industry partners to provide greater choice in communications options and

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[76] To better understand the capabilities and limitations of 900-MHz and 2400-MHz communications technologies in a real world environment, SCE conducted tests in abandoned housing units at March Air Force Base (AFB) in Riverside County, California.
[77] *Advanced Metering Infrastructure,* Final Feasibility Report. Southern California Edison, January 2007.

interoperability. Additionally, many of the Automated Meter Reading (AMR)/AMI communications suppliers have been developing enhanced network capabilities that include supporting two-way communications to premise devices using the meter as an information gateway. Several of the industry leaders have announced development and/or actual availability of Home Area Network communications using non-proprietary protocols, which include IEEE 802.15.4, also referred to as the ZigBee™ wireless standard.

The results of Phase I are universally positive both in terms of improving technology and developing a viable business case; moreover, they supported the continuation of SCE's three-phase AMI deployment strategy.[78]

Phase II

Phase II allowed SCE to test and resolve technical issues with the integrated AMI meters and communications system before full deployment, to validate the overall business case assumptions by analyzing vendor responses to the RFPs, and to identify additional costs and benefits made apparent through the testing process, all of which will enable a more accurate picture of the costs and benefits of AMI deployment in SCE's final business case. In the early stages of Phase II, SCE will obtain new information on pricing from its RFPs and more information on product performance based on the results of SCE's testing of the first production models of metering and communication products, which will tighten the risk factors and likely reduce the contingencies. It is also possible that the enhanced functionality of the new AMI meters will generate additional, unforeseen AMI benefits and/or cost savings. SCE expects that revisions to the present estimates may reduce the costs and/or increase the benefits of AMI.

Phase II also involved the evaluation of the responses received to the RFPs issued in December 2006 for AMI meter and communications systems technology, as well as for a meter data management system. Among other goals, the field testing sought to validate the majority communications network's coverage. SCE expects that the majority of communications system will provide network coverage to a very high percentage of meters in SCE's territory. The field testing will also validate the compliance of the first AMI meter solution and the majority of communications system with service levels identified in the RFPs.

In Phase II, SCE conducted the first fully integrated test of the end-to-end functionality of the AMI system ("Release 1" of the AMI system), which will be executed in Phase III. Phase II activities will lay the necessary groundwork for full deployment activities to begin in January 2008.

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[78] On August 7, 2006, SCE published an *Advanced Metering Infrastructure (AMI) Conceptual Feasibility Report (CFR).* The CFR documented the results of SCE's efforts during the first eight months of the Phase I effort and concluded that SCE's AMI solution was conceptually feasible. On December 21, 2006, SCE filed Application (A.)06-12-026, requesting authority to proceed with AMI Phase II, the pre-deployment phase.

Phase III

In July 2007, SCE requested authority from the CPUC to proceed with Phase III of its AMI deployment strategy.[79] Whereas Phase I was dedicated to developing the functional requirements for the next generation of AMI metering systems and Phase II was focused on procuring the new AMI technologies, selecting a deployment contractor and validating the costs, and benefits of the full deployment business case, Phase III will involve the deployment of SCE's AMI solution—Edison SmartConnect™—to all residential and business customers under 200 kW in SCE's service territory.

SCE's five-year deployment of Edison SmartConnect™ will entail a major technical, logistical, and financial undertaking at an estimated cost of $1.7 billion. As part of the detailed planning for deployment, SCE identified three distinct releases for all the systems development and integration work associated with Edison SmartConnect™. Phase III will begin with the execution of the first release, which involves the final development and testing of the meter data management system and telecommunications network management system and integration with the customer billing system. A second field test of up to 10,000 additional meters will validate the installation processes and any revised version of the meter/telecom products based on Phase II engineering and development.

Phase III deployment will include two additional releases of the AMI system, each being slated to achieve a higher and more complex level of functionality than the previous one. The ramping-up of meter installations in relation to each respective release will take place over time through June 2012 for the full Phase III deployment period.

Costs of AMI Program[80]

The costs of the AMI program were significant but were in proportion to the challenges of moving technology forward and creating a positive business case for AMI. The costs are allocated by Phase. Phase I was $12 million; the CPUC has substantially adopted SCE's ratemaking proposal and set an authorized Phase II expenditure level of $45.220 million.

Phase III 2008 – 2012 revenue requirements include all capital-related costs and incremental O&M expenses, net of forecast operational benefits, needed from customers to recover the cost of the Edison SmartConnect™ project. SCE's forecast revenue requirement reflects Phase III funding of $384.2 million in O&M expenses and $1,330.7 million in capital expenditures over the period commencing January 1, 2008 through December 31, 2012.

The cost/benefit comparison and related key drivers are shown in Figure 4-4.

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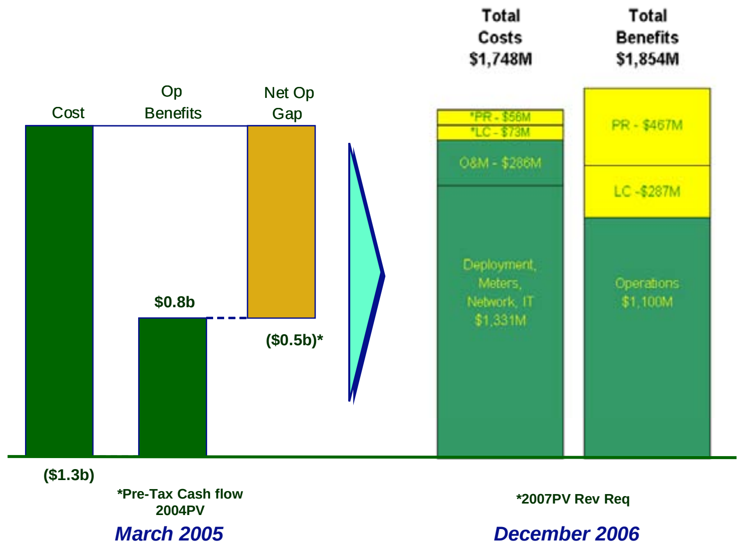
[79] Southern California Edison Company's (U 338-E) Application for Approval of Advanced Metering Infrastructure Deployment Activities and Cost Recovery Mechanism. July 31, 2007.
[80] Southern California Edison Company's (U 338-E) Application for Approval of Advanced Metering Infrastructure Deployment Activities and Cost Recovery Mechanism. July 31, 2007.



Key Drivers

- Cost effective residential meter w/integrated service switch & home area network
- 100% telecom system coverage and remote turn-on/off capability yield additional labor savings
- Demand response provides 1,000 MW of estimated peak load reduction from TOU/CPP rates and A/C load control
- AMI System creates incremental benefits for meter to cash processes, load forecasting and distribution field operations

Figure 4-4
Cost/Benefit Comparison

Reassessing Cost Benefit

During Phase I, SCE undertook a complete revision of its cost-benefit analysis. The final cost-benefit analysis concluded that the Edison SmartConnect™ project is expected to produce customer benefits of $109 million in PVRR. This represents a $1 billion improvement over the initial cost-benefit analysis presented by SCE in its "best-case" full deployment scenario in March 2005.[81] The costs and benefits are shown in Table 4-2.[82]

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[81] Edison SMARTCONNECT™ Deployment Funding and Cost Recovery, Exhibit 3: Financial Assessment and Cost Benefit Analysis, Before the Public Utilities Commission of the State of California. July 31, 2007.
[82] Ibid.

Table 4-2
Project Cost/Benefit Analysis Results ($Nominal and 2007 Present Value of Revenue Requirement, in Millions, Rounded)

Benefits	**Nominal**	**PVRR**
Operational Benefits		
During Deployment Years	278.2	
During Post-Deployment Years	4,299.0	
Demand Response Benefits		
During Deployment Years	216.2	
During Post-Deployment Years	2,792.6	
Sub-Total Operational Benefits	**4,577.2**	
Sub-Total Demand Response Benefits	**3,008.8**	
Total Benefits	**7,586.0**	**2,076.0**
Costs		
Phase II Costs (Pre-Deployment)	**45.2**	
Deployment Costs		
Acquisition of Meters and Communication Network Equipment	838.0	
Installation of Meters and Communication Network Equipment	296.6	
Implementation and Operation of New Back Office Systems	191.2	
Customer Tariffs, Programs, and Services	112.1	
Customer Service Operations	84.1	
Overall Program Management	45.6	
Contingency	147.3	
Post-Deployment Costs		
Billing	127.1	
Call Center	93.5	
Meter Services	399.1	
Back Office Systems	344.4	
Customer Tariffs, Programs, and Services	245.0	

Table 4-3 (continued)
Project Cost/Benefit Analysis Results ($Nominal and 2007 Present Value of Revenue Requirement, in Millions, Rounded)

	Nominal	PVRR
Sub-Total Pre-Deployment Costs	45.2	1,627.0
Sub-Total Deployment Costs	1,714.9	
Sub-Total Post-Deployment Costs	1.209.0	340.0
Total Costs	2,969.1	1,967.0
Total Benefits Less Total Costs	4,616.9	109.0

The improvements that have occurred over the past two years are the result of fast-moving 20 technology improvements, some of which were motivated by SCE in its endeavor to deliver a cost-effective AMI solution that fully satisfies the functionality requirements. The vast improvements in benefits largely result from the incorporation of a remote service (connect/disconnect) switch into the meter, improved communication system coverage and functionality, improved meter life, and refined energy conservation and customer demand response programs based, in part, on the enabling home area network (HAN) interface technology. The improvements in benefits are enumerated below.

Improved communication system coverage. In the original business case, products were estimated to provide 90% coverage, which means a communications could not be established with a significant portion of customer meters, which would continue to require manual meter reading. SCE now believes 100% can be achieved, reducing meter reading costs and adding more customers to demand-response programs. ($45M)

Remote connect and disconnect abilities. Thanks to advancements in technology, smart meters will be able to disconnect and reconnect customers remotely for non-payment, saving labor costs. ($298M)

Reduced meter failure rates. SCE's original business case assumed deployment of advanced meters in just under 9 months. The new scenario has a more reasonable ramp-up schedule. In addition, improvements in technology cut the expected failure rate (25% over the life of the AMI system) in half. By incorporating a more exacting quality assurance program, SCE expects to reduce meter failure by 50%. ($33M)

Changes in demand response assumptions. The newly envisioned AMI system can incorporate load-control techniques into the system TOU pricing, and programmable communicating thermostats (PCTs) are expected to encourage a reduction in customer demand. ($315M)

Previously unidentified benefits. The new study found benefits arising from transformer overload prevention, reduced "no power" field visits, billing exception processing reduction, summary billing lag, meter reader and field service workers compensation reduction. ($70M)

Total cost improvement. Subtracting the $247M cost expected for meters and communications infrastructure, SCE arrives at an estimated $514M improvement in costs over the 2005 business case.[83]

SCE AMI Program

In summary, SCE has an AMI program of substantial dimensions that has a positive cost benefit, and is designed to minimize the risks of technological obsolescence.

SCE AMI Program

- Replace 5 million meters on all SCE's small commercial and residential customers <200kW

  Electronic meters with 200A integrated service switch

  Home network gateway

  Outage detection

  Voltage measurement

  Theft/tamper detection and remote upgradeability

  Robust and secure two-way network (supports 99+% meter reads + messaging)

  New meter data management system and interfaces to ERP

  Outage management

  Load forecasting

  Wholesale settlement

- Products and services

  Time-of-use rates w/critical peak pricing option

  New load-control programs leveraging Title 24 communicating smart thermostat

  Service automation for remote turn-on/off and new bill payment options

- Deployment Cost

  $1.3 billion through deployment in 2012

[83] This improvement in costs and benefits resulted in the improvement in the PVRR from a negative $871.2 million to a positive $109.0 million.

Contribution to Electric Utility Industry and Technology Development

At this point in its AMI Program, it can be said the SCE provided a catalyst for industry innovation toward next-generation technology based on added functionality and open and flexible solutions that extend functional life and minimize the risk of technology obsolescence. SCE has approached the issues of technological obsolescence and taken deliberate and conscientious steps to mitigate them, thus delivering value to its customers, shareholders, and the industry.

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