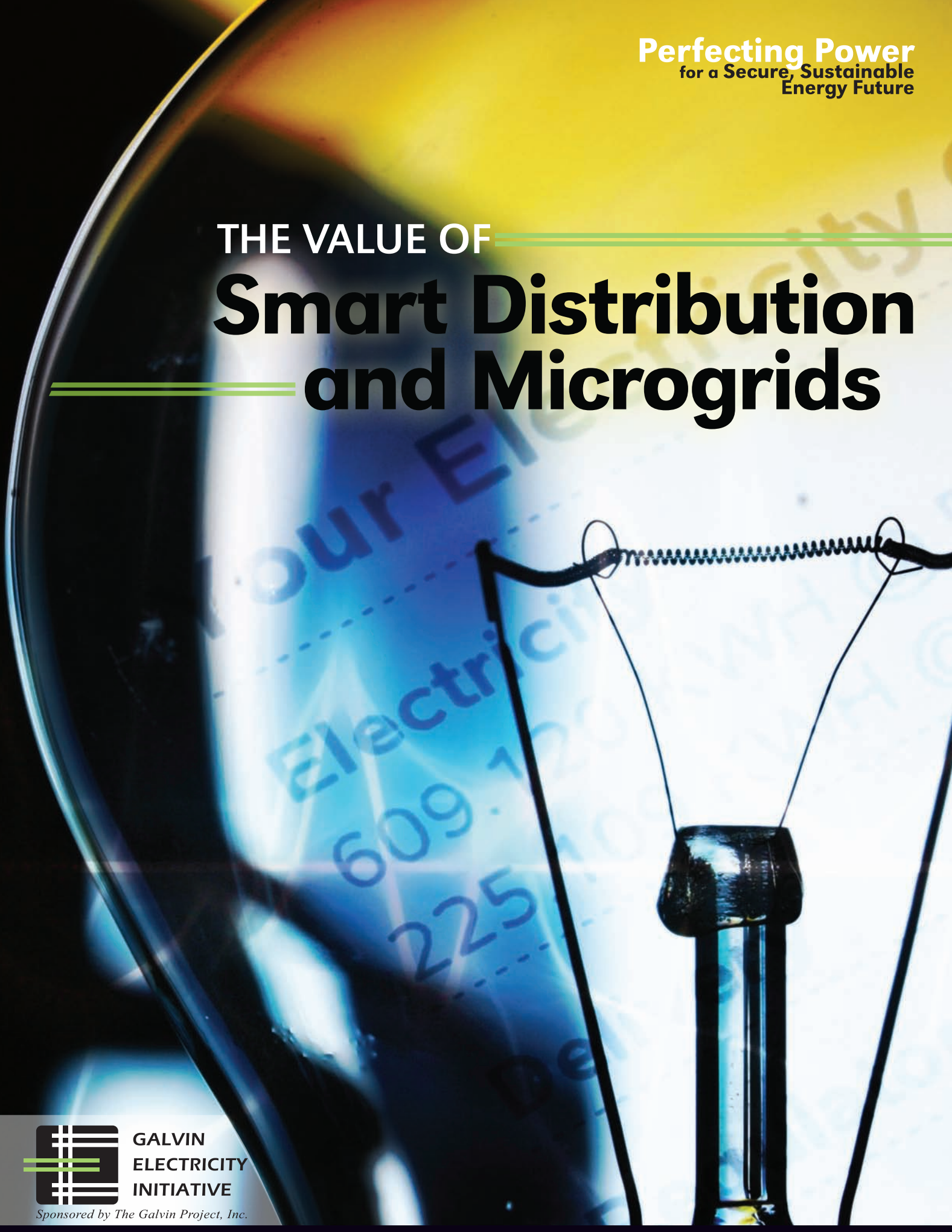
Perfecting Power
for a Secure, Sustainable
Energy Future

THE VALUE OF Smart Distribution and Microgrids



GALVIN
ELECTRICITY
INITIATIVE

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The Value of Smart Distribution and Microgrids

U.S. economic vitality depends on the reliable, secure, efficient and clean delivery of electricity to businesses and homes. Unfortunately, our power system infrastructure is outdated and incompatible with the needs of today's digital world. Employing technology that dates back to the 1950s and earlier, the system includes a great deal of equipment that is several decades old and on the verge of failure. The resulting power outages cost our citizens upward of $150 billion each year and threaten our country's global competitiveness. At the root of the issue is our equally outdated state regulatory system, which has effectively squelched needed improvements, as well as competition and innovation, for decades.

Whether the goal is funding a demonstration project or sustaining the improvements after the funding runs out, many are examining smart grid costs and benefits. A common argument is that modernizing the electricity distribution grid is too expensive and that the majority of benefits go to the utility, at the expense of the consumer. This is a valid concern, as the system is currently designed to prioritize the needs of the supplier and its shareholders.

Electricity is one of the few business sectors where performance and earnings are not directly aligned with the interests of consumers or their satisfaction. Instead, utilities answer primarily to state regulatory agencies, elected officials and to a lesser degree federal authorities, and operate under monopoly and regulatory rules that were established during the New Deal when the nation was originally being electrified. As a result, a utility's rates and earnings are based largely upon what it spends to make and deliver power to consumers, not the quality and efficiency of the electric service. It is also not generally held accountable for economic losses due to power outages, nor do utilities have incentives to invest in research, development and the useful products and services consumers expect of other industries. In many ways, the electricity system is a vestige of the past century.

Thanks to stimulus funding, utility service providers are beginning to take steps to address these inadequacies. As such there has been a flurry of activity aimed at developing a sound business case for the smart grid. Done right, the smart grid shifts the focus from the utility to the consumer – the demand side of the meter – by enabling the numerous service and even supply opportunities that an effective smart grid transformation can make available there. Only then will smart grid benefits outweigh its costs, and grow over time as end-users become active buyers and sellers of electricity

THE POWER SYSTEM THAT EVOLVED IN THE LATE 19TH CENTURY TO PROVIDE POWER TO THE NEWLY INVENTED LIGHT BULBS...

1879 — Thomas Edison developed a "Practical Light Bulb"

Line crew of Niagara Falls Power Co. in 1895

... HAS REMAINED ESSENTIALLY THE SAME AS IT POWERS THE ESSENTIAL SERVICES AND THE DIGITAL REVOLUTION IN THE 21ST CENTURY

August 29, 2005: Power poles are pushed over in a flooded street after Hurricane Katrina

- Powers the critical pumps that provide our water and make drinking water in a water treatment plant
- Powers the communication towers and central telephone stations that are essential for the communication infrastructure
- Powers the essential life-saving services in a hospital and for in-home care
- Powers the continuous process industries that are the lifeblood of an industrial society
- Powers the computers, servers, routers and the billions of power supplies that power the digital revolution

and innovators and investors are incented to engage in bringing the system into the digital age. This paper discusses the model that maximizes the return on the smart grid investment: the smart microgrid.

WHY ADD INTELLIGENCE?

The basic idea of the smart grid is to replace today's passive, one-way, analog-controlled electricity distribution system with one that is two-way and in tune with 21st century needs. We face a formidable set of challenges today, with the electricity service industry at the nexus of at least three major issues. One is the **rising cost of energy**, in a world where the impact of carbon dioxide emissions upon the climate has led to grave concerns about several of the main fuels and mechanisms for generating electricity. Another is the comprehensive transformation of the **U.S. from an economy and living standard based on analog mechanical devices to one enabled by digital electronic technology**, the latter of which requires a much higher standard of electrical quality and reliability. The third and closely related challenge is the **increased vulnerability of electricity service** to natural and man-made disturbances.

A smart grid which emphasizes the local consumer service distribution systems could resolve each of these issues and in turn yield numerous benefits to individual consumers, businesses, the economy and the environment. Think of the existing electromechanically controlled grid as analogous to the one-way radio broadcasts of the 1930s; the smart grid would function much like the Internet. Indeed, the smart grid can be best understood as integrating a comprehensive electronic control and telecommunications system with the existing grid, providing an instantaneously accurate two-way flow of energy and information. This will give

SIX KEY CHARACTERISTICS OF A SMART GRID

- **It is self-healing.** The grid rapidly detects, analyzes, responds to and restores faults.
- **It empowers and incorporates the consumer.** It accommodates consumer equipment and behavior in grid design and operation.
- **It is tolerant to attack.** The grid mitigates and is resilient to physical and cyber attacks.
- **It provides the power quality needed by 21st century users.** The grid provides quality power consistent with consumer and industry needs.
- **It accommodates a wide variety of supply and demand.** The grid integrates resources ranging from demand-response and combined heat and power to wind, solar and other renewables.
- **It fully enables maturing electricity markets.** The grid allows for and is supported by competitive markets.

consumers at all levels user-friendly control of their electricity use, which will result in much higher efficiency and much lower cost. Moreover, as alternative power generation systems are installed on homes and large buildings, the smart grid can efficiently route any excess electricity produced to where shortages exist, reducing and perhaps eliminating the need for expensive and environmentally detrimental new power plants while providing an additional revenue stream for consumers. But achieving this reality requires a fundamental change from the electric utility industry's traditional focus on supply-side technology and infrastructure, which ends at the meter, to the demand side.

Bringing about a holistic, robust smart grid transformation will require that these regulations change to reflect the tenets of demand-side economics and the basic rights of consumers in the marketplace. The Galvin Electricity Initiative has developed a set of Electricity Consumer Principles that are based on end-user needs and are designed to guide policymaking in this sector; they are included at the end of this paper.

The technical path to a smart grid is a bit clearer than the regulatory one; the areas of innovation have been identified and are within reach. They include:

THE GRID TRANSFORMATION RESULT

20th Century	21st Century
Analog/electromechanical	Digital
Totally centralized	Accommodates decentralized
Radial topology	Network topology
Manual restoration	Self-healing
Average priced	Real-time priced
Commodity-based	Service-based
No consumer choice	Many consumer choices

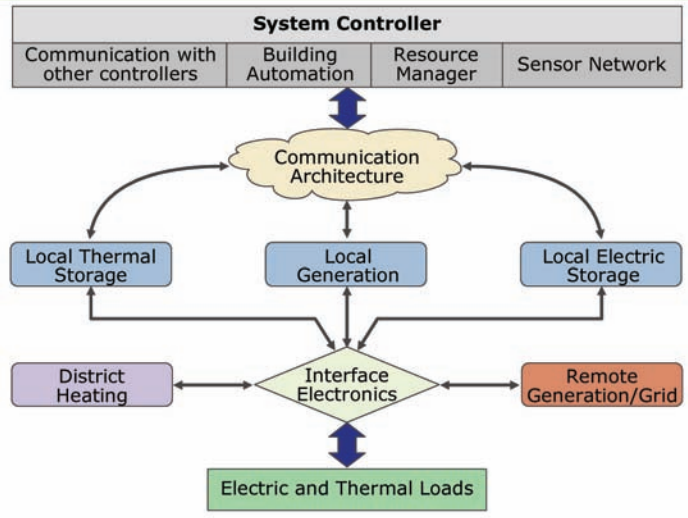
- **Merging electricity and telecommunications** to create a dynamic infrastructure that enables today's electronic appliances and end-use devices to automatically exchange electricity and information with the bulk power distribution grid.
- **Electronically controlling and monitoring the distribution system** in order to direct the flow of power with pinpoint precision, and to anticipate disturbances and correct them before they occur.
- **Transforming today's "iron curtain" electric meter** into a smart consumer portal that enables electricity, price signals and demand decisions to flow back and forth at the direction of the consumer.
- **Seamlessly integrating local distributed power resources**, including solar power and plug-in hybrid electric vehicles, allowing communities and consumers to purchase *and* profitably supply excess power, while also helping states meet clean energy standards.

Only when it embraces each of these technical areas will the distribution grid be truly smart. And with intelligence comes reliability, security, economic vitality and efficiency, as well as environmental performance. The result is the electricity equivalent of the Internet: an "electranet" that distributes electricity the way the Internet distributes information, through a network of smaller, local power systems that involve consumers and businesses as full participants.

MICROGRIDS: IMPLEMENTING THE SMART GRID ON THE LOCAL LEVEL

The system architecture that achieves smart grid benefits and value most cost-effectively and touches on each of the four technological areas above is the **smart microgrid**. Built for office parks, resorts, universities and entire communities, these systems incorporate the range of smart technology in one location. They augment

DISTRIBUTED MICROGRID POWER SYSTEMS



the bulk grid with alternative and renewable power generation, which in turn expedites investments in such resources and reduces the reliance on conventional power. Intelligent controls provide the unfailing service reliability that is required in the digital era. Customers have the ability to take advantage of changing electricity rates automatically and in real time, which will allow them to make informed choices about their consumption.

These smart local power distribution systems can grow and self-organize in response to individualized user needs while significantly raising the consumer value. Indeed, these entrepreneurially developed and implemented smart microgrids are intended to work in cooperation with the local bulk power utility, which remains the primary energy source. In the future, utilities will likely operate under different rules, with different incentives that emphasize reliability and a lighter environmental footprint, rather than merely delivering "dumb" electricity. And while the transformation may well generate discomfort and even resistance, it's clear that bulk power utilities will be critically needed assets for many decades to come.

A COST-BENEFIT ANALYSIS

The costs of distribution grid modernization to a typical U.S. household are quantifiable and the benefits significant. Tables 1 and 2 (located on page 6) show an evaluation of the investment and annual payback of the various elements involved. While a smart grid project might choose to focus on only a few of the upgrades listed, a smart microgrid integrates all of them, and thus maximizes the return on investment. In essence, microgrids are a way to optimally build the consumer-focused smart grid, one community at a time.

For communities and their citizens, the revolutionary adoption of smart microgrids is estimated to have a benefit-to-cost ratio of at least 4-to-1 within five years of installation. Beyond that, the potential for growth is limited only by the energy needs of the location at hand. More qualitative benefits include fairer and more equitable electricity rates; improved customer satisfaction; the encouragement and assimilation of continued

PERFECT POWER AT IIT

The Galvin Electricity Initiative is a leading advocate of the cooperative and yet entrepreneurial microgrid model, through a project now under development at the Illinois Institute of Technology in Chicago. Even while acquiring most of its electricity from the local utility, Commonwealth Edison, the university's computer-controlled smart grid will prevent blackouts, reduce energy consumption, enable power sales to the utility grid and ensure that IIT's digital equipment is supplied with perfectly reliable power.

TABLE 1: GRID MODERNIZATION COSTS PER RESIDENTIAL RATE PAYER

Technology	Installed Cost
1. Integrated Communications	$40
2. Automatic Sensing and Measurement	$30
3. Distribution Automation	$120
4. Substation Automation	$200
5. Circuit Loops and Smart Switches	$500
6. Distributed Energy Microgrids	$500
7. Smart Consumer Portal Meters	$200
Approximate Total	$1,600
ANNUALIZED CAPITAL COST (10 YRS)	$200/YR
ANNUAL O&M COST	$25

TABLE 2: BENEFITS PER RESIDENTIAL RATE PAYER

Category	Net Present Value/YR
1. Improved Reliability	$250
2. Electricity Consumption Savings	$100 +
3. Time of Use Savings, Shifting Peak Demand	$75 +
4. Avoided Capacity Costs	$120
5. Job Creation and Increased Income	$300 +
6. Reduced Power Distribution and Competition Losses	$25
Approximate Total	$870 + /YR
Longer Term Potential • Households Become Electricity Suppliers • CO_2 Emissions Reduction (15¢/kWh) • Energy and Homeland Security	$1,000 + 300 + priceless

innovation; robust competition with expanded and higher quality retail offerings; and perhaps most important, greater security with much reduced vulnerability to natural disasters or attacks against the electricity system.

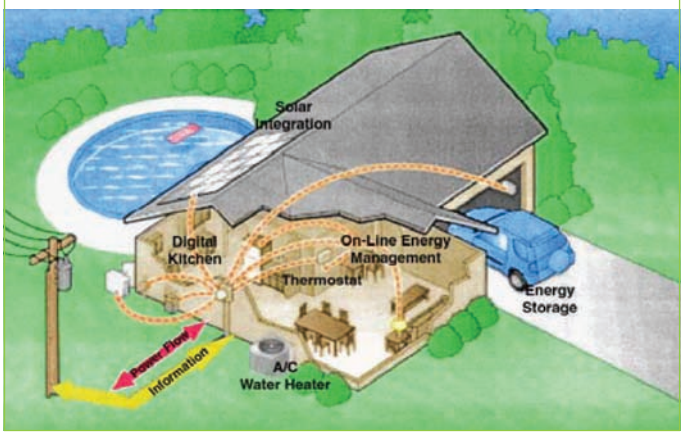
Given the societal benefits, cost-benefit analyses for both smart grid projects at all levels require that these benefits be quantified, as best they can be. While several financial models have been offered to do this, there are some basic facts that add perspective to the figures in Tables 1 and 2:

- The cost of electricity unreliability is passed on to consumers in the price of all the goods and services that they purchase. This unnecessary cost adds at least $1,000 a year to each household's expenses and on average more than doubles the real cost of electricity. While a smart local distribution grid cannot eliminate all these costs, it can easily reduce them by at least 25 percent.
- A smart grid that provides real-time price signals to household appliances can, at the homeowner's discretion, save significant power and money. Electricity prices can easily soar five times higher in the course of a single day, especially in peak periods when collective demand is the highest, such as late afternoons during heat waves.
- Utilities are required to build plants to meet peak demands, even though the facilities may sit idle 80 percent or more of the time. The capital costs of this underutilized reserve capacity are embedded in rates paid by all consumers. If smart grids allow the collective consumer base to shave peak demand, the need for such plants may vanish—an exchange, so to speak, of kilowatts for negawatts.
- One of the greatest benefits of a smart distribution grid revolution to individuals and communities is the opportunity for job creation and increased income. Direct jobs would come from installation and service of smart grid systems; communities with smart and totally reliable smart distribution grids will have a distinct advantage in attracting modern digital-based businesses and industries, which also generate high-value employment and tax revenue.

In sum, the savings and improved quality of life that are part of the smart grid vision are limited only by our imaginations. A properly designed and developed smart grid project – ideally a smart microgrid – promises to:

- Enable active participation by all consumers;
- Accommodate all distributed power generation and storage options;
- Facilitate the rapid and economic adoption of alternative energy production, which in turn can help reduce carbon emissions;
- Provide the power reliability and quality needed by the digital economy;
- Support new entrepreneurial energy markets, including allowing consumers to sell excess production into the bulk electricity market;
- Optimize grid asset utilization and efficiency;
- Anticipate and instantly correct system disturbances; and
- Operate resiliently against attack and natural disaster.

SMART GRID SYSTEM INTEGRATION AT THE CONSUMER LEVEL



THE URGENT NEED FOR REGULATORY REFORM

A variety of entrepreneurial private enterprises both large and small are poised with the technology and capital to work with communities and their citizens to transform their distribution grids and electricity service quality. Given the opportunity, these innovators can profitably produce savings for the consumer, the community and even existing utility companies. While each smart grid project will yield a set of learnings in this arena, in most cases their value is limited by a broad set of hard regulations – arguably fossilized remains of a different time – that are impeding the energy evolution that the regulations originally envisioned.

Indeed, in most jurisdictions it is illegal for any entity other than a utility to string a power line over or under a street. The law made sense in the late 1800s, when a dozen power companies were competing for customers along a single avenue. Today, it prohibits companies, communities and others from connecting buildings in a smart microgrid. The utility monopoly can also limit home automation, which works to further restrict consumers. While the dynamics around the power business have obviously changed, America has a model of the potential for wise reform: the telecommunications industry.

OBSTACLES

Ineffective governance
Short-term thinking
Inability to imagine the new virtual utility paradigm
Lack of collaborative spirit
Lack of standards, definitions, interoperability
Unwillingness to deconstruct the paradigm

Today's power system is in fact very much like the telephone monopoly prior to 1984, when consumers were forced to rent a black, rotary-dialed phone from the original AT&T, and had no other options for equipment or service. Thanks to sweeping legislation that broke up this monopoly and opened the door to competition, the telecommunications choices that emerged – including cell phones, wireless computers and all that's followed – was an advancement with a value equivalent to the Industrial Revolution, if not greater.

Attempts to deregulate electric power in the 1990s had limited success at the wholesale level. Under the guise of "protecting rate-payers," state regulations still give retail customers no choice of electricity service providers, and discourage utilities from innovation and upgrades other than for emergencies. The focus is not on multiple sources of bulk power, but rather on giving consumers access to a range of services and technology that can help them use that power to best advantage. The federal Energy Independence and Security Act of 2007 – which includes support for smart grid investments – was an encouraging step, but it did not put in place compliance requirements for states. This is critical because electricity has evolved as a regional enterprise, with most policy control resting with the states.

> "THE PERFECT POWER SYSTEM WILL ENSURE ABSOLUTE AND UNIVERSAL AVAILABILITY OF ENERGY IN THE QUANTITY AND QUALITY NECESSARY TO MEET EVERY CONSUMER'S NEEDS. IT IS A SYSTEM THAT NEVER FAILS THE CONSUMER."
>
> Bob Galvin – founder, Galvin Electricity Initiative

The Electricity Consumer Principles

The Galvin Electricity Initiative intends to bring these issues and possibilities to the forefront of political and social discussions. Only an informed and resolved citizenry can persuade institutions and regulators entrenched in the status-quo – however sensible that structure once was – to consider major changes to a system as important to the nation's well being as electricity generation and distribution. The benefits of such change are abundantly clear.

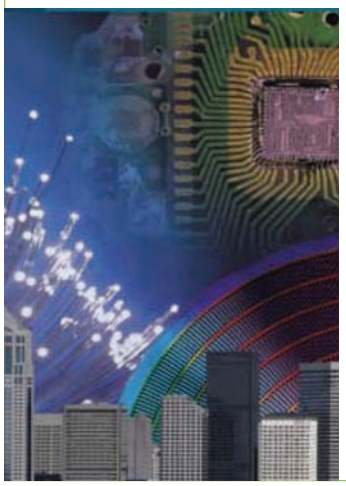
While the smart grid is a complex undertaking, the Initiative promise of encouraging technical advances in working microgrid projects, educating the public on the possibilities of the smart grid and advocating for policy and regulatory change will bring clarity and purpose to this challenge. Built on the conviction that **quality always saves**, perfection, based on the consumer's perspective, is a fundamental principle guiding the Initiative.

Therefore, the Initiative has articulated five Electricity Consumer Principles that serve as a consumer bill of rights and create a new industry paradigm that is consumer-focused, where communities and citizens are no longer mere rate-payers, but active participants and benefactors.

1. **All electricity consumers have the right to receive dynamic electricity pricing** and the means and incentives to use this information to their best advantage.
2. **All electricity consumers have the right to buy their retail electricity services from any source they choose** in open, competitive markets.
3. **All electricity consumers have the right to electricity service system reliability and quality** that protects life and safety under all conditions, and meets the needs of today's digital society.
4. **All electricity consumers have the right to access, at all times, the fully transparent performance metrics** of their electricity service system.
5. **All communities have the right to improve their electricity distribution system**, with the full cooperation of their utility, in order to best serve the needs of their citizens.

States, utilities and leaders around the country are beginning to recognize that given our current climate, reliability and economic concerns, the business model for the electricity industry needs to change. The new paradigm will recognize the Electricity Consumer Principles and embrace consumer participation, entrepreneurial innovation, distributed generation and private investment. The challenge now is to use the momentum and public awareness generated by federal legislation to explore changes in not just the infrastructure, but the rules that govern it as well. **The intelligent transformation of both infrastructure and policies is the key to achieving a confidently sustainable economic, environmental and energy future for today's citizens and for future generations.**

VALUE OF THE 21ST CENTURY TRANSFORMATION



Increases the functionality and value of electricity through consumer benefits that far outweigh the cost

- Transforms power system reliability and security
- Increases productivity and GDP growth rates
- Substantially improves energy efficiency and electricity intensity
- Accelerates reduction in carbon emissions
- Reduces the cost of infrastructure upgrades and expansion

Suggested Readings

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3. Integrating New and Emerging Technologies into the California Smart Grid Infrastructure, Electric Power Research Institute for the California Energy Commission; Sacramento, CA (CED-500-02-014 (April 2008).
4. Power Delivery System of the Future – A Preliminary Estimate of Costs and Benefits; Electric Power Research Institute Final Report 1011001, Palo Alto, CA (July 2004).
5. San Diego Smart Grid Study Final Report, prepared by Science Applications International Corp. (SAIC), for the University of San Diego School of Law (October 2006).
6. The Cost of Power Disturbances to Industrial and Digital Economy Companies, Electric Power Research Institute Final Report 1006274, Palo Alto, CA (June 2001).