Pecan Street Inc. Summary Report

By the Capital Area Council of Governments
About this Paper

The following report chronicles CAPCOG’s involvement in an EDA-funded project (opportunity number EDA10012008EDAP) awarded with the express intent of fostering and observing the creation of a new innovation-based industry cluster within Central Texas. As part of this grant award, Pecan Street Inc. produced three exhaustive reports outlining their efforts at spurring clean energy innovation within the Austin region. While these publications provide a comprehensive account of the challenges and potential opportunities related to smart grid technologies, they also include significant technical detail. Readers interested in obtaining thorough understanding are encouraged to read these three white papers included in a separate technical addendum.

In contrast, this summary report provides a concise overview of Pecan Street Inc.’s work. Written by CAPCOG Executive Director Betty Voights and Economic Development Director John Rees, this report is based on information from reports and documents shared with CAPCOG, including deliverables in the contract funded by EDA as well as other articles in the media and public domain.

This planning project was accomplished by the Capital Area Council of Governments under Project No. 08-83-04453. The statements, findings, conclusions, recommendations, and other data in this report are solely those of the contractor and do not necessarily reflect the views of the Economic Development Administration."
I. Why did CAPCOG invest in the project?

Many metro regions and beyond are now interested in all that is green – jobs, energy, buildings. In 2009, the Austin Regional Office (AURO) of the Economic Development Administration (EDA) approached an economic development district in each of its five states to solicit projects involving innovation clusters. Operating under the premise that future economic development strategies needed to be sustainable, CAPCOG determined that innovation was a necessary ingredient. CAPCOG in its capacity as the Capital Area Economic Development District was one of the five approached and thus began to contemplate what an “innovation cluster” might involve. CAPCOG met with Greater Austin Chamber of Commerce, the Austin Technology Incubator, Austin Energy, and others who are typically ahead of the curve on economic opportunities. Familiar with the Pecan Street Project initiative related to renewable energy and deployment of a smart grid, CAPCOG staff met with the Pecan Street board to learn more and ultimately decided that the nature of the project and its links to the university and private sector would likely generate business spinoff opportunities that could be the beginning of an industry cluster in the region—an innovation cluster.

Becoming a region recognized for clean energy and smart grid technological innovation seemed likely for Central Texas. The region’s standing as a significant technology economy is believed to have come about when we were successful in being designated the MCC site, the first computer research and development consortia in the United States. While Austin remains competitive in many aspects of technology development such as semiconductors and other chips that power today’s electronic devices, there have been a few ups and downs and our employment trends show job losses of more than 6,000 during the past decade in this sector which suggested that we need to begin to think about positioning Austin and the surrounding region to take advantage of the world’s next innovation-driven, technologically disruptive industry cluster—clean energy and related smart grid technologies.

According to “Competitive Strategy: Techniques for Analyzing Industries and Competitors” by Michael Porter, Harvard economist and creator of the cluster concept, a cluster built around energy displays characteristics of emerging industries forming or reforming through technological innovations, shifts in relative cost relationships, emergence of new consumer needs, or other economic and sociological changes that elevate a new product or service to viable business opportunities.

In 2009, CAPCOG contracted with the Pecan Street Project, later to become Pecan Street Inc., using AURO funding. The funding was necessary to ramp up the Pecan Street Project as it obtained funding for its proposed grid research and ongoing operations and testing. In return for the funding, CAPCOG became an integral factor in the organic formation of a new industry cluster from the earliest stages. Furthermore, CAPCOG’s investment ensured that Pecan Street Inc.’s staff would document this process; that documentation is contained in the three attached white papers:

- The Customer-focused Smart Grid, Part 1: What’s in it for the Customer?
The impetus for Pecan Street’s formation was a Spring 2008 discussion between City of Austin and Austin Technology Incubator representatives about a clean energy economic development collaboration; when CAPCOG became familiar with the Project, economic development was a consideration but the focus was on renewable energy.

“Technologies are developing that are starting to integrate the major energy systems of utilities, buildings, and transportation sector and communications. That’s going to fundamentally change the way people generate, use, and think about energy. There are a lot of elements of this project dealing with that bigger picture” according to a New York Times quote by Roger Duncan, former general manager of Austin Energy and president of the Pecan Street board. Duncan’s comments would turn out to be even more prophetic than that quote indicated at that time.

II. How Pecan Street Inc. started – a focus on energy distribution and user power management

Pecan Street Inc. was unveiled in December 2008 by a consortium of the Austin Chamber of Commerce, Environmental Defense Fund, the City of Austin with Austin Energy, and UT’s Austin Technology Incubator. The Project as described by then Mayor ProTem Brewster McCracken was to design a new energy infrastructure, a proving ground for energy technology of the future. Pecan Street Inc. was incorporated as a 501c3 in 2009 and began its work on a smart grid interoperability lab with $50,000 of seed funding from UT. McCracken would ultimately be named the executive director.

As Isaac Barchas, director of ATI and Pecan Street Inc. board member, noted in a September 2009 article in the Austin Business Journal, “today most electricity is produced in big generation facilities and passed down dumb pipes to consumers who have very little control over how it is used or what they pay for.”

In a document developed by Pecan Street Inc. in March 2010 titled “Working Group Recommendations,” some of the goals cited include:

- Allow for a real-time two-way flow of energy and data
- Customers can sell excess power
- Users manage use and consumption online or on their phones
- Austin Energy can better control peak demand while customers will be encouraged to use less energy
- An integrated grid management for both electric and water
- Reduced carbon output
- UT leads nation in clean energy patents and start-up companies
- Austin becomes the clean energy capital of the nation
While a pretty expansive list for the Project to achieve, ultimately their work would result in revelations that would be more far reaching than this list.

The Pecan Street Inc. began to attract corporate interest from companies joining their consortium including Freescale, Intel, Oracle, Sony, Best Buy, LG Electronics. It also established formal research collaborations with National Renewable Energy Laboratory, Galvin Electricity Initiative, and Underwriters Laboratories. Participation in the consortium provides member companies with an unparalleled opportunity to deploy and test their products in a real-world environment.

The Pecan Street Project not only gives companies a chance to test their innovations in a more cost-effective manner, but also allows companies to observe how their technologies interact with other products. The world’s most advanced personal computer, for example, would be relatively worthless without the ability to connect to the internet, your phone, your office server, and your printer—much of the value of a computer rests with its ability to leverage a broader network of devices and applications. Smart grid technologies operate within a similar technological framework—consumer-driven innovations will likely succeed or fail depending on their ability to integrate with a host of other technologies and appliances.

III. What the Project demonstrated

By 2011, Pecan Street Inc. began to frame the foundation for their ultimate findings.

Power grids haven’t changed much since the beginning of the 20th century as the business of getting electric power to the customer has expanded in scale but didn’t change much in concept. Power plants’ generators convert a source of energy into electricity which is transmitted through a distribution system to a customer – residential, commercial, or industrial. Improvements have come in standardization cost reductions, scale, resilience, access, and multisourcing from nuclear, wind, coal, solar, geothermal. Yet these advances still support a centralized unidirectional electric power transmission, distribution, and demand-driven system.

Electric grids are still challenged by high, uninterruptible demand as well as quality of service protocols based on priorities, security threats, employment of alternative power generation for intermittent supply, and conservation goals that also lessen peak demand surges. Addressing these challenges are important for the utility and for the “greater good.” Knowing more about and fixing problems with the electrification “system” is not a consumer concern or problem thus discussions about future modern grids paid little attention to the consumer.
Pecan Street Inc.’s work is extremely significant because it postures that, only when the consumer becomes a driving force, does the modern grid become relevant as a realistic energy conservation approach, and for this project, a contributing factor to business development.

To redefine the industry, the successful smart grid will:

- Enable the provision of power resources on demand rather than as a fixed asset.
- As demand increases, the job of the grid is to manage the load while keeping the complexity invisible to users.
- Costs are incurred only as resources are needed in these new economics of power distribution.
- The smart grids are “hired” by user applications, not by users acting as administrators.

**IV. How Innovation Seeds the Cluster**

Is this an industry worth getting into and if so, how do you get into it? Brewster McCracken asked this question at the beginning of his October 2011 presentation to the Capital Area Economic Development District board. Then he went on to explain innovation. This conversation becomes important to any economic development proponent seriously interested in understanding innovation clusters.

McCracken explained disruptive innovation, sustaining innovation, and regulatory fiat – the three underlying causes for a business to innovate. When a law and regulation drive demand for a product such as the requirement for smoke detectors, it’s considered regulatory fiat. When an existing product must continually be updated with new bells and whistles – think of laundry detergent, airplanes, smart phones – this is sustaining innovation. Disruptive innovation occurs when a new technology replaces existing products like transistor radios, paper maps, photocopies, cameras using film, and calculators. The Pecan Street inc. would provide examples of each type of innovation.

Energy conservation will spur business development as technology enables consumers to have choices from home services systems that will integrate smart appliances, solar panels, electric automobiles, advanced thermostats, home security systems, and energy storage devises. Innovation will occur within each of these niche areas, providing rich opportunities for nascent start-ups. Additionally, the emergence of these devices will give rise to a new information network requiring critical innovations in home management software. The new network must manage communication between all of these devices while also providing relevant information to both the customer and the utility. Ultimately, the resulting wave of innovation will create new, unimagined technological hurdles. Within high-technology industry sectors, however,
problems often become the foundation of cutting-edge companies that create solutions via innovation.

So what is this cluster likely to include? Perhaps the cornerstone of this new cluster was the realization that some type of internet like that which connects banking, digital media, and entertainment was needed to connect an energy system. When it came time to install such a system, the Pecan Street Inc. quickly discovered that there no cost-effective products on the market. Thus the Pecan Street Inc. solicited proposals from a multitude of firms. After testing the technologies of several national and international companies, the Pecan Street Inc. selected a new product from the start-up firm Incentergy. The company’s team is a microcosm of the smart grid sector, with employees possessing a diverse range of experiences in software development, data communications, wireless technology, and electricity infrastructure. Just as no single company initially possessed the capacity to deploy a smart grid system sufficient for the needs of the Pecan Street Inc., no single professional discipline provided the skills necessary to develop a capable smart grid system. As is often the case with high-tech industry clusters, innovation is only possible through the integration of previously separate areas of expertise.

Innovation, however, starts with a proper understanding of the problem to be solved via technological advances. Pecan Street Inc. is predicated on the idea that the successful adoption of smart grid technology will rest on consumer demand. Virtually all previous smart grid projects have been motivated by the desire of utilities to address difficulties in making electricity demand more level and predictable. Unfortunately, such approaches provide very little value to most end users of electricity and have thus far failed to catalyze meaningful economic growth or produce regional technology clusters. Pecan Street Inc. set out to change this.

Pecan Street Inc.’s customer-oriented approach might seem curious at first. Residential customers, for example, consume far less energy than commercial and industrial users. Nonetheless, changing residential customer behavior is important for several reasons—there remains far more curtailment capacity in the residential sector, as commercial and industrial electricity users have invested in significant efficiency measures in recent years. Additionally, residential users are the prime cause of electricity load spikes and thus a primary contributor to peak demand spikes.

All too often, however, getting residential customers to change behavior by not running appliances during peak demand only serves the interest of the utilities. Because the cost of electricity is the same regardless of time of day it is used, a comprehensive energy management system will be required to drive smarter energy consumption. Developing such a system, however, requires real-time data on energy usage.

As a result, the first step in creating a consumer-driven smart grid system is to understand the behavior of residential consumers. While we would like to say energy conservation will be


driven by our environmental concerns, ongoing reports about the planet’s problems have not produced a seachange of energy usage by the average household. As Pecan Street executive director Brewster McCracken explained, “Before anyone starts prescribing solutions, we must develop a much better understanding of what customers value and how they’re using energy now.”

Pecan Street Inc. quickly discovered that there was a dearth of information on consumer behavior. Prior to the efforts of Pecan Street Inc., for example, there was but a single publicly-reported research project on the daily energy profiles of Sunbelt homes. Furthermore, the study was more than 10 years old and did not incorporate data on rooftop solar panels and the presence of the homes’ energy efficiency attributes. If Pecan Street was going to analyze consumer electricity behavior, it was going to have to collect the data itself.

In 2010, Pecan Street Inc. announced the selection of Austin-based Incenergy for the first deployment of advanced smart grid systems in the organization’s smart grid demonstration project in the Mueller community. Incenergy’s system integrates the company’s sophisticated energy measurement software with voltage measurement and wireless networking hardware to measure and manage the minute-to-minute energy usage of a range of home appliances and systems. In deployment’s first phase, Pecan Street established “before” energy use profiles for residential units at the Mueller community prior to the installation and testing of new technologies, information, efficiency and pricing systems.

Pecan Street Inc. has deployed monitoring technology in 100 homes at Mueller, all of which are green built and 11 of which have rooftop solar PV systems, as well as a second group of 100 homes outside Mueller that are at least 10 years old. Data captured from participating homes is wirelessly reported to and securely maintained at the University of Texas’s Texas Advanced Computing Center. Already, the scale and depth of Pecan Street’s detailed information on energy and water use at the residential level is unrivaled.

As the Pecan Street deployed its advanced smart grid systems, the organization was also working to establish a Smart Grid Consortium along the lines of previously successful models such as MCC and SEMATECH. In 2011, the Pecan Street announced its Industry Advisory Council members, an impressive list of some of the county’s leading technology, retail, and consumer product companies. Currently, the consortium is comprised of Best Buy, Freescale, Intel, Landis+Gyr, LG Electronics, Oncor, Oracle, SunEdison, Sony, Texas Gas Service, and Whirlpool. Together, these companies will work with Pecan Street Inc. to test, evaluate and endorse consumer smart grid architectures, metrics, systems interoperability and applicable industry standards.

In 2011 Pecan Street Inc. also announced a partnership with General Motors. As part of the agreement, Chevrolet will provide 100 Volts for purchase or lease by Mueller residents
participating in the Pecan Street demonstration project. Thanks to incentives from Pecan Street Inc., as well as existing federal rebates, the purchase price of these Volts will fall to approximately $25,000. Ultimately, the launch of the Chevy Volt program will likely create the densest electric vehicle neighborhood in the country. As executive director Brewster McCracken explained, Pecan Street Inc. is “going to test the impact these vehicles have on household energy use and the grid itself, and we will try innovative solutions that charge the cars with rooftop solar panels.”

Pecan Street Inc. is also preparing to break ground on $1.5 million research laboratory that will provide researchers and companies with an unparalleled opportunity to better understand the relationship between customer and smart grid technologies. The research lab will allow researchers from Pecan Street Inc., The University of Texas, National Renewable Energy Laboratory, multiple utilities and private sector companies to test and evaluate interoperability industry standards. The lab will also test performance and integration of multiple companies’ home smart grid systems with electricity, gas and water utility distribution and back office systems.

Together, Pecan Street Inc.’s demonstration site, technology consortium, and the research laboratory place the Austin region at the forefront of smart grid technological innovation. Much like past innovative ventures such as MCC and SEMATECH helped spur the region’s rise as one of the world’s leading clusters for semiconductor manufacturing, the efforts of Pecan Street Inc. may lead to the emergence of another leading innovation cluster within Austin. The Pecan Street Inc. research laboratory, for example, will allow smart grid companies to test and verify their product prior to launch. As Isaac Barchas, Director of the Austin Technology Incubator explains, "There’s no other place in the world where companies can go and study how human behavior interacts with energy."

Ultimately, the competitive edge provided by Pecan Street Inc. will produce a wave of innovative start-ups within the Austin region (much like Incentergy). Already, SustainLane Government, an online exchange for government officials involved in sustainable development, named Austin a “Cluster Maven.” And we’re just getting started. In the years ahead, public officials and corporate leaders within the Austin may look back on 2009 not as a period of economic difficulty, but as the initial seed that introduced an exciting era in the region’s history that helped promote long-term economic prosperity and to economic developers, a regional innovation cluster.
I. The Customer-focused Smart Grid, Part 1 - What’s in it for the Customer?

II. The Consumer-focused Smart Grid, Part 2 - The Disruptive Smart Grid

III. Creating a Smart Grid and Clean Energy Economic Cluster in the CAPCOG Region
The Customer-focused Smart Grid, Part 1

What’s in it for the Customer?

The utility challenges driving smart grid are legitimate and significant...

...but current approaches on smart grid and clean energy are unlikely to create consumer buy-in or drive new green collar job opportunity

by

Brewster McCracken
Horace Dediu
Preface
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Executive Summary

Smart grid has been hailed as the next Internet or the next wireless telecom – a $100 million market that will drive a seismic wave of green technology economic growth that “could be the largest economic opportunity of the 21st century.” ¹ Consumer excitement for smart grid will take off, some smart grid advocates say, once customers are educated on how smart grid will benefit them. ²

That raises two questions. First, what benefits are customers actually poised to realize from smart grid? And, how do these touted benefits compare to the benefits that consumers realized from the economic booms to which smart grid and clean tech are compared: the Internet and wireless telecom?

In no particular order, here are lists of consumer benefits that have emerged out of the Internet and wireless telecom revolutions:

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<th>Benefits of Internet</th>
<th>Consumer products</th>
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<tr>
<td>Access to information</td>
<td>World Wide Web, Wikipedia, Google</td>
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<tr>
<td>New forms of communication</td>
<td>Email, blogs, Skype, Webex</td>
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<tr>
<td>Online marketplace</td>
<td>.com, Amazon, Expedia</td>
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<td>Entertainment choices</td>
<td>Netflix, YouTube, iTunes</td>
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<td>Social connection</td>
<td>Facebook, LinkedIn, chat, Match.com</td>
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<th>Benefits of wireless telecom</th>
<th>Consumer products</th>
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<tr>
<td>Communication mobility</td>
<td>mobile phones, text messaging</td>
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<tr>
<td>Access information anywhere</td>
<td>mobile Internet, Google Maps, AroundMe, Yelp</td>
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<tr>
<td>Access services anywhere</td>
<td>Fandango, Open Table, mobile banking</td>
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<tr>
<td>Mobile apps – hundreds of thousands</td>
<td>App Store, Android Marketplace</td>
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<tr>
<td>Mobile entertainment</td>
<td>Pandora, Angry Birds, Netflix app</td>
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<tr>
<td>Mobile computing</td>
<td>iPhone, Android, iOS, productivity apps</td>
</tr>
<tr>
<td>Social connection</td>
<td>Twitter; Facebook app, Flickr, Game Center</td>
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Now, let’s compare these to commonly touted benefits of smart grid: 3

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<th>Touted benefits of smart grid</th>
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<tr>
<td>Improved billing efficiency</td>
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<tr>
<td>“utility cost savings from remote and automated disconnects”</td>
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<tr>
<td>Faster outage detection</td>
</tr>
<tr>
<td>Fewer trucks to read meters</td>
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<tr>
<td>Help utilities integrate more renewables</td>
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<tr>
<td>“customers will be transformed from passive ‘ratepayers’ to active, engaged participants in electricity markets”</td>
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However helpful each of these may be, to the customers who pay for smart grid deployments these benefits increasingly appear underwhelming.

That is the view of the Association for the Advancement of Retired People (AARP). “We vigorously oppose the mandatory imposition of these smart meters in peoples’ homes,” says AARP spokesperson Marti Doneghy. “Everybody has to pay for this change, and a lot of the 50-plus population simply isn’t that interested.” 4

Disinterest may be the least of utilities’ problems. Take this post from Tea Party Patriots:

**What is Smart Grid?** Smart grid is just like it sounds; a power grid that is infused with smart technology. This can give utility companies and the government information like when you leave and get home from work each day by analyzing the amount of power that is used. They will be able to control the temperature within your home by remote access and even shut the electricity off when they deem it to be most efficient for them. If this should become mandatory and by the looks of things it will; [sic] you will pay lots more for electricity. I am personally against this type of government and corporate intrusion into my life. 5

In its postmortem of Xcel Energy’s SmartGridCity in Boulder, Colorado, Time magazine concludes:

[T]he fanfare exceeded the reality. . . . What’s more, most Boulder residents have yet to see much pay off . . .

. . . .

“From Xcel’s perspective, there are a lot of benefits from the infrastructure they’ve installed,” says Kara Mertz, local environmental action manager for the city of Boulder. “But what the city is interested in, and the community is waiting for, are the customer applications.” 6

As the above reflects, if the only apparent benefits of smart grid are to utility operations, and if smart grid investments fail to deliver clear consumer benefits, customers may question
whether smart grid is even necessary or useful. Or, to put in another way, customers are likely to ask: *What’s in it for the customer?*

The national smart grid effort is approaching an important moment of truth. Will smart grid become the enabling platform for a new wave of innovation and opportunity? Or will it instead descend into an expensive one-time upgrade to utility billing infrastructure?

This is the first of a two-part white paper series, *The Customer-focused Smart Grid*. In these white papers, we analyze the efforts to catalyze a dynamic economic sector built around smart grid and clean energy technologies. The second white paper applies innovation theory and research on the state of industry standards to lay out a roadmap for creating a dynamic smart grid-based economy similar to what was achieved in Internet and mobile telecom.

In this, the first white paper, we take up these initial questions:

- Do utilities really need smart grid?
- Are current smart grid deployment approaches well-structured to create economic, environmental, utility and consumer benefits?

By evaluating original data from the utility sector using utility sector economics and economic innovation theory (developed most prominently by Harvard Business School’s Clayton M. Christensen), we reach the following conclusions:

- **The utility challenges driving smart grid deployments are legitimate, significant, and cannot be solved without use of smart grid technologies.**
- **Current smart grid approaches are unlikely to change consumer behavior or achieve broad consumer engagement.**
- **Current approaches for smart grid and clean energy are unlikely to catalyze meaningful economic growth.**
- **If consumers do not voluntarily adopt smart grid-enabled products and services, smart grid deployments will almost certainly fail to achieve an important outcome that drove their deployment.**

In short, if residential customers decide, for the question, “What’s in it for the customer?” that the answer is, “Not much,” then the national smart grid effort faces the likelihood of failing to achieve its touted promise by nearly every measure.

**The utility challenges driving smart grid deployments are legitimate, significant, and cannot be solved without use of smart grid technologies.**

For utilities, meeting the demand for electricity on summer afternoons and winter mornings is expensive, frequently unprofitable and logistically challenging. (There is a reason why utility discussions of smart grid focus so heavily on ideas like turning off consumers’ air conditioners, charging more for electricity on summer afternoons and on “engaging” consumers to manage their electricity use.)

Electricity system demand varies significantly during a day and also by season. Driven in part by limitations of status quo electricity system technologies, distribution utilities and generation utilities must build, operate and maintain power plants and wires infrastructure
that sit idle for much of the year. From the perspective of retail, distribution and generation utilities, this results in significant market inefficiencies and creates risk.

Moreover, under current economic, technology and customer usage trends, these challenges are likely to intensify. While residential customers make up a smaller portion of overall electricity demand than commercial or industrial, spikes in summer afternoon and winter morning electricity are driven overwhelmingly by residential customers and the surge in power hungry consumer electronics and appliances that fill their home. Early research on electric vehicles suggest that owners’ preferred charging approach is to charge at home in the late afternoon and that electric vehicle ownership patterns will likely cluster. That could lead to even more pronounced spikiness of electricity demand on impacted distribution feeders.

Utilities – particularly distribution and retail utilities – are looking for ways to make system-wide electricity demand more level and predictable. Systems don’t use electricity, though – customers do. Achieving more level and predictable system energy demand will therefore require technologies that provide real-time information on electricity usage down to the meters of individual customers. It could also potentially require technologies to send pricing signals during the day and to alter the energy usage during the day of individual premises and even of individual applications.

In essence, utilities are hiring smart grid to do a job: levelize electricity demand. Legacy electricity systems are not able to perform this job. How will utilities perform this job has significant impacts on reliability, cost of service, customer service, customer bills and utility profitability.

Current smart grid approaches are unlikely to change consumer behavior or achieve broad consumer engagement.

This is not a problem driven by lack of customer education or of inadequate utility public relations. This is a problem of substance.

New technologies like smart meters make it possible for distribution and retail utilities to have better real-time information on energy usage down to individual meters. They also make it possible for distribution and retail utilities to communicate this information back to consumers.

Current smart grid approaches focus overwhelmingly on using new smart grid technologies to charge higher summer afternoon prices and to provide customers with frequent, real-time information about these prices, about their electricity usage and possibly about their usage compared to other customers. Methods of communicating include web portals, emails, text messages, in-home displays and even a display orb that changes color from green to yellow and red to alert customers about grid conditions.

Armed with this information, the hope is, customers will change from passive, uninformed users to active, engaged managers of their electricity usage during the course of the day. Well-established research on choice architecture and consumer behavior – as well as results from early research – demonstrate the likelihood that such approaches will fail to achieve these aims.
Current approaches for smart grid and clean energy are unlikely to catalyze meaningful economic growth.

Under innovation economic theory, for customers to embrace a new technology, it must help them do a job that they are currently trying to do and for which status quo offerings provide an inadequate solution.  

As we will explore in our second white paper, there are a number of important jobs that customers are currently trying to do, for which current offerings are ineffective, expensive or unavailable, and for which energy data, energy efficiency and distributed generation would add valuable functionality.

However, as most current smart grid and clean technologies are currently positioned, they either provide inferior performance on the measures of performance important to the customer compared to the status quo technologies, or they perform jobs that the targeted customers are not currently trying to accomplish.

The relatively poor customer adoption of thermostat programming and the low likelihood that customers will change their behavior noted above suggest that providing customers with products to engage in consciously managing their energy usage is also unlikely to catalyze meaningful growth.

**If consumers do not voluntarily adopt smart grid-enabled products and services, smart grid deployments will almost certainly fail to achieve an important outcome that drove their deployment.**

A major job for smart grid systems is to level electric loads. In fact, it is arguably the major job. Therefore, if smart grid technologies are deployed in ways that do not result in more level electric loads, smart grid will have failed to achieve a major job justifying its expense and disruption.

While residential customers make up a smaller portion of overall electricity demand than commercial or industrial, “the residential power market has more demand curtailment capacity than commercial and industrial markets.” Industrial customers, with their relatively flat load curves, contribute much less to peak demand spikes. This means residential customers cannot be ignored – and may in fact be the key market segment in which the most valuable impact can be achieved for smart grid’s biggest job.

If we are correct that the current utility-focused approach on smart grid deployments is unlikely to change residential customer energy usage behavior, this would in turn portend risk of failure for smart grid deployments in achieving overall load leveling – an important outcome driving smart grid deployments.

Not all is hopeless. We believe smart grid and green technologies have tremendous potential to generate significant – even disruptive – economic opportunity. In fact, many smart grid and green technologies already possess commercially valuable attributes that have the potential to provide meaningful improvements to current consumer and utility challenges. We will explore the circumstances under which this can occur at the end of this white paper and in much greater detail in the second white paper.
Smart grid and clean energy technologies for the most part are not consumer end products; they are enabling technologies. *How* these enabling technologies are deployed will significantly impact the types of products and services that are – and are not – created. If smart grid technologies are deployed less like cash registers and more like cell phone towers – i.e., as platform technologies that promote opportunities for private sector companies to provide consumer products and services – they have the potential to enable the creation of new markets that resemble those created by the Internet and wireless telecom infrastructure.

That is not the way that smart grid and clean tech are currently being deployed. Instead, these technologies are being deployed to solve very real utility challenges but in ways that ignore well-established economic innovation theories. In short, utilities are deploying smart grid more like cash registers than cell phone towers.

Here is why that is a problem.
Section 1: The “When” Challenge

The greatest internal challenge confronting utilities is managing increasingly volatile energy usage loads. For utilities, the financial and engineering impacts of these volatile usage patterns are significant and costly. These load challenges impact retail, distribution and generation utilities in very different ways. Utilities cannot address these challenges using status quo systems; they can only be addressed successfully through system-wide deployment of smart grid technologies.

The job of electricity providers is to ensure that customers have as much electricity as they want, when they want it. Utilities’ success in reliably meeting this demand is one of the great economic and technical achievements of all time. In 1950, the average American home used 138 kilowatt-hours (kWh) a month; by 2010, that number was nearly 1,000 kWh. This increased access to affordable, reliable electricity has been the foundation for prosperity and higher standards of living.

Meeting the “as much as” and the “when” demands is proving increasingly challenging, however. These two demands are the drivers for the two large challenges – one externally-driven, the other internal to the industry – confronting an electricity sector that has long operated with little of the information technology advances that have long been common to telecom, cable, newspapers and airlines.

One challenge – reduction in pollution – arises from external societal and policy pressures. It is a challenge driven by the electricity sector’s efforts to meet the “as much as” demand. Specifically, generators have historically built large power plants to provide customers with as much electricity as they demand. These power plants – particularly older plants and coal plants – produce significant air pollution. Solutions to as much as-driven challenges are typically presented as either (1) using less electricity or (2) using cleaner sources. These solutions frequently result in higher costs, lower profitability, system reliability problems, or all three.

While the bulk of attention surrounding smart grid has focused on using it as a tool to reduce the as much as-driven environmental impacts of electricity, the industry also confronts a large, structural challenge driven by “when” demands: managing increasingly volatile energy loads. This when challenge is internal and particular to the electricity industry.

While the when challenge is highly intertwined with as much as challenge, it is not an environmentally-driven problem. Perhaps surprisingly, however, many of the smart grid and clean technologies that are problematic as solutions for as much as challenges turn out to be highly effective when targeted to addressing when challenges.

To understand why, it is important first to understand better these when grid management challenges. Because the nature of these challenges vary considerably based on the type of utility, we will first describe the types of utilities. From this point forward, any description of a “utility” challenge will identify the specific type of utility that is the subject of the analysis.
**Types of utilities**

Electricity services involve three separate business functions:

- generation
- transmission and distribution
- retail services

In competitive markets, these services are provided by separate companies, while in coop and public power markets, two or all three of these functions may be vertically integrated into one firm. About half of the United States is served by public power or coop providers, while the other half has retail electric competition.  

**Retail Electric Providers**

Retail providers in competitive markets are the companies that customers receive their bill from. While retailers are the companies responsible for providing customers with electricity and related services, they typically do not own power generation, wires or meters. Instead, retailers obtain power for their customers from generation utilities, and this power is transported over wires owned by distribution utilities.

**Generation companies**

These are the companies that own and operate power plants and other most sources of electricity generation (such as dams and wind farms).

**Transmission and distribution utilities**

Transmission and distribution utilities (“distribution utilities”) own and operate the electric grid wires that deliver power to customers. Even in competitive markets, distribution utilities remain regulated monopolies.

Because they operate the grid, distribution utilities are the companies overwhelmingly responsible for deploying enabling smart grid technologies such as smart meters. However, in competitive markets, distribution utilities do not have a direct customer relationship. This means that only retail providers can offer any innovative new services that might be made possible through smart grid functionalities – even though the retail providers do not operate the smart grid infrastructure and have limited ability to optimize these systems.

This structure differs from that of two other major grid-based industries: telecom and cable television. In those industries, the grid operator has a direct retail relationship with customers. In both the cable and in the wires line telecom sectors, relatively little competition has emerged. This is due overwhelmingly to the significant barrier to entry of building and operating a competing wires-based grid.

Only wireless telecom has seen meaningful competition. Even in that industry, most innovation has arguably been driven by retail device and software companies (such as smart phone makers), although the existence of competition among wireless carriers has almost certainly played an important role in opening markets for smart phones and app stores and in strengthening customer demands for network improvements.
Public utilities and coops
Public utilities, including municipal utilities, typically provide retail and distribution services. Larger public utilities also own generation assets. Vertically integrated public utilities have historically set their rates at levels sufficient to cover the total system cost of service rather than setting rates for each unit as a stand-alone business. However, their cost structures for generation, distribution and core retail services (such as customer service, billing and service connection) are the same as the cost structures of retail, distribution and generation utilities.

Electric cooperatives operate in much the same way as public utilities, but instead of a public agency, their members (customers) are the owners.

For purpose of our analysis, statements in this white paper pertaining specifically to retail, distribution or generation utilities also apply to the retail, distribution and (if applicable) generation divisions of vertically integrated public utilities and coops.

Tranches of electricity generation
Generation utilities provide power in three tranches: baseload, intermediate and peak. Each tranche’s power is provided by a dedicated class of power plants.

Baseload
Baseload power represents the minimum amount of electricity that is used in a service area at all times. Baseload power comes from a dedicated class of power plants that are very large, expensive to build, have low operating costs and either do not ramp up and down (nuclear) or ramp up and down inefficiently (coal). These plants produce electricity at an essentially constant rate and run continuously. They typically operate at a capacity factor of approaching 90 percent. In essence, baseload plants are nearly always operating at full capacity. Baseload power comes largely from nuclear and coal.

Individual homes and businesses use a minimum amount of power at all times and therefore contribute to baseload demand. Examples of household items that are always operating – and therefore contribute to baseload – include cables boxes, refrigerators and alarm clocks. Across large groups of homes, a certain level of air conditioning or electric heating is on at all times.

Intermediate
Intermediate load power is the power that comes on-line generally as people wake up, go to work, and, in the process, turn on lights, TVs, toasters and other home and office systems. This power is typically provided by natural gas plants but may be provided by coal plants in certain parts of the U.S.

Peak
Peak power plants are used to generate power when power demand exceeds the combined generating capacity of available baseload and intermediate sources. In the portion of Texas for which ERCOT manages the grid, the summer peak generally occurs from 3 pm to 7 pm in June through September.
Under the status quo, utilities meet this power demand by building and operating an entirely separate class of power plants – peaker plants. Peak-load generating units are normally the least efficient of the three unit types. Providing this tranche of power turns out to be very challenging to deliver – and expensive – to distribution and retail utilities.

**Managing wide swings in demand**

As anyone who has experienced power outages on a summer afternoon or winter morning knows, the electricity system is prone to strain during particularly high demand periods like hot summer afternoons. These high demand periods present significant engineering and economic challenges, and the status quo tools that utilities can employ are limited and expensive.

The challenges created by wide swings in demand extends beyond high demand events, though, and impacts the three types of utilities differently.

**Seasonal load swings**

The daily demand curves below reflect actual demand for select days in North Central Texas (centered around the Dallas-Fort Worth metroplex). As reflected by these graphs, electricity demand has large seasonal variations.
While loads in the spring and fall tend to be relatively flat, demand in winter is frequently the highest in the early morning. In Sunbelt locations like North Central Texas, the peak events occur on summer afternoons – usually in the 4-5 pm range.

One can see the variation across the span of a year in the following graphics depicting daily load curves in North Central Texas for 2009. The gray band represents available baseload generation capacity, and the yellow band represents available intermediate generation capacity. Points where the load lines cross above the yellow band represent those points when peak generation capacity is needed.

<table>
<thead>
<tr>
<th>Year</th>
<th>Max (MWh)</th>
<th>Min (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>23,187</td>
<td>9,612</td>
</tr>
<tr>
<td>Aug.</td>
<td>22,096</td>
<td>8,758</td>
</tr>
<tr>
<td>June</td>
<td>21,967</td>
<td>7,866</td>
</tr>
<tr>
<td>Sept.</td>
<td>20,286</td>
<td>7,212</td>
</tr>
<tr>
<td>Jan.</td>
<td>17,958</td>
<td>6,883</td>
</tr>
<tr>
<td>Dec.</td>
<td>17,773</td>
<td>7,386</td>
</tr>
<tr>
<td>2009</td>
<td>Max (MWh)</td>
<td>Min (MWh)</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>May</td>
<td>18,141</td>
<td>6,758</td>
</tr>
<tr>
<td>Oct.</td>
<td>15,958</td>
<td>6,705</td>
</tr>
<tr>
<td>Feb.</td>
<td>14,937</td>
<td>6,847</td>
</tr>
<tr>
<td>April</td>
<td>14,611</td>
<td>6,751</td>
</tr>
<tr>
<td>March</td>
<td>14,602</td>
<td>6,775</td>
</tr>
<tr>
<td>Nov.</td>
<td>12,947</td>
<td>6,569</td>
</tr>
</tbody>
</table>

**Individual home loads**

The graph below, created using data from a 1999 University of Central Florida study’s data on home energy usage, shows two categories of information. First, it shows the electricity usage lines for Sunbelt single family over the course of the day in the summer and in the spring. The graph also shows an individual home’s contribution to demand in each of the three tranches.
The load curves in spring and summer for the Florida homes closely match the spring and summer loads for North Central Texas shown above, and they also closely align with the load curves that Pecan Street Project is observing in our own research with residential customers.

**Impacts of load swings on utility finances**

It is hardly news to most electric customers that electricity usage – and electric bills – are much higher in the summer. What may surprise many is how unprofitable it is, particularly for retail and distribution utilities, to provide this summer electricity.

**Generation utilities**

Generation utilities make money by selling electricity generated from their power plants. Power plants are expensive to build and own, so generators have an understandable interest in using their capital assets as much as possible. That is not the way it works, though.

To ensure customers have access to as much electricity as they want when they want it, grid operators ensure that sufficient generation capacity is available at all times. Total generation capacity also includes a “reserve margin” of extra capacity above and beyond forecasted maximum demands – frequently about 15 percent. (In the case of ERCOT, the target reserve margin is 13.75 percent above maximum forecasted demand.) Further, generation utilities must run certain power plants in idle – approximately five percent of total demand at any given time. This is known as spinning reserve.

That means generation utilities (in aggregate) must have available at least 13.75 percent of their available power plant capacity with the intention that it will not be used – and therefore not generate revenue – for even a minute during the year. Additionally, for every megawatt of demand, generation utilities effectively must operate 1.05 megawatts of capacity.

As noted earlier, generators operate three tranches of power generation: baseload, intermediate and peak. While generators’ baseload plants operate nearly continuously, with
capacity factors approaching 90 percent, their intermediate capacity plants in a typical year operate at 35 to 55 percent of their total available capacity. 22

For peaker plants, the capacity factor typically ranges from five to 15 percent. 23 That means these power plants sit idle for the vast bulk of the year – and produce no revenue for the bulk of the year.

The following graph shows a sample of generation sources with their actual capacity factors for 2007 (except for Decker’s intermediate and peaking capacity factors, which are for 2008). 24 The South Texas Project plant is nuclear, Big Brown and Laramie River are coal, and Sweetwater is wind. (Wind is identified as “partial” because it does not represent a complete substitution for baseload, intermediate or peak generation sources.) The rest are gas-fired plants that are either intermediate, peak or (in the case of Decker) a mix of intermediate and peak units.

As this graph demonstrates, peak generators and even many intermediate plants sit idle for much of the year.

This raises an important economic question: if spiked load curves result in generation utilities only being able to run some plants a few hours a year, how do they recover their costs and earn a profit on these plants?

The answer, it turns out, is that they charge a higher price for the electricity from these plants. In many instances, the price is much higher.
Retail utilities
Retail electric providers do not generate the electricity they sell to customers; instead, they acquire this power through a mix of contracts with generation utilities, through purchases on spot markets and (where such markets are in place) through purchases on a balancing market.

Because energy demand changes significantly during the day and on a seasonal basis, the electricity that retailers acquire comes from a mix of baseload and intermediate plants. On the few hours a year when demand is particularly heavy, additional power can only be obtained from peak power plants that are turned on for just those few hours, then turned off again.

Retail providers typically only purchase electricity on the balancing market when their customers’ demand exceeds the amount of energy the retailer has already secured through contracts with generation utilities (or intermediary sellers). In making their decision of how much to put under contract, retailers must predict the amount of electricity they will need to meet customer demands. If a retail utility’s prediction is incorrect, and its customers use more electricity than it had secured, the retailer must acquire the balance of its customers’s demand on the spot market or balancing market.

Retailers can pay a heavy cost for predicting incorrectly.

Retail electric providers overwhelmingly price the electricity they sell to customers one way: at a fixed rate per kilowatt hour, regardless of the time of day the customer uses this electricity. However, the price that retail utilities must pay to obtain electricity on spot and clearing markets can change considerably over the course of the day.

In part, this is because, as utility sector economist Peter Fox-Penner notes, “the cost of making a single kilowatt-hour changes by a striking amount during the day, especially on very hot or cold days when electricity use is high.”

Due to that, as well as price changes driven by demand, the price that retail providers must pay to generation utilities and to the balancing market for an extra megawatt hour of electricity changes during the course of the day. The hourly spot or clearing price is set by the single highest-price power plant turned on by system operators to balance supply and demand.

That means a retailer’s cost to obtain electricity depends significantly on when it needs this electricity. During the summer, the Marginal Clearing Price for Energy (MCPE) for a megawatt hour will typically be fairly low during the early morning hours, rise throughout the day and spike during peak periods.

Under a fixed dollars-per-kilowatt hour rate, the price that retail utilities pay to obtain peak power for customers frequently exceeds the price they charge under the fixed dollars per kilowatt hour rate.

The graphic below, prepared by ERCOT, shows just how dramatic the swing in clearing prices can be. This graphic shows the marginal clearing price for electricity on August 4, 2008 (a period of high natural gas prices). That day, clearing prices started at $19.50/MWh at 5 a.m., rose to $90/MWh at noon, then topped out at $360/MWh at 5 p.m. As most retail utilities do every day, retail utilities charged the same rate throughout the day even though the price they paid to obtain this electricity changed dramatically.
Just how dramatic the impact of changes in clearing market prices can be on retail utility profitability is shown by the graphic below for August 2, 2010 – a period of low natural gas prices.
prices. This graphic shows the net profitability from selling an extra megawatt hour of electricity during the course of that day. As this graph reflects, retail utilities frequently lose money from selling additional electricity during peak demand periods.

Or consider this graphic to the right, showing the net profitability of selling an extra megawatt hour of electricity on Monday, August 23, 2010 (again, a period of low natural gas prices). On this day, the clearing price ranged from a low of $22.16 per megawatt hour at 2:30 am, to a high of $2,200.01 per megawatt hour at 4:15 pm. That day also experienced three 15 minute intervals where prices reached $1,000.01 per megawatt hour, and an interval with a price of $750.01. 29

Moreover, with technologies that could lead to increases in peak demand (such as from electric vehicles), retail utilities face the prospect of losing money from selling additional electricity during these peak demand periods.

It isn’t just retail utilities who lose in this scenario. Customers frequently pay a higher cost for electricity over most of the day to make up for the losses retail utilities experience from providing peak power from plants that sit idle most of the year. As a result, customers who use less energy in the afternoon (e.g., because they invested in energy efficiency or run their thermostat at a higher setting) are financially penalized by current fixed-rate structures.

**Distribution utilities**

As with retail electricity providers, electricity distribution utilities must build capacity sufficient to handle the maximum demand. And, as with retail providers, distribution
providers must build capacity to serve peak demand that goes unused for most of the year. In other words, we build fat pipes that sit empty most of the time.

The excess distribution capacity required to serve power spikes is also expensive. It is time-consuming to build and sits idle up to 95 percent of the time. This has financial implications for distribution utilities and consumers.

The graphic below shows the load curve for July 2009 but in this instance presents it – at scale – to reflect the minimum transmission and distribution capacity required to serve the available generation capacity. The bottom band reflects baseload T&D capacity, the middle band is for intermediate, and the top band represents peak transmission and distribution capacity. The dark blue in each tranche reflects utilization of that wires capacity over the course of the month. 

As this graphic demonstrates, baseload transmission and distribution capacity was almost fully utilized over the course of July 2009, intermediate capacity was largely utilized and peak capacity was somewhat less so.

Broken down by tranche, here is what capacity utilization for intermediate and peak looked like in 2009:
This following table shows peak tranche distribution utilization – again, presented at scale.
As these show, peak tranches of capacity goes completely unused for months at a time. This is the minimum distribution capacity utilization for distribution infrastructure that is required to serve spikes in peak demand. This capacity’s costs are fixed. However, under the status quo pricing model of a fixed rate per kilowatt hour, the distribution utility only earns revenue during the few hours a year when this capacity is actually used by customers.

As retail electricity providers do, distribution utilities charge higher rates for all distribution services so that they can recover their costs and earn a return on this rarely used infrastructure.

This pricing structure relies on accurately forecasting how much capacity will be used. It is through this forecasting work that the distribution utility’s rates can be set at a level that – hopefully – is sufficient to recover costs and earn a return on investment, rather than being set too high (thereby harming consumers) or too low (and potentially hobbling the distribution utility).

The risks and contradictions inherent in this pricing structure are manifold. For instance, when the forecast turns out to be too optimistic, then the rate is insufficient to cover the distribution utility’s costs and the utility loses money.

Consumers and distribution utilities alike benefit when peak is better managed and demand curves are flatter. Existing capacity is more fully utilized and less rarely needed capacity must be built and paid for. But under the current rate per kilowatt hour pricing structure, distribution utilities are financially disincentivized from encouraging energy efficiency and other measures that would encourage peak reduction because that would result in less revenue, and their rates are based on prognostications of usage that are sufficient to cover their current costs.
Electric Vehicle Impact on Distribution Systems

The potential environmental and economic benefits of electric vehicles are significant. According to the Texas Public Utility Commission, powering a car with electricity rather than gasoline results in 93 percent less smog-forming volatile organic compounds and 31 percent less nitrogen oxide emissions. 31

Additionally, operating costs of electric cars are likely to be significantly lower than those of gasoline-powered cars, costing the equivalent of $.75 to $1.25 per gallon of gasoline. 32 But under the status quo, electric cars may result in significant peak electricity spikes that destabilize distribution feeders and require the construction of expensive, rarely-used capital equipment.

In a 2007 DOE-funded study, researchers from Pacific Northwest National Laboratory examined the impact of plug-in hybrid electric vehicle (PHEV) charging on electricity distribution systems.33 They found that existing Pacific Northwest distribution systems could manage 120V charging with PHEV penetrations up to 50 percent on a distribution feeder. The catch? Cars with 120V charging take 8-20 hours to charge. 34 That isn’t likely to be popular with consumers.

Fortunately for consumers, there’s an alternative. With 240V charging, it takes just three hours to charge. 35 That’s the voltage level for home systems such as electric washer-dryers.

But the Pacific Northwest National Lab researchers noted that with consumers charging at home when they get home (confirmed by the overwhelming research to date on consumer preferences and actual usage patterns), utilities would experience load surges for homes with PHEVs.

“[I]t is possible,” the authors observed, “to have multiple residences on a single transformer charging at the maximum rate, at the same time. The issue of localized coincidental loads could have significant additional consequences on the secondary distribution system.” 36 With 240V charging by a number of homes on a distribution feeder, “equipment rating limits are expected to be exceeded with the 240V rapid-charging profile.” 37
The study concludes: “From the results of the 240V rapid-charging analysis, it is clear that for any significant level of penetration a ‘smart charging’ device will be necessary to prevent the charging from occurring on peak, otherwise the distribution feeders will become the limiting infrastructure.” 38

Figure 10 illustrates what happens to the load curve (from Figure 2) for a single family home in the summer with an electric car and 240V charging. The home’s electricity usage nearly doubles at peak.

To exacerbate this looming challenge, research on hybrid vehicle buying patterns indicates that early adopters of electric vehicles are likely to cluster in a few neighborhoods. This map prepared by the City of San Antonio shows densities of hybrid vehicle ownership in San Antonio.

The exact challenge predicted by the Pacific NW Nat’l Lab researchers – concentrations of electric vehicle owners on particular distribution feeders – is almost certain to happen. That means distribution utilities could face significant operational and cost issues managing electric vehicles, even at low levels of PHEV market penetration.

In the short run, it means owners of electric vehicles – and their neighbors – would be the most likely to experience blackouts and service disruptions. That isn’t likely to be popular with car owners, their neighbors or car manufacturers that have invested heavily in new electric vehicle technologies.

And under the status quo tools that distribution utilities have to work with, they will have only one option: build even more distribution capacity that will sit idle for most of the year and will only be used for a few hours each summer.
Section 2: Caring, and the consequences of not

To succeed in leveling electric loads, smart grid technologies must get customers to reduce their usage during peak demand periods and possibly make even greater alterations in their energy usage. However, current smart grid approaches are unlikely to change consumer behavior or achieve broad consumer engagement. This is not a problem driven by lack of customer education or of inadequate utility public relations. This is a problem of substance.

The futility of requiring too much engagement


In its American Voices section, The Onion asked for people’s reactions. “That’s probably for the best,” said solar panel installer Carlos Menuck. “I was getting sick of forgetting to check the advisory before traveling.” 39

Homeland Security was not giving up on the idea, however, of using a barrage of information to transform travelers into watchful participants in airport security:

The National Terrorism Advisory Systems plans to alert the public of terrorist threats through a variety of methods including traditional media, the Department of Homeland Security’s website, Facebook and Twitter.

... Overall, Napolitano said she believes the new system will help keep the public more engaged in national security. 40

Current smart grid approaches focus overwhelmingly on using new smart grid technologies to charge higher summer afternoon prices and to provide customers with frequent, real-time information about these prices, about their electricity usage and possibly about their usage compared to other customers. Methods of communicating include web portals, emails, text messages, in-home displays and even a display orb that changes color from green to yellow and red to alert customers about grid conditions.

Providing this information, hope proponents of this approach, will “chang[e] passive power customers into active participants in energy savings.” 41
There’s a problem, though, with the approach of using reams of constantly updated energy usage information to drive changes in consumer behavior and achieve consumer engagement. It almost certainly won’t work.

But given Americans’ dismal track record on changing their consumption habits, that voluntary shift may not be as simple as it sounds, says Richard Thaler, a behavioral psychology economist at the University of Chicago’s Booth School of Business and co-author of *Nudge*, a how-to book on decision-making.

"If it involves people actually doing something, it won’t happen," Thaler says. "Just look at everyone who never figured out how to program a VCR."

Thaler points to Americans’ adoption and use of programmable thermostats as an example of laziness trumping logic. According to a 2005 survey by the Energy Information Administration, only a third of Americans own the devices and less than a fifth use them to change their homes’ temperature during the day, even though half of Americans leave their houses empty from morning until evening. "People tend to be passive," Thaler says. "For smart meters to work, they’d have to be pre-programmed."

There’s a well-documented reason that people will not act in response to information, even when this information benefits them, write Chip and Dan Heath in *Switch: How to Change Things When Change is Hard*. Making numerous decisions that require the exercise of self-control tires people and leads to diminishing returns with each act of control that a person must take in response to information. 43

The concept is referred to as “choice overload.” Provide customers with too much information, and they will increasingly stop acting on this information. So how does one tell if the customer is receiving more information than they want or than they can manage?

Asking the consumer may not help. On nudges.org, the companion site to Thaler and Cass Sunstein’s book *Nudge*, Thaler and editor John Balz describe false signals that consumers may send in relation to a particular type of choice overload: daily deal emails. Customers may stop acting on or even reading barrages of daily deal emails from sources such as Groupon and Living Social. But due to a related concept – “anticipated regret” – customers will elect to continue receiving informational emails to minimize the regret that they might miss out on something of interest, even though they at most scan the subject lines and do not otherwise read the emails. 44

So if direct information does not work, what does? First, one cannot make a blanket statement that information does not change behavior. However, the context in which information and choices are presented has a significant influence on the resulting behavior; this is the choice architecture concept pioneered by Thaler and Sunstein.

We will discuss in the second white paper our hypotheses on which choice architectures are likely to be the most effective at driving consumer changes that reduce environmental and peak demand impacts. This is a major focus area in Pecan Street Project’s consumer smart grid research for a reason – because very little real world information exists on what types of systems optimally alter customer peak demand and environmental impacts while simultaneously increasing customer satisfaction and driving new product adoption.
In short, our hypothesis is that rather than relying on in-home displays, emails and text messages to achieve smart grid aims, a customer-focused Home Energy Management System most likely needs to come with default settings that optimize environmental and peak demand benefits and provide consumers with information, the ability to alter defaults and a clear explanation of the consequences of altering the system defaults.

For reasons we will explain in the next section, such a system is unlikely to be attractive to customers without additional functionalities. But assuming companies can create commercially viable consumer systems that integrate energy management functionality with other offerings, these systems are more likely to achieve smart grid’s ambitions if they incorporate these peak management and environmental goals as system default.

There is an additional consideration, though. Given the challenges in creating residential smart grid systems that achieve the goals of leveling customer energy usage, could distribution and retail utilities simply ignore residential customers and better achieve the goals of smart grid by focusing on commercial and industrial customers?

The answer, it turns out, is “no.”

**Home is where the smart grid must be**

Retail utilities typically serve three types of customers: residential, commercial and industrial. The customer percentage mix can differ considerably among utilities, but as a general matter, residential customers make up a smaller portion of overall electricity demand than commercial or industrial.\(^45\) They also represent a far greater number of customers.

For example, here is Austin Energy’s customer and energy demand mix for 2007.\(^46\)

<table>
<thead>
<tr>
<th>Customer class</th>
<th>No. customers</th>
<th>Revenue</th>
<th>Revenue / customer</th>
<th>Consumption (kWh)</th>
<th>Consumption (kWh) / customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>345,197</td>
<td>$356,143,000</td>
<td>$1,032</td>
<td>3,908,318,000</td>
<td>11,322</td>
</tr>
<tr>
<td>Commercial</td>
<td>41,825</td>
<td>$365,991,000</td>
<td>$8,751</td>
<td>4,350,912,000</td>
<td>104,027</td>
</tr>
<tr>
<td>Industrial</td>
<td>75</td>
<td>$113,248,000</td>
<td>$1,509,973</td>
<td>1,930,289,000</td>
<td>1,509,973</td>
</tr>
</tbody>
</table>

In their 2011 industry analysis, electricity sector research firm GTM Research concludes, however, that “the residential power market has more demand curtailment capacity than commercial and industrial markets.”\(^47\) In part, this is because industrial and large commercial customers have engaged in energy management upgrades for years, which reduces the potential for significant advances in load management. Additionally, industrial customers have relatively flat load curves. Because the challenges driving smart grid are load spikes — not overall energy demand — this means industrial customer energy efficiency gains would likely do little to alleviate the inefficiencies and load management challenges created by peak demand spikes.
Further, as the load analyses from section one of this white paper demonstrate, peaks in energy demand coincide with rush hour—i.e., when customers begin returning home. This suggests that residential demand is a driver for at least some significant portion of peak demand surges. (The precise contribution of retail and commercial demand to overall peak demand spikes requires more fine-grained data of individual meter reads at different hours during the day—the exact type of data that is only possible to obtain through smart meters.)

This means residential customers cannot be ignored—and may in fact be the key market segment in which the most valuable impact can be achieved for smart grid’s biggest job. If we are correct that the current utility-focused approach on smart grid deployments is unlikely to change residential customer energy usage behavior, this would in turn portend risk of failure for smart grid deployments in achieving overall load leveling—an important outcome driving smart grid deployments.

Finally, the numbers in the table of Austin Energy customers reflect a daunting reality. Retail, distribution and generation utilities do not earn that much from residential customers or even the average commercial customer. If a home smart grid system helps a customer reduce energy usage by 10 percent, that translates (using the Austin Energy example) to a monthly savings of just $8.60 for a residential customer and $73 for a commercial customer.

Commercially viable smart grid solutions for residential and even commercial customers therefore faces challenges in justifying their prices based on potential energy savings alone. The value proposition for smart grid for residential and even commercial customers will almost certainly require that premises energy management systems provide value to customers beyond reducing peak energy usage.

**Section 3: It’s the customer, stupid**

Current approaches for smart grid and clean energy are unlikely to catalyze meaningful economic growth.

Here is another way to look at the table of residential, commercial and industrial customer data. The amount that the typical residential customer spends on electricity is about the same as what a smart phone customer spends on his or her monthly mobile carrier service plan. That’s before the customer uses the smart phone to download apps, music, movies, books and a range of other new products and services.

And virtually everyone is connected to the network. This represents a very large pool of customers that may soon experience significant information technology upgrades.

The size of the installed base means that persuading even a modest share of customers on the network to buy one’s product or service could drive significant growth. But developing a great technology is not enough. “Green energy technologies, just like those that drive personal computers, mobile phones, and software, must follow the rules of innovation and avoid its pitfalls,” observe Clayton Christensen, Shuman Talukdar, Richard Alton and Michael Horn write in the Spring 2011 Stanford Social Innovation Review. 48

As most current smart grid and clean technologies are currently positioned, they either provide inferior performance on the measures of performance important to the customer compared to
the status quo technologies, or they perform jobs that the targeted customers are not currently trying to accomplish.

The relatively poor customer adoption of thermostat programming and the low likelihood that customers will change their behavior in response to utility information suggest that providing customers with products to engage in consciously managing their energy usage is also unlikely to catalyze meaningful growth.

Jobs-to-be-done
Under innovation economic theory, for customers to embrace a new technology, it must help them do a job that they are currently trying to do and for which status quo offerings provide an inadequate solution. Importantly, it must be a job customers are already trying to accomplish: “Customers don’t just ‘change jobs’ because a new product becomes available.”

Therefore – as with any technology – in evaluating the potential for a smart grid or clean energy technology to achieve commercial success, it is necessary to ask these questions:

- Who would be the customers?
- What job does the technology help the customers do that the customers currently are trying to do?
- What offerings are the customers currently employing to do this job?
- Compared to the existing offerings used by the customers, how would the new technology help the customers “accomplish more effectively and conveniently what they’re already trying to do.”

As we will explore in our second white paper, there are a number of important jobs that customers are currently trying to do for which current offerings are ineffective, expensive or unavailable, and for which energy data, energy efficiency and distributed generation could add valuable functionality. These include products that provide solutions for consumers in the areas of home improvement, home health care and detection of problems in home appliances, vehicles and consumer electronics.

However, current smart grid offerings – with their overwhelming focus on providing customers with information to monitor and adjust manually their home energy usage – likely fail in this area. Christensen et al. observe, “[C]onsumers will change their behavior only if the technology helps them accomplish a job they were already trying to do. . . . Those who were not looking for a system to help manage electricity usage will probably have little interest in smart grid technologies. They will not change their behavior, because the technology does not help them do a job they were already trying to do.”

GTM Research states this case bluntly:

- Improved reliability, remote connect/disconnect, and automated meter reading are not sufficient. These are benefits to utilities, not consumers. Utilities need to put a tangible face on the smart grid that consumers can touch, hold and use. . . .
- At a minimum, every home with a smart meter should also have home energy management technology that displays consumption data, price signals, and utility messaging.
Companies looking to develop home smart grid solutions therefore most likely should think about energy management as a feature of an overall home system. Home alarm system companies have shown the viability of building a successful service business out of outfitting a home with monitoring equipment, selling a subscription service package and over time scaling out the range of services that are provided to include smoke and fire detection.

In fact, home alarm companies may emerge as powerful competitors in an emerging home smart grid space. Other non-utility companies that could emerge as competitors include mobile telecom companies – with their superior data management, networking and business model expertise – and cable companies, which understand already how to deliver and manage content inside of a home and to up-sell additional services such as Internet and VOIP phone service.

Finally, energy usage data could provide an important enabler of application functionality in the same way that GPS has proved an important enabler of smart phone application functionality. Done wrong, smart grid deployments could result in little more than a one-time big ticket upgrade to utility distribution systems. By following well-established innovation theory learnings, though, smart grid technologies could open the door for the electricity version of a mobile phone app store – where, for every home challenge, ranging from home repair to remotely checking the contents of your refrigerator at the grocery store over your mobile phone to prompting a dilatory 7-year-old boy to get in the shower quicker by showing him reductions in his allowance from the cost of running hot water (our personal favorite), the answer could again be, “There’s an app for that.”

The importance of data
Energy data may provide the most powerful driver of new economic possibilities. In fact, it is hard to imagine any kind of breakthrough successes emerging from smart grid without customer access to performance data, and the ability for customers to decide to whom they provide this data.

Networked information technology systems in customer homes that can capture and manage energy data could open the door to a wide range of new customer products and services based on actual performance and usage data.

Given the importance of data to driving customer-focused solutions, it is critical to the success of smart grid that customers – and not distribution utilities – control who has access to their data. Mobile telecom has wrestled with (and is still resolving) many of the data access and privacy issues that solutions providers will confront in a customer-focused smart grid and provides useful learnings.

Why the economic failure of smart grid would be bad for utilities
Why should distribution utilities care whether their smart grid investments generate economic activity?

As we demonstrate in this white paper, a core purpose of adding significant information technology to electric distribution systems is to make it possible to manage the increasingly variable loads on the customer side of the meter. Without large-scale adoption by customers of
systems that make it possible to manage the increasingly variable loads on the customer side of the meter, it will be impossible to achieve this core purpose of utility smart grid deployments. And customers will not adopt smart grid systems on a mass scale unless these systems possess additional functionalities that help customers solve problems in their lives.

I.e., the success of smart grid load management likely depends on the emergence of commercially successful products and services that include home energy management as a component.

Section 4: Solutions Characteristics

In this section, we describe what we see as the characteristics of the solution from the perspectives of key stakeholders.

Whether a technology or system qualifies as a “solution” depends heavily on the perspective of who is asked. The most effective solutions will create improvements that all stakeholders conclude, from their perspective, create improvements over the status quo.

Customers
For a potential smart grid or clean technology to be embraced by customers, it should advance these interests:

- Helps customers solve problems they are already trying to solve
- Does not require active engagement and lots of decision-making

Whether a product or service is attractive to customers depends highly on customer segments. I.e., some customers will be moved by exciting new consumer electronics, while others will be motivated more by security, price or environmental concerns. This means smart grid is likely to be most successful in areas where consumers are offered a wide range of product and services choices.

Distribution utilities
For a potential smart grid or clean technology to be embraced by distribution utilities, it should advance these interests:

- Flattens load curves
- Does not increase complexity of grid management
- Works with recently deployed smart meters

Retail utilities
For a potential smart grid or clean technology to be embraced by retail utilities, it must advance these interests:

- Reduces relative unprofitability of peak demand sales
• Is so enticing to customers that it serves as an inducement for customer recruitment and retention

**Generation utilities**
For a potential smart grid or clean technology to be embraced by customers, it should advance these interests:

• Better asset utilization (i.e., existing generation capacity is used more closely to full capacity)

**Public interest**
Considerable public dollars have gone into smart grid investment. Additionally, distribution utilities – the entities responsible for building out and operating electricity distribution systems – are regulated monopolies throughout the U.S. and much of the world. As such, the public interest is an important stakeholder even as electricity moves toward becoming a more dynamic, entrepreneurial sector.

For smart grid systems as a whole to promote progress for society, they should advance these public interests:

• A stronger economy
• Broadly-distributed opportunity
• Broadly affordable
• Environmental improvements
• Reliability is maintained or improved
Endnotes


2 See ‘Whole new effort’ at schooling consumers coming this year, Smart Grid Today, Jan. 24, 2011, at 1.


9 Peter Fox-Penner, Smart Power 16-17 (eBook ed. 2010).

10 Fox-Penner, supra note 5, at 54-55 (eBook ed. 2010).

11 Fox-Penner, supra note 5, at 37; Electric Reliability Council of Texas [hereinafter ERCOT], ERCOT Board Members Overview and Orientation 36 (March 2010), http://www.ercot.com/content/news/presentations/2010/ERCOT_Board_Orientation_2010.pdf.


13 ERCOT, ERCOT Board Members Overview and Orientation at 23.

14 A 100 percent capacity factor would mean the plant was operating at maximum capacity for 24 hours a day, 365 days a year.

15 ERCOT, ERCOT Board Members Overview and Orientation at 23.

The assumptions on baseload and peak were drawn from the above-cited sources. Specifically, we based the assumption of North Central Texas baseload capacity by adding 2009 ERCOT data on total available capacity of nuclear, coal and wind generation (for which ERCOT assumes a capacity factor of 8.7 percent). This came to 10,400 MW. For determining the line delineating intermediate load from peak, we took Austin Energy information that peak capacity factors range from 5 to 15 percent, assumed a midpoint for the peak dividing line at 10 percent, and took the 10th percentile highest demand hour of 2009 in North Central Texas as the dividing line between peak and intermediate loads. These dividing lines are not intended to represent with certainty the dividing lines for peak, intermediate and baseload tranches but to provide a close representation.

The load generation curves represent the actual reported loads from ERCOT, and all monthly graphs are presented at the same scale.

Figure 1 is a graphic that Pecan Street Project created using the data presented in this study. This study appears to be the only publicly reported study to date on how Sunbelt home residents use electricity down to the device level over the course of the day. In the first phase of its demonstration project, Pecan Street Project starting in early 2011 began conducting the second such study. The study captures electricity, gas and water usage data on a minute-to-minute basis from the home and from individual appliances and systems in participating homes.

Fox-Penner at 76.

“ERCOT says it will have plenty of power this summer,” Austin American-Statesman, May 31, 2011, http://www.statesman.com/blogs/content/shared-gen/blogs/austin/theticker/entries/2011/05/31/ercot_says_it_will_have_plenty.html; ERCOT, ERCOT Board Members Overview and Orientation at 54.

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Id. at 114-15.

Id; see also Christensen et al., The Innovator’s Solution at 151, n.6 (“Price gravitates to the cash cost of the marginal, or highest-cost, producer whose capacity is required for supply to meet the quantity demanded.”)

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49 Clayton M. Christensen & Michael E. Raynor, The Innovator’s Solution at 205 (1st eBook ed. 2004).

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The Consumer-focused Smart Grid, Part 2

The Disruptive Smart Grid

Smart grids are designed to benefit consumers and utilities ...

...but the value they create cannot be easily measured, priced or captured by those who pay for it.

This paper proposes the business architecture for smart grid deployments that which are likely to create the greatest economic benefit.

by

Horace Dediu
Brewster McCracken
Preface

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Executive Summary

The electric utility industry has been centralizing for the better part of a century. In so doing it has become detached from the needs of its customers and exceeded performance on measures that sustain it while ignoring new measures of performance that its customers crave.

As the industry became defined by cost structures, its planning and investment priorities omit accounting for value created thus implicitly discounting the potential of value-based innovation.

The challenges faced by the grid are being addressed by simplistic solutions which are based on contradictory and inconsistent explanations of the causes of those challenges.

Innovations necessary to overcome the barriers to breakthroughs will come from external disciplines which will describe the causes for the industry's problems and lead to increasingly simpler and clearer solutions.

We believe smart grid and green technologies have tremendous potential to generate significant – even unforeseeable – economic opportunity. In fact, many smart grid and green technologies already possess commercially valuable attributes that have the potential to provide meaningful improvements to current consumer and utility challenges. We will explore the circumstances under which this can occur at the end of this white paper.

Smart grid and clean energy technologies for the most part are not consumer end-products; they are enabling technologies. How these enabling technologies are deployed will significantly impact the types of products and services that are – and are not – created. If smart grid technologies are deployed less like transformers and more like cell phone towers – i.e., as platform technologies that promote opportunities for private sector companies to provide consumer products and services – they have the potential to enable the creation of new markets that resemble those created by the Internet and wireless telecom infrastructure.

That is not the way that smart grid and clean tech are currently being deployed. Instead, these technologies are being deployed to solve very real utility challenges but in ways that do not take advantage of well-established economic innovation theories. In short, utilities see the technology as sustaining to their core business and not as a disruptive innovation.

Here is why that is a problem.
1. Introduction

How centralization drove the greatest engineering achievement of the 20th century

Centralization

When Thomas Edison invented the light bulb the prospect of building a new empire on the basis of this new invention must have been very tempting. However, even though he was already a wealthy man, he could not afford to build a light bulb factory. Producing light bulbs for the mass market required large factories, hiring thousands of skilled workers and purchasing large amounts of raw materials and tooling. Worse, light bulbs were worthless without a reliable supply of electricity.

Deploying electric lighting technology therefore required an "enabling" technology of generating plants and a transmission grid. This required an order of magnitude more capital than bulb production facilities. Nothing like this had been built before. Canals, Railroads and the Telegraph had created cycles of boom/bust but nobody had put anything as complex--requiring multiple risks in the generation, transmission and consumption of electricity--together. Given the complexity and challenges involved, anyone looking at the light bulb must have thought that it was a pretty poor business idea. The electric grid was inconceivable.

And yet it happened.

Electrification or the build out of the electrical generating and distribution systems occurred in the United States, England and other countries from the mid 1880's until around 1940 and is still in progress in developing countries. It not only enabled illumination but also also the upgrading of industrial power from shared line shaft and belt drive (using steam engines and water power) to tools powered by local electric motors boosting productivity and output enormously. Electrification has been declared "the greatest engineering achievement of the 20th Century" by the National Academy of Engineering.[2]

So how did a nation build this new infrastructure when it looked like the most onerous, inter-dependent and risky proposition in the late 19th century?

The answer is that it was a process of progressive centralization of resources, processes and business models. The trajectory of improvement took a road toward and integrated, centralized infrastructure.

The Hiring of Capital

Edison did not do it alone. Electrification depended on the vision and support of another innovator: J. P. Morgan. However, even Morgan's personal fortune was not large enough to underwrite the Edison Electric Light Company. Morgan's innovation was the coordination of large armies of banks into syndicates that could furnish huge amounts of capital. His advantage was that he could easily arrange the aggregation of hundreds of millions of (nineteenth century) dollars necessary to create railroads, utilities and steel companies.

But electric grids posed significant technology risk to financiers. By the late 1800s bankers had grown weary of technology due to a history of bubbles. The railway bubble of the 1840s (which
followed the canal company bubbles of the 1700s) was still fresh in the mind. As a result, Morgan and his partners preferred proven technologies. Fortunately, in Edison's case, Morgan made an exception.

The reason was that he started with a de-centralized approach, centralizing only gradually. Morgan started out by outfitted his mansion at 219 Madison Avenue in New York City with some of the first light bulbs. He tolerated a noisy and smoky generator behind the house and the persistent risk of fire from cabling that had not yet been properly insulated. After his own residence, Morgan then funded the building of Manhattan's first large power plant which supplied electricity to the offices of Morgan Bank at 23 Wall Street. This was, no doubt, for the purpose of improving the conditions for his bankers working non-stop through the night--a tradition current investment bankers still maintain.

It was only after repeated waves of refinement that the grid emerged.

The Incentives for Centralization
The Morgan/Edison story highlights the constructive role played by capital markets and the increasing centralization of production to create a more reliable service. It was a long and rocky road. Morgan and investment banker Henry Villard helped capitalize Edison's early ventures in the 1880s and subsequently consolidated the original Edison Electric Light Company into Edison General Electric, which, after a few more mergers and patent struggles, became General Electric.

The story of the grid from then on is rich with lore and engineering anecdote, but if we step back and look for patterns through the lens of innovation theory, we observe steady improvements along the same basis of performance: Improvements have made because of a definition of benefit that has been unchanged since the Edison/Morgan first set out their business plan.
2. The Centralization of Electrification

[How increasing centralization led to crucial improvements that offered what consumers needed most and how that trajectory continued beyond what could be absorbed]

Since the beginning of the 20th century electric power has been on a trajectory of continuous improvement. The question we have to ask first is what was being improved? The choice of what was necessary (and hence what was not) determined how the grid became architected technologically, as a business and as a regulated entity.

Getting electric power from where it is generated to customers who need it remains the critical requirement in electrification. The power grid hasn’t changed much since its earliest days, except in scale. Power plants equipped with generators convert a source of energy—fossil fuel, falling water, wind, the sun, a nuclear reactor into electricity. That electrical power is then transmitted through the distribution system to individual buildings, factories, homes, and farms.

20th-century engineers got to work making things better—inventing and improving devices and systems to bring more and more power to more and more people

We can see the pattern what the industry celebrates as milestones:

1. **Standardization.** A central electric power generating can provide power more efficiently and at lower cost than small generators. The capital and operating cost per unit of power is also cheaper with central stations. The choice of AC over DC power is a result of the need for transmission over long distances. The innovation of steam turbines was a practical improvement in power plants as it was more efficient in large scale than reciprocating designs.

2. **Cost reduction.** Transmission lines were designed with centralization in mind. In 1917 the first long-distance high-voltage transmission line was established by American Gas & Electric (AG&E), an investor-owned utility. The line originated from the first major steam plant to be built at the mouth of a coal mine, eliminating fuel transportation costs.

3. **Scale.** The need for corralling hydroelectric power led Congress to pass legislation establishing the Tennessee Valley Authority (TVA). Today the TVA manages numerous dams, 11 steam turbine power plants, and two nuclear power plants. These projects could not have easily been implemented without government action and coordination.

4. **Resilience.** In 1953 The American Electric Power Company (AEP) commissions a 345,000-volt system that interconnects the grids of seven states. The system reduces the cost of transmission by sending power where and when it is needed rather than allowing all plants to work at less than full capacity. By 1990s the bulk power system in the United States evolves into three major power grids, or interconnections, coordinated by the North American Electric Reliability Council (NERC), a voluntary organization formed in 1968. The ERCOT (Electric Reliability Council of Texas) interconnection is linked to the other two only by certain DC lines.
5. **Universal access.** In 1935 President Roosevelt issues an executive order to create the Rural Electrification Administration (REA), which forms cooperatives that bring electricity to millions of rural Americans. Within 6 years the REA has aided the formation of 800 rural electric cooperatives with 350,000 miles of power lines.

6. **Multi-sourcing.** Nuclear, wind, coal, geothermal, solar are all co-opted as centralized resources plugged into an expanding grid.

The Challenges of Never-ending Improvements

The improvements enumerated above have led to a technology and business architecture predicated on centralized unidirectional electric power transmission, distribution, and demand-driven control. They represent a vision of what was thought possible in the 19th century but seem quaint in contrast to the sophistication of computing and communications networks established in the last few decades.

New networks enjoy high utilization, responsiveness and scaleability. They absorb increasing loads easily and have capital influx which drives increasing innovation and user adoption. In terms of users, cellular networks overtook wireline networks within a decade and both have a far broader footprint than electrification on a global scale.

In contrast, electric grids are still unable to address modern challenges, such as:

1. Security threats, from either energy suppliers or cyber attack
2. Goals to employ alternative power generation sources whose intermittent supply makes maintaining stable power significantly more complex
3. Conservation goals that seek to lessen peak demand surges during the day so that less energy is wasted in order to ensure adequate reserves
4. High demand for an electricity supply that is uninterruptible
5. Quality of service protocols that assign power on the basis of priorities. For example although many devices have digital controllers, they cannot alter the nature of the electrical load. For a simple example, timed Christmas lights can present significant surges in demand because they come on at near the same time (sundown or a set time). For another example, electric vehicles [EVs] equipped with intelligent charging controls are unable to coordinate charging within a community due to a lack of load information. Without coordination, the increased use of such devices lead to electric service reliability problems, power quality disturbances, blackouts, and brownouts.

Causes to why electric grids so rigidly inflexible

Arguments typically begin with the technological limitations. But we have to appreciate that what was considered possible in communication networks changed dramatically over time. Given the green light of opportunity, engineers, venture capitalists, and companies have been remarkably innovative with solutions to seemingly intractable technology problems.

Another argument is a perceived institutional risk aversion that utilities feel regarding use of untested technologies on a critical infrastructure they have been charged with maintaining.
However, again, historically technologies have been folded into the grid which were compliant with sustaining the architecture.

The problem may be with the priorities given for improving the grid from where it is today. The major driving forces to modernize current power grids can be divided in four, general categories.

1. Increasing reliability, efficiency and safety of the power grid.
2. Enabling decentralized power generation so homes can be both an energy client and supplier (provide consumers with an interactive tool to manage energy usage, as net metering).
3. Flexibility of power consumption at the clients side to allow supplier selection (enables distributed generation, solar, wind, biomass).
4. Increase GDP by creating more new, green-collar energy jobs related to renewable energy industry manufacturing, plug-in electric vehicles, solar panel and wind turbine generation, energy conservation construction.

Categorizing Benefits
Before examining particular technologies, a proposal can be understood in terms of what it is being required to do. The governments and utilities funding development of grid modernization have defined the functions required for smart grids. According to the United States Department of Energy’s Modern Grid Initiative report, a modern smart grid must:

1. Be able to heal itself
2. Motivate consumers to actively participate in operations of the grid
3. Resist attack
4. Provide higher quality power that will save money wasted from outages
5. Accommodate all generation and storage options
6. Enable electricity markets to flourish
7. Run more efficiently
8. Enable higher penetration of intermittent power generation sources

As noted in our first paper, the second requirement is the only one which addresses consumers. All the other benefits are targeted to the utility or the “greater good”. We’ve also shown that the provision of more information is not sufficient to cause behavior change. Knowing more about the grid is not a problem consumers seek to solve. Finally, the absence of consumer engagement tends to doom the adoption of the entire initiative as the consumer shoulders the ultimate financial burden and wields the political veto. Thus, failing on the second requirement risks failure of all the other goals.
3. The de-coupling of cost and value

[How pricing is not a reflection of supply and demand and how the loss of pricing signals robs the industry of a means to allocate innovation-inducing capital]

As the industry increasingly centralized, it became defined by cost structures. Definition and measurements of value became increasingly abstract as the investment decision was distanced from the source of income. This phenomenon is not unique to the industry. If we look at health care and education industries we see that systematic integration lowers costs and increases quality but at the cost of a loss of the ability of measuring value, pricing it and allowing those who innovate to benefit from the innovation.

Conversely, administratively fragmented and specialized institutions have higher costs but allow better value capture for innovators.

When planning and investment priorities omit accounting for value created they implicitly discount the potential of value-based innovation. They obscure the profit potential and cloud the judgement of entrepreneurs.

As penetration of electrification reached saturation (already by late 1950’s) prices stabilized and have remained steady since (in constant dollars.) In 1900, 2 percent of homes had electricity. In 1950 about 80 percent did. By 1955 about 99 percent of American homes had electricity. Electric bills are much lower today than in the past. In 1900 the wage-indexed price of electricity was six times above its current level. Residential electricity costs were nearly 10 times higher than today.

The following chart shows the history of penetration and cost of electricity in the US during the last century.
What should be noted however, is that by this measure of performance, the grid was “good enough” in the 1950s. The normal cycle of innovation would imply that a new basis of competition would emerge at that point. Either increased flexibility, convenience, or cost structures would improve. But disruptive changes did not emerge.

The trouble with good enough: How cellular overtook ‘better’ wireline consumption. The tendency in free markets is for disruptive innovations to reset the basis of competition and allow for lower performance on existing basis of competition (reliability) but improvements in unmet needs (convenience, flexibility or cost.)

To illustrate, consider the evolution of telecommunications. When cellular phones emerged in the 1980’s wireline phones were excellent. Penetration was at 99 percent and prices had never been cheaper. The industry was deregulated and phone companies were competing fiercely over long distance calling plans. In contrast, the new cellular phones were not “good enough” on the basis of what was considered necessary for making critically important phone calls. Sound quality was poor, coverage was spotty and battery life laughable. But they allowed a whole new consumption model of communication to emerge. They allowed a caller to call a person not just a place and a cellular user to always be able to be reached or reach someone. Over time, this simple value proposition caused a powerful profit formula to emerge. That formula led to extremely rapid improvement in the quality of the network and devices that...
connected to it. It caused such a cataclysmic change that twenty years hence it became possible (even natural) for consumers to “cut the chord” and abandon wireline communications altogether.

The “good enough” wireline industry was dead and many of the incumbent companies faded into insignificance. The lesson from this and other changes in industry reversals of fortune is that bases of competition—the definition of what is important and where profit is captured—change. The change is often imperceptible at first but dramatic in the end.

The impact of internet on voice communications
Another parable from telecom is the impact of the internet on voice communications. Voice traffic is steadily moving to internet protocols and away from the traditional switched voice network (TDM or time-division multiplexing.) Nonetheless, the FCC regulates via an inter-carrier compensation (ICC) regime devised around assumptions based on voice traffic utilizing TDM switching platforms. ICC reform proposals remain largely focused on revising the increasingly less relevant TDM voice framework.

Standalone voice will represent a vanishingly small segment of overall network traffic. The following charts illustrate the changing nature of the relationship between traditional voice traffic and modern IP-based communications.
The chart shows on a log scale how in 1997 US Internet traffic was an emerging market with only 3,300 TB/mo vs. 54,000 TB/mo for Interstate and Intrastate Voice traffic. By 2000, Internet traffic had grown to 28,000 TB/mo while voice traffic peaked at 66,000 TB/mo. By 2005 IP traffic began to spike and reached 669,000 TB/mo vs. 48,000 TB/mo for voice. Within the IP traffic IP voice traffic was emerging at 2 TB/mo.

In 2010 IP voice begins catching up with public switched telecommunications network (PSTN) traffic with 21,000 TB/mo for IP voice vs. 36,000 TB/mo for PSTN voice. IP traffic was already astronomical at 5,723,000 TB/mo.

The projection for 2015 is that IP voice will be near parity with PSTN traffic at 23,000 TB/mo and 26,000 TB/mo respectively. Consumer IP traffic for North America is projected at a staggering 19,415,000 TB/mo, nearly 1000 times more than voice.

As in the cellular disruption, the vast growth (from 3,300 TB/mo to 19,415,000 TB/mo—an exponential increase of 5,880 times in 18 years) was due to de-centralization and new business model innovation. In so doing, a tiny, emergent use case of voice over IP (VoIP as enabled by Skype, Google Voice, iChat, Facebook, Vonage et. al.) is expected to overtake the original phone network in consumption.

Nobody would argue that when it emerged VoIP was either convenient or easy. But it was cheaper; free in fact. Now VoIP is so common that it’s the backbone of international calling and corporate communications. It’s even emerging as a contender over cellular networks.

The decoupling of cost and value in telecom

However, not all is rosy in telecom regulation. Due to several regulatory decisions, the US mobile network operators are finding themselves at a competitive disadvantage globally. Consider AT&T’s intent to acquire T-Mobile USA. Will regulators look at the deal through the lenses of sustaining the traditional industry’s profit allocation or through the lenses of device-led disruption?

In theory, regulators are to make a determination on whether the deal will reduce customer choice. But the question is really choice of what? The focus is presumably on the choice of service plans. That’s understandable. However coupled to that choice is the choice of devices and even more importantly, the choice of platforms.

The trouble is that US consumers have never had much choice and the US wireless marketplace has been a minefield of incompatibilities and obstacles to market forces.

To begin with, US carriers maintain multiple incompatible network standards. Phones which work on one network do not work on any other. A Sprint phone won’t work on AT&T or on Verizon. In fact, some Sprint phones won’t work on all of Sprint’s network as it still uses the iDen standard legacy from the Nextel acquisition. Even the iPhone which is designed for the AT&T network does not handle T-Mobile’s version of 3G. So a consumer cannot make a decision on devices independent of a decision on carrier. This is a phenomenon unique to the US.
Secondly, in the US carriers charge for incoming minutes and have shunned pre-paid customers. There was a time when SMS messages were not compatible between networks, which led to the emergence of RIM as the only wireless messaging solution available, though initially not to the average teenager.

Thirdly, because of the multiple incompatible standards, network coverage in the US is still quite poor relative to other countries—even less developed ones. Each carrier has had to build out parallel (incompatible) networks at great expense using non-standard equipment over a vast landmass. The result is not only a very expensive network whose capex demands high service fees, but a very poor quality network which is always both spotty and capacity constrained. Operators are therefore keen to lock customers in to post-paid plans to ensure cash flows that drive capital allocations. This is essentially an upmarket flight which does not encourage low end innovation.

These idiosyncrasies are rooted in historical regulatory rulings that led operators to create a uniquely American wireless market. The key regulation was that the US shall have no single wireless standard. In the spirit of *laissez-faire* this may make sense. But the result has been failure of the common good. This is sharply contrasted with other developed countries which (with notable exceptions) deliver superior service with high efficiency.

The US is so unique that it developed its own “Galapagos syndrome”. Few global brands can be bothered to invest in it. Vodafone tried to play in the US with Verizon, but its minority position offered no leverage because Verizon spent the better part of a decade avoiding global networking standards. Now T-Mobile is desperate for an exit after trying to leverage the foothold it paid dearly for and failing to offer devices that capture users’ imaginations (because they were railroaded into another incompatibility with 3G). Conversely, no US brands have been able to expand internationally. US operators are non-entities abroad, even in what would be natural expansion territories like Latin America or the Caribbean. Those markets belong to European investors today.

Given this background, it’s very likely that regulators will look at the deal in terms of balancing what is essentially a deeply flawed, cobbled together industry. Companies can argue that they are rationalizing through consolidation but regulators can argue that “choice” is decreasing. These arguments are mostly moot. The problem is that the US wireless market is balkanized and byzantine.

It’s therefore perhaps stunning that the platforms that are currently winning in mobile computing are American: iOS and Android². Note further that none of these winners came from the world of wireless or telecom. These new points of profit condensation in the industry entered from a different industry: computing.

But are they now pursuing telecom-compliant strategies? Arguably no. We choose to call them mobile computing and not phone platforms specifically because they will tolerate the cellular regimes as long as they need to, and no longer. Once they will reach the perch of power, the industry will conform to them, not vice versa.
What’s not good enough about the grid?

We established that the grid has been good enough on its foundational goals for many decades. We’ve also shown that many improvements sought by utilities, regulators and policymakers are unimportant to end users and thus are unlikely to end up being implemented.

So in order to see the future of grid innovation we have to discover what new vector of performance can be offered that is appealing to consumers. We have to find out what’s not good enough about the grid. In other words we have to ask: What unserved need could a user ask the grid to solve?

Put another way: What jobs does a consumer need to solve in her life for which a smarter grid is uniquely qualified to be hired?
4. The Jobs that Smart Grids can be Hired to do

Before we delve into the Smart Grid’s job descriptions, we’ll recount the “Job-to-be-done” theory of market segmentation and categorization.

A job is the fundamental problem a customer needs to resolve in a given situation. To illustrate what a job is and how much clearer the path to successful innovation can be when innovators uncover job-described needs, we’ll offer an illustration from the smartphone market, where companies historically have segmented their markets along the traditional boundaries of product and customer categories, but would greatly benefit from segmenting by job.

Hiring Mobile Computers

If you think about the difference between a smartphone with an unlimited data plan and 3G connectivity and a voice phone, the difference in capabilities is stark. But more than just the enabling of new features, there are subtle changes in what people “hire” the new phone to do vs. what the old phone did.

In our earlier discussion on the disruptive impact of mobile telephony vs. fixed, wireline telephony we mentioned that the new mobility allowed the caller to “call a person not a place”. That’s a change in the job description of the technology. Calling a person has enormous connotations: it means you can feel safer if that person is your child. It means you can do more instead of waiting for a call at home. It means even more to a salesperson who can change plans mid-day.

Now when we reflect on the change that a mobile computer in you pocket can have in your life, it becomes yet another job re-definition. It’s not just a tricked out phone. It becomes an enabler to yet another lifestyle. The explosion of app consumption (14 billion downloads in less than three years) shows that users found completely new ways to use these devices. Ways which even its creators could not envision.

Hiring Mobile Offices

Here’s another illustration. Automobile market researchers segment their markets into product categories such as sub-compacts, compacts, mid-size and full-size sedans; SUVs and minivans; light vs. full-size trucks; sports cars and luxury cars. In the belief that their market is structured by product category, they design their cars to slot into a category, believing that if they have better features and performance than other cars in their category, they’ll succeed.

However, These segmentation schemes don’t reflect the way that customers experience life when buying and driving a car – the jobs that they hire a car to do. Millions, for example, hire a car primarily to be a mobile office. Many others hire them as “school run” shuttles built for a singular purpose through a period of a child’s life. Teenagers (and some adults) hire cars to sustain fragile egos. All these purchase/hiring decisions force consumers to filter through a maze of bizarre categories to decide which matches their real-life need.

No company has designed a car that is optimized to do the mobile office job that these millions of people need to do. These customers must test-drive car after car, and then buy one that doesn’t do the job well. While they resist premium prices for features that are irrelevant to this
job, they put up with all kinds of inconvenient compromises and work-arounds as they try to make phone calls, enter data, answer emails, file papers, enter or check the status of orders, find sales literature, use the Internet, keep their computer's battery charged, and eat lunch.

Every job has functional, emotional, and social dimensions. The weight of these three elements varies by job. For example, the need to feel a certain way – to feel macho, sassy, pampered or prestigious – is a job that arises in many of our lives on occasion. When we find ourselves needing to do one of these jobs we can hire products with names like Gucci and Louis Vuitton, where it is the brand, rather than the product, that carries the freight. The functionality dimension of the job isn’t nearly as important as its social and emotional dimensions. In consumer cleaning products, in contrast, the functional dimensions of the job are predominant.

The Smart Grid Job Description

So given the difficulty industry has uncovering unmet jobs for products that are vastly more malleable and conformable, how do we hope to find unmet jobs for something as rigid and specific as an electricity grid?

The way we do it is by looking at the centralization/de-centralization dichotomy discussed in section 2 The Centralization of Electrification. Centralization was the means by which the network became good enough. Now that it’s more than good enough (as far as the consumer is concerned) the disruptive growth will come from the migration of intelligence, control and value capture to the edge of the network.

As we alluded throughout this paper, the de-centralization of computing power and communication power has been a symptom of the powerful growth in the computer and telecom industries. We believe that this centrifugal force will be the defining characteristic of a successful smart grid.
5. Principles of a disruptive smart grid

In order to re-define the industry, here are the principles guiding a disruptive smart grid which take into account innovation theory.

1. A disruptive smart grid must enable the provision of power resources on demand rather than as a fixed asset. This is addressing both the needs of the consumer and the needs of the utility. A disruptive smart grid is a load-balancing grid that does not impinge or curtail consumption but offers power with lower resource demands. The intelligence will permit better utilization of existing resources like transmission lines and power plants.

2. It is a model of power as service management presented to the customer as an abstraction that hides complexity and is thus simpler and more conformable to the user's needs. As consumers will increasingly load the grid with products hired to do new jobs, and as these new products create additional loads which will need balancing (e.g. electric vehicles), the job of the grid is to manage the load while keeping the complexity invisible from the user.

3. It enables new economics for power distribution where costs are incurred only when the resources are needed rather than as fixed costs to be continuously amortized. This means a pricing model where consumers are given signals for scarcity and abundance while offering margins for innovators to hedge and arbitrage between the two.

4. Unlike traditional generation and transmission solutions, disruptive smart grids are hired by user applications not by users acting as administrators. This is an important distinction because it means the "administration" shifts to the application (device, vehicle, appliance) rather than to the consumer. It also means that the definition of performance changes to what the new "administrator" deems to be most important. In other words, it goes from meeting standards or arbitrary criteria or best practices to solving a problem.

By hiding details and inner workings, the disruptive grid allows this new population of non-expert customers (who do not want to or cannot administer) to make money saving and ecologically sensitive purchase decisions. Whereas power was a resource managed and allocated by experts with authority to balance scarcity and capital intensive resources, smart grid allows application builders to allocate service on an as-needed basis.
1 Japan has a similar problem but less pronounced

2 Microsoft is still in the running as is Palm, both American
Creating a Smart Grid and Clean Energy Economic Cluster in the CAPCOG Region
This report details the work, findings and recommendations of Pecan Street Inc. (Pecan Street) on smart grid and clean energy cluster development. Pecan Street carried out this work as a subrecipient to the Capital Area Planning Council of Governments (CAPCOG). Funding for the work came from an Economic Development Support for Planning Organizations grant from the U.S. Department of Commerce’s Economic Development Administration.

**Introduction**

In the quarter century since Austin’s surprise selection in the 1983 MCC site selection competition, “Silicon Hills” has solidified its standing as a significant technology economy center. Richard Florida labels emerging high tech centers as “Global Austins”, the Milken Institute writes that Austin is a “poster child for the concept of a 21st-century knowledge-based community”, and Time describes the city as “the Southwest’s technology center” and “a model of hope” during the Great Recession. i

In economic development, the technopolis model developed by the late University of Texas business school dean George Kozmetsky and first put into action during the MCC recruitment, has proved impactful. In fact, the technopolis model is also described in many economic development circles as the “Austin Model”. ii A seminar announcement from February 11, 2011 at Louisiana State University urges people to attend a lecture to learn how “the ‘Austin Model’ has influenced technology and wealth creation around the globe.” iii

The slight, but relatively stronger, growth in employment in the Austin-Round Rock Metropolitan Statistical Area (MSA) masks, however, an underlying erosion of technology jobs – particularly in manufacturing. The very jobs and accompanying higher standard of living that Austin catalyzed through the region’s success in technology sector development are slipping away, and the jobs replacing them are overwhelmingly lower-paying, lower skill jobs in non-technical service fields.

As with job-seekers and leaders in many global metropolitan areas, Austinites are examining with increasing interest the potential of new “green collar” job opportunities in clean energy, green building, smart grid and related areas. Beginning in 2009, Pecan Street set out to understand the factors that are necessary for development of a clean technology economic cluster and work toward advancing the development of such a cluster that is based in the CAPCOG region and focused on global markets. This report details Pecan Street’s work, findings and recommendations.
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About Pecan Street Inc.

A research organization based at The University of Texas at Austin (UT), Pecan Street is modeled on UT’s vision of the university-public-private consortium as a catalyst for innovation and commercialization. It operates as an industry-university research and development consortium with three core areas of focus:

- Engaging in scientific research focused on technology, business model and customer behavior surrounding advanced energy management systems
- Supporting research and scholarship opportunities for University of Texas researchers and students in fields related to advanced energy management systems and supporting technologies (such as wireless, energy storage, distributed generation, networking and semiconductor technologies)
- Supporting technology commercialization programs and activities of The University of Texas at Austin

The consortium incorporated in August 2009 and received tax exempt designation under section 501(c)(3) of the Internal Revenue Code in October 2010.

The organization’s first employee began on January 1, 2010. By the conclusion of Fiscal Year 2010-11, the organization had nine employees and three contractors. The organization also funds the consortium research of 10 University of Texas faculty members and seven UT graduate students. In July 2011, the consortium began development of a smart grid interoperability lab in Austin (slated to open in April 2012).

The organization’s board includes representatives from The University of Texas, Austin Energy, Environmental Defense Fund, the Austin Technology Incubator (part of UT), the City of Austin and the Greater Austin Chamber of Commerce.

Pecan Street Project began operations through seed funding of $50,000 from UT. Since then, the organization has provided over $3 million in direct funding to UT researchers and students.
The organization’s year-to-year operating funding comes primarily from dues payments by consortium member companies. (At the end of FY 2010-11, the consortium had eight member companies: Best Buy, Freescale, Intel, Landis + Gyr, LG Electronics, Oracle, Sony and Texas Gas Service.) It has also established formal research collaborations with National Renewable Energy Laboratory, Galvin Electricity Initiative and Underwriters Laboratories. These organizations participate in consortium research managed by Pecan Street.

In addition to member company dues payments, the consortium has received funding through CAPCOG as a subrecipient of the EDA grant. In November 2009, Pecan Street received a U.S. Department of Energy stimulus award for a Smart Grid Demonstration Project centered on Austin’s Mueller community. In November 2010, Pecan Street received an award from the Doris Duke Charitable Foundation to research energy usage and the impact of energy efficiency retrofits in older homes.

Smart Grid News in 2010 listed Pecan Street’s smart grid demonstration number two on its list, “10 Pretty Darn Interesting Stimulus-Funded Smart Grid Projects.” In March 2010, Pecan Street released a report of recommendations for how to spur energy system advancements. The recommendations were the product of joint industry-university-utility-public sector working groups. In September 2010, Pecan Street announced at Austin Technology Incubator’s Clean Energy Venture Summit that it had selected Incenergy LLC for the first deployment of advanced smart grid systems in the organization’s smart grid demonstration project in Austin’s Mueller community. Incenergy is an Austin-based start-up company with wireless networking and software expertise whose founders come from the telecommunications industry.

After carrying out field trials of the Incenergy systems in the homes of participating volunteers, Pecan Street went live on its 12-month baseline data collection research on February 1, 2011. The systems it deployed came in at a cost of $241 per home plus $100 per home installation costs. These systems report electricity usage from the whole home and six circuits in 15-second increments. In the spring and summer of 2011, Pecan Street and Incenergy expanded the scope of these systems to gather natural gas and water usage data as well, marking the first time in such research has taken place in the United States. The systems report all data to UT’s Texas Advanced Computing Center.

Dr. Michael Webber, a UT engineering professor and Pecan Street researcher, has concluded, “The Pecan Street Consortium’s smart grid research is generating incredibly valuable information on how, when and on what customers use energy. It will end up as the single greatest collection of consumer energy data that has been developed in the United States.”

Cluster development in emerging industries
Potential economic clusters built around clean energy technologies largely display the characteristics of emerging industries (as opposed to mature markets). Economist Michael E. Porter describes an emerging industry this way:
Emerging industries are newly formed or re-formed industries that have been created by technological innovations, shifts in relative cost relationships, emergence of new consumer needs, or other economic and sociological changes that elevate a new product or service to the level of a potentially viable business opportunity.

Therefore, a region seeking to establish a clean energy/smart grid economic cluster must utilize the economic strategies particular to emerging technology sectors. These strategies include the following:

- Focus on particular sectors within the umbrella terms of “clean energy” and “smart grid”. Multiple industries fall within these umbrella terms, and a number of them, such as biofuels and battery development, have few if any overlapping competencies.
- The targeted industries must be global industries.
- A research university must form the nucleus of a region’s effort.
- The region should also develop or support the creation of complementary assets, such as technology incubators, joint industry-university research consortia and support networks for entrepreneurs.
- For emerging sectors that are more likely to gain traction through disruptive innovations, the university and consortium’s research efforts should include applied research on platform development.

Success factors in developing emerging technology clusters

Drawing on its own original research as well as the economic theory of Clayton M. Christensen, Kozmetsky, Carlota Perez and Porter (among others), Pecan Street has identified the following principles and actions that form the basis for development of a clean technology economic cluster:

- A research university in the region must serve as the nucleus of the region’s strategy.
- A university-centered cluster strategy must include consortia, incubators and other key private sector and public entities.
- A local market is important for developing a cluster.
- Being an early mover is critical to success.

A research university in the region must serve as the nucleus of the region’s strategy.

In their 2007 Economic Development Quarterly analysis of the impact of research universities on the development of high-technology centers, Raymond Smilor, Niall O’Donnell, Gregory Stein and Robert S. Wellborn conclude that “the nucleus in the development of a technology center is a research university.”

Examples of regions that have successfully built high tech centers around research universities include Silicon Valley, the Boston Route 128 corridor, Austin, Raleigh-Durham, and San Diego. San Diego’s example is most striking: it did not have a research university when it set out to become a high-technology center, so an early action that civic leaders undertook was creating
such an institution: the University of California-San Diego. vii UCSD was the catalyst for – and university researchers were involved in the creation of – the global wireless telecommunications industry as well as San Diego’s globally significant life sciences sector. viii Research universities serve as “instigator; promoter; collaborator; and magnet for talent, technological innovation, and entrepreneurial activity.” ix The companies and technologies that emerge from research universities “benefit society and universities, including [through] their effects on local economic development, their ability to produce income for universities, their tendency to commercialize technology that otherwise would be undeveloped, and their usefulness in helping universities with their core missions of research and teaching.” x There is little precedent for a region successfully developing into a technology center without a research university-centered approach. In fact, “if a research university is not in place, a technology center is not likely to develop.” xi

**A university-centered cluster strategy must include consortia, incubators and other key private sector and public entities.**

In addition to anchoring its efforts at a research university, a region must implement the complimentary strategies and develop the complimentary assets that Kozmetsky describes in his technopolis model. These include:

- Establishing “academic and industrial collaborations and industrial R&D consortia” xii
- Developing collaborations of “business, government, entrepreneurial, and academic partners” xiii
- Focusing initiatives of these collaborations and consortia on global markets. Regional leaders should begin by identifying the global industry into which the local initiative is targeted, then identify the relevant institutions that make up some part of the innovation chain for that sector.
- Supporting the work of (or establishing, if not in place) –
  - technology business incubators
  - educational programs for business-training assistance
  - technical support and assistance programs
  - organized networks of experienced businesspeople, local advisors, and professional associations and support groups xiv

**A local market is important for developing a cluster.**

A cluster is unlikely to develop in a particular region without the existence of a local market in that industry. This is due to the confluence of the research university’s role in cluster development, the preponderance of early stage companies and the need for customer feedback.

While the entrepreneurs who create new companies frequently come from outside the university, research universities play an essential role in the creation of an emerging technology industry cluster because universities are major generators of radical technologies and highly skilled technical talent. xvi The potential for a university to catalyze commercializable
technologies is tied to the extent the university’s research is funded by industry. \(^{xvi}\) (This reinforces the need for an industry-research university consortium.)

The emerging nature of the sector and the role of a region’s research university in producing technology research, highly skilled talent and (frequently) company founders mean that many companies initially are start-ups located close to the university. \(^{xvii}\)

Early concept technologies and businesses built around these technologies require extensive customer feedback to ensure that the offerings meet customer needs and have commercial potential. \(^{xviii}\) Given the importance of obtaining this needed customer feedback, companies are more likely to locate and succeed where customers are geographically proximate. \(^{xix}\)

Therefore, regions with research universities that lack a local market will struggle to compete against regions that have both research universities and a local market. That is because new entrepreneurs and inventors that operate in a region without a local market will have limited ability to obtain needed customer feedback. Such a region will be at a strategic disadvantage vis-a-vis regions with both research universities and local markets. In those regions, companies will have the ability to obtain customer feedback that is critical to refining technologies into commercially viable products and services that solve customer needs.

Conversely, areas with a potential local market but without an engaged research university are at a competitive disadvantage as these regions are unlikely to generate the new technologies that form the basis for an emerging sector.

**Being an early mover is critical to success.**

In her review of previous technological revolutions, Carlota Perez concludes, “Each of these revolutionary clusters irrupts in a particular country, sometimes even in a particular region.” \(^{xx}\)

The consequences of being first are profound and enduring: “In fact, each technological revolution originally develops in a core country, which acts as the world economic leader for the duration of that stage.” \(^{xxi}\)

Paths to market development

New technologies typically enter the marketplace in one of three ways:

- as sustaining innovations
- as disruptive innovations
- by regulatory fiat. \(^{xxii}\)

Whether a technology enters the marketplace as a sustaining innovation, as a disruptive innovation or by regulatory fiat has a profound effect on the resulting economic impact and on the types of companies that prevail. Properly executed, sustaining innovations typically have a positive but modest economic impact, and the companies that benefit are large incumbents. \(^{xxiii}\)

Disruptive innovations are harder to achieve but have the potential to create “explosive” rates of growth in new markets. \(^{xxiv}\) New companies almost always prevail against incumbents when the basis of competition is a disruptive innovation. \(^{xxv}\)
The economic impact of technologies of products that enter the market through regulatory fiat is highly situation specific. In general, “buyers usually will purchase the lowest cost alternative that meets the technical requirements.” xxvi Such technologies are unlikely to drive significant new growth after an initial burst resulting from compliance costs.

As a result, new economic clusters are unlikely to arise when targeted technologies enter the market as sustaining innovations or by regulatory fiat but typically only emerge through disruptive innovations that are developed by early mover regions.

**Sustaining innovations**

Sustaining innovations are:

- what move companies along established improvement trajectories. They are improvements to existing products on dimensions historically valued by customers. Airplanes that fly farther, computers that process faster, cellular phone batteries that last longer, and televisions with incrementally or dramatically clearer images are all sustaining innovations. xxvii

Customers to whom sustaining innovations are targeted represent the most demanding customers of a product for whom the current products are not good enough. xxviii Such customers will pay a premium to obtain products that better address their needs; the area of performance on which the product is not good enough is subjective and is “along whichever dimension of performance customers in a given tier of the market care about the most.” xxix

Sustaining innovations are often initially targeted at these demanding customers, and then once the products have improved or a new generation of even more advanced technologies have come to market, the original advanced technology moves into the volume tiers of the market. xxx

The dimension of performance is frequently technology-based, but ethical, moral or health-based attributes of products can also qualify as sustaining improvements. For example, faster processors and higher touchscreen resolution are examples of dimensions of performance that are important to the most demanding customers for smart phones, and these customers will pay a price premium for such devices. Foods that are organic, and meat from animals that were ethically treated are attributes of foods that are important to demanding customers who emphasize ethical, moral or health-based product attributes, and they, too, will pay a price premium for these foods. The success of Whole Foods demonstrates that even though customers motivated by ethical and health concerns do not represent the large middle market, these demanding customers can contribute to meaningful economic opportunity for providers who cater to these customers.

The upmarket technologies in sustaining innovations are not necessarily incremental improvements in the technology. In fact, they can represent very significant performance enhancements in an area of performance that the most demanding customers care about enough to buy a new product containing the new features, and pay a premium for it:

- Radical sustaining innovations are at the complex end of the continuum. These “great leaps forward” tend to be complicated, interdependent, and expensive. Two classic examples of radical sustaining innovations are the systemwide
upgrade of the telecommunications network from analog to digital technology and the move from black-and-white to color televisions. xxxi

Cramming

“Cramming” is a variant of sustaining innovations. It frequently occurs when an incumbent attempts to introduce a technology with disruptive potential into its existing products and processes:

Instead of embracing the innovative product’s inherently disruptive nature, the incumbent inevitably tries to morph the product to fit into its existing processes and values. The problem with cramming is that it . . . takes an innovation from a circumstance in which its unique features are valuable to a circumstance in which its unique features are a liability. xxxii

Signs that cramming is occurring include:

• Industry incumbents are the ones implementing the new technology.
• The companies installing the new technologies experience performance problems in integrating the new technology into their existing delivery model or product processes.
• The company implementing the new technology “must convince customers to change their behavior or put up with something they don’t seem to want.” xxxiii

Cramming is “almost never successful. It costs a lot of money and usually ends with disappointing results.” xxxiv

Disruptive innovations

Most technologies “are not intrinsically sustaining or disruptive in character.” xxxv Rather, how the technology is deployed impacts whether the resulting product will constitute a sustaining innovation or a disruptive innovation.

Disruptive innovations come in two types: low-end disruptions and new-market disruptions. xxxvi

Low-end disruptions “are those that attack the least-profitable and most overserved customers at the low end of the original value network.” xxxvii Examples of low-end disruptions include early Toyota and Honda cars (which were smaller, cheaper, less powerful and had fewer features than the successful models sold by American and German car companies), Sears and Montgomery Ward (whose catalog retailing extended retail services to people in rural America) and Dell Inc. (whose direct-to-customer distribution model initially allowed it to sell personal computers more cheaply). xxxviii

New-market disruptions, by contrast, do not compete with existing products; rather, they “create new markets or reshape existing markets” and “introduce a new value proposition”. xxxix

Disruptive innovations achieve growth through generating sales of –

products [that] are so much . . . simpler to use that they enable a whole new population of people to begin owning and using the products, and to do so in a more convenient setting. The personal computer and Sony’s battery-powered transistor pocket radio were new-market disruptions, in that their initial
customers were new consumers – they had not owned or used the prior generation of products and services. Canon’s desktop photocopiers were also a new-market disruption, in that they enabled people to begin conveniently making their own photocopies around the corner from their offices. \textsuperscript{xi}

To be successful, such products must “help customers do more easily and effectively what they were already trying to get done instead of forcing them to change behavior or adopt new priorities.” \textsuperscript{xli} They “are not always cheap on an absolute scale. . . The first mobile phones, personal computers, cameras, and so on – all were expensive. . . Subsequent improvements typically create production efficiencies that enable price reductions that make the disruptive product or service available to wider customer groups.” \textsuperscript{xlii}

New-market disruptions typically follow two patterns:

1. They introduce a relatively simple, affordable product or service that increases access and ability by making it easier for customers who historically lacked the money or skills to get important jobs done.
2. They help customers do more easily and effectively what they were already trying to get done instead of forcing them to change behavior or adopt new priorities. \textsuperscript{xliii}

While new-market disruptions frequently “lack the raw functionality of existing products”, they offer new benefits – such as convenience, customization, or lower prices. The attribute bundle means the product will only find success if it takes root among new customers or in a new context of use. Demanding customers who are already consuming a potentially competing product will reject the innovation because of its performance limitations. Competing against non-consumption entails clearing a lower acceptance hurdle. \textsuperscript{xliv}

Regulatory fiat

The third way in which new technologies enter the marketplace is when buyers are compelled to purchase a product by regulatory fiat or through requirements imposed by other entities such as insurance companies. \textsuperscript{xlv} Examples of industries created through regulatory fiat include smoke alarms and corn ethanol. \textsuperscript{xlvi}

Another example of fiat-driven growth came in 1999 when corporations made large information technology purchases in response to Y2K concerns. Once the immediate compliance concern had been addressed, corporate IT purchases dropped dramatically in early 2000.

The imperative of customer benefit

Regardless whether the technology is sustaining or disruptive in the way it is deployed, it must help customers accomplish a job that is important to the customer:

[A] reason promising technologies fail commercially is that, although they provide technically sophisticated functionality, they do not help customers do a job they need to have done. By job, we mean a fundamental problem a customer
needs to solve, including a specific result or outcome. If a technology helps customers accomplish a job they are already trying to do in a superior way, it is far more likely to succeed. If a technology tries to solve a job with which a customer isn’t terribly concerned, it is likely to face headwinds.

The benefit to the customer is “[p]erhaps the single most important determinant of the receptivity of the buyer to a new product or service.” When assessing the market potential of a new product using the metrics of cost and performance, early markets are moved more frequently by products that provide performance advantages than products that provide cost advantages.

Under innovation economic theory, for customers to embrace a new technology, it must help them do a job that they are currently trying to do and for which status quo offerings provide an inadequate solution. Importantly, it must be a job customers are already trying to accomplish: “Customers don’t just ‘change jobs’ because a new product becomes available.” Therefore, in evaluating the potential for a new technology or service, it is necessary to ask these questions:

- Who would be the customers?
- What job does the technology help the customers do that the customers currently are trying to do?
- What offerings are the customers currently employing to do this job?
- Compared to the existing offerings used by the customers, how would the new technology help the customers “accomplish more effectively and conveniently what they’re already trying to do.”

Answering these questions – which are fundamental to evaluating the potential of a product or service – requires knowing in fact what problems customers are trying to solve in their lives. To achieve this understanding, companies and researchers should “focus not on the industry or what is being sold but rather on the underlying customer need.” Companies and researchers therefore must start with research and observation rather than solutions and technologies.

Typically, the only way to identify the problems that target customers are attempting to solve in their day-to-day lives is by directly observing the activities and daily routines of these customers at granular levels of detail.

Only with this direct knowledge of customer activities and unexpressed needs can companies and researchers develop products, services and systems that help customers perform jobs better than current offerings do: “Knowing what job a product gets hired to do (and knowing what jobs are out there that aren’t getting done well) can give innovators a much clearer road map for improving their products to beat the true competition from the customer’s perspective – in every dimension of the job.”

Preconditions for new markets driven by disruptive innovations

Economic theory and repeated real-world experience demonstrate that new markets capable of explosive growth only arise through disruptive innovations. Carlota Perez writes that for a
technology economy revolution to take hold, a “techno-economic paradigm” must emerge that guides behaviors and how the new technologies are applied into new products. lvii

The precursors for development of disruptive new markets and of a techno-economic paradigm include:

- New platform
- Attractors – killers apps and big-bang products
- New business systems and models
- Changing customer capabilities
- Changes in regulations lviii

These market precursors are particular to new markets arising from disruptive innovations and “are quite distinct from the factors to monitor in established markets.” lviii

**Platform**

As demonstrated by the Internet, Microsoft Windows and the Apple iOS App Store, platforms play a critical role in enabling new markets built on disruptive innovations. In fact, one of history’s most disruptive platforms is the electric grid, which enabled a broad of disruptive innovations in lighting, cooking, personal comfort (air conditioning and fans), food preservation (refrigeration), cleaning and entertainment (phonographs, radio and television) that profoundly altered people's lives.

The most successful platforms are open “plug-and-play” platforms with high levels of market interoperability (i.e., developed market structure). They also have high levels of technical and semantic interoperability – well-defined and broadly adopted interfaces and system architectures that enable a wide array of companies to provide solutions. lx Examples of successful interfaces include light bulb sockets, 120-volt plugs and outlets, USB ports and the World Wide Web's http protocol.

Such open platforms “can trigger innovation in completely unexpected directions.” lx

New platforms typically build on previous platforms or combinations of platforms, and the new platforms rarely enable just one use. li Further, new markets frequently emerge on platforms that were originally built for purposes unrelated to the new markets that emerged on these platforms. lii

For example, while mobile telecom networks were originally constructed to carry voice communications, they became platforms for mobile email, text messaging and the world’s largest Internet platform. Apple built its iOS platform (and Google subsequently built its Android Marketplace) on a combination of mobile telecom, World Wide Web and GPS platforms. The iPhone and iOS App Store platform have proved disruptive to a wide array of industries that seemingly had little connection to a mobile telephone operating system.

Industries to which iPhone and iOS have been disruptive
Industries to which iPhone and iOS have been disruptive

- GPS services
- Calculator makers
- Map makers
- Camera companies
- Stopwatch makers
- CD and DVD manufacturers
- Video camera companies
- Compass makers
- Large software companies

As reflected by the example of iPhone and iOS, one industry to which the Apple ecosystem was not disruptive was mobile telecom carriers. That is because iOS (subsequently joined by Android) created a platform that made the incumbent mobile telecom platforms more valuable and indispensable. A platform that once was only useful for making phone calls became one of the underlying platforms (along with the Internet and GPS) for a platform that enables so many consumer solutions that it gave rise to Apple's tagline, “There’s an app for that.” Further, because the new platform is built on existing platforms, the new platform relies implicitly on the continuing viability of these underlying platforms.

Business Models and Systems

The second component of “techno-economic paradigm” is the economic pillar of the paradigm. New technologies by themselves are not enough, because “most customers do not buy raw technology, but, instead, buy products or services. Therefore [companies] need to create something that customers will buy.”

Examples where a new business model catalyzed explosive growth for offerings that integrated new technologies include:

- Haloid Corporation’s decision to move from the razor and razor blades model favored by incumbent makers of “wet” photographic copy machines to a leasing model for its new copier that used electrostatic charges and toner. Haloid’s machine had been rejected by every company to which it presented before it moved to the leasing model. After it moved to the leasing plus cost-per-copy model, the company that renamed itself Xerox was so successful that it achieved 41 percent compound growth for the next 12 years and vaulted the previously anemic copier industry into a central place in every office.

- George Eastman invention of celluloid film failed for 10 years to catapult photography from the realm of highly skilled photographers to mainstream market customers. However, his camera became a commercial sensation when he introduced a new business model in which customers sent their camera to Rochester for the film to be developed and the camera reloaded with new film and returned to the customer. This new business model made cameras vastly simpler for average people to use and led to significant growth of mainstream market cameras.
• The market in for-sale digital music downloads struggled to combat piracy rampant in free music sharing services like Napster until October 2001. When Apple entered the crowded MP3 market not just with the iPod but also introduced music downloads at 99 cents a song for any song and $9.99 for any album, the growth in digital music sales took off and became the dominant form of music consumption within a few years.

As these examples illustrate, products with new technologies that are languishing can became commercial successes through application of new business or value models. These business and value models normally are simple to understand and use.

**Killer app**

Even with all of the other conditions for new market formation in place, new markets will not take off without the emergence of an “attractor” – a killer app or big-bang product that is necessary to kick off an age, as did the Model T in 1908 and the Intel microprocessor in 1971, and cause a “society to veer strongly in the direction of a new set of technologies”.

The absence of readily identifiable products and services that trigger customer excitement is a warning sign that a new market has not reached the point of viability.

**New energy sectors**

New markets emerge from the application of new technologies in products or services that are consumed in new locations or contexts or are purchased by customers who currently are not consumers. Given the ubiquity of electricity availability in the United States, disruptive new markets are unlikely to emerge from providing electricity to customers who currently lack electricity access. (This is not the case in large parts of the developing world, however.)

Therefore, the most viable new markets to emerge out of smart grid and clean energy technologies will be those that have the following characteristics:

• A new platform – particularly one that has multiple uses and which builds on current commercially successful platforms

• New contexts for consumption – products and businesses that create consumption or generation of value in new locations outside of existing delivery channels

In seeking to identify new markets that could lead to economic cluster development, venture capitalist Rob Day observes that –

“Cleantech” simply isn’t an industry. It’s an umbrella term covering a wide range of sectors and markets. And from a Porterian Cluster perspective, it’s almost an irrelevant term. Take the issue of talent, for example: solar PV engineers have very little overlap with water tech entrepreneurs, nor with energy efficiency service providers, nor with smart grid solutions providers, etc. Similarly, the customers are different, the inputs are different.

. . . If a region already has a nascent cluster, the economic development agency should double down on helping to build out that ecosystem, rather than try to attract cleantech startups from other sectors.
The task for regions seeking to build a new market cluster, therefore, is to identify the technologies that, when applied on new platforms and in new contexts, can lead to new markets that generate explosive growth.

Component new energy technologies
Technologies do not create new markets. Rather, the application of new technologies into products and services determines whether the resulting product or service is capable of creating a disruptive innovation that generates explosive growth.

That said, the component technologies are still relevant. As reflected by cramming situations, technologies that are poorly suited for certain applications and contexts of consumption may be well-suited for others.

Identifying and understanding the component technologies that will go into the products and services that drive new services is also important to a region looking to develop a cluster around targeted new markets. A particular new market may hold considerable potential, yet the region could still face challenges in developing a cluster around these new markets if it lacks the local expertise to create advances in the new market’s component technologies.

Therefore, for a region to be competitive in one of the potential new markets of new solutions that integrate new energy technologies, it is important to have local technical expertise in one or more of these technologies:

- Solar photovoltaics (PV)
- Batteries
- Fuel cells
- Software
- Semiconductors
- Networking technologies
- Controls
- Wireless technologies

The local technical expertise should be located in a research university located in the region, a global technology company’s headquarters or major research outpost located in the region, or both.

Potential platforms for new market development
For a new market to irrupt, a techno-economic paradigm must first be established that is built on a new platform. These platforms establish the conditions for new markets built on disruptive innovations. Without development of one or more new platforms, there is little prospect that dynamic new markets employing clean energy and smart grid technologies will emerge.

Successful new platforms have the following characteristics:
- Technical and semantic interoperability: well-defined and broadly adopted interfaces and system architectures that enable a wide array of companies to provide solutions
- Open “plug-and-play” platform – a platform onto which a broad array of companies can offer products and services to end consumers
- Built on one or more existing platforms
- Capable of more than one use
- Market interoperability: a business model paradigm that guides dynamic, predictable market interactions

Potential platforms that manifest the characteristics of successful new market platforms are:

- Home and building systems
- Distributed microgrids

**Home and building systems**
Home and building systems offer the promise enabling disruptive innovations in the following ways:

- Simplifying a wide array of in-home consumer jobs
  - Security (such as detecting intruders, setting lighting times during vacations, detecting water and gas leaks through changes in usage)
  - Energy, gas and water management and information alerts
  - Monitoring performance and detecting malfunctions in appliances and systems
  - Ensuring contractor and new product warranties and performance (through measuring the performance of newly installed work and products)
  - Grocery shopping (with smart refrigerators that survey refrigerator contents and suggest needed items through a mobile phone app)
  - Home repair and improvement (by detecting evidence of issues such as roof and window leaks, suggesting the best value replacement and even finding nearby highly rated stores and contractors)
  - Appliance replacement and shopping (e.g., a consumer electronics app that the customer installs can detect aging appliances and offer coupons for new appliances)

- Creating new contexts for consumption
  - Managing electric vehicle charging in the garage
  - Home health care monitoring
Home management systems

<table>
<thead>
<tr>
<th>Platform requirement</th>
<th>Potential characteristics and functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>New platform</td>
<td>Home energy management system (HEMS) or similar hub-based platform. The HEMS captures energy usage data from a broad array of in-home sensors, devices and appliances. The consumer can select software apps that access the home data and use this data to provide a range of in-home services that are currently difficult for consumers to perform due to complexity, cost or lack of information.</td>
</tr>
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</table>
## Home management systems

<table>
<thead>
<tr>
<th>Platform requirement</th>
<th>Potential characteristics and functionality</th>
</tr>
</thead>
</table>
| Built on one or more existing platforms | • Electricity, gas and water meter data management systems  
• Home broadband Internet system  
• Home alarm systems  
• Smart device application stores (in turn built on mobile telecom, Internet and GPS platforms) |
| Capable of more than one use | A platform capable of monitoring the usage, activity and performance of multiple systems can carry out uses that include:  
• Home health care monitoring (monitor medical devices with embedded communications and ensure that usage patterns in the house reflect normal healthy person routines)  
• Edge utilities (in which an apartment building, e.g., could operate off-grid, with the units in the apartment building and electric vehicles powered through natural gas-fed fuel cells, solar panels and thermal storage and usage in individual apartments optimized with smart appliances and individual HEMS  
• Home security and defect monitoring  
• Electricity, gas and water management  
• Management of electric vehicle charging  
• Ensuring contractor and new product warranties and performance  
• Appliance replacement and shopping |
| Well-defined and broadly adopted interfaces and system architectures | There is growing consensus that the HEMS should serve as the hub and that the meter should interact with the HEMS rather than individual appliances and devices. Remaining issues in contention include:  
• whether the platform should permit the electricity distribution operator to monitor separately the car and manage its charging  
• the industry standards to be employed for informational interoperability (ZigBee, Wi-Fi, power line or cellular) and semantic interoperability (UDP or TCP/IP data format) of individual devices and the HEMS hub |
| Market interoperability | This is not currently resolved. |
| Open “plug-and-play” platform | This is not currently resolved. |
Distributed microgrid
A distributed microgrid is a type of electricity management system that would manage the electricity distribution of a single area (such as a neighborhood or distribution feeder loop) and as a separate system (rather than controlled through top-down centralized distribution management).

Through deployment of sophisticated enterprise software, it would enable these local grids to generate, store, buy and sell electricity within their self-contained island – and buy and sell electricity from the broader grid as needed. They would operate in a manner similar to corporate Intranet that also has interfaces to the Internet.

Such systems could, in theory, operate with high penetrations of locally-sited solar PV, large batteries, and gas turbines or fuel cells.

While a distributed microgrid meets some of the key tests of a new platform, it represents an enormous leap in complexity over current distribution systems. In the absence of prolonged energy shortages (such as those experienced in Japan after its 2011 earthquake and tsunami), there appears to be a low likelihood that there would be an economically compelling catalyst to establish such a microgrid. However, microgrids are increasingly appearing in multi-building communities under common management such as university campuses.

Sustaining innovation applications
The list below identifies clean energy and smart grid technologies that have potential sustaining innovation applications. To the companies that succeed in selling products containing these sustaining innovations, they represent a potentially attractive business opportunity to up-sell to the industry’s most demanding current customers.

When a technology is deployed into the incumbent delivery model, its potential is governed by the economic rules that apply to sustaining innovations. In particular, sustaining innovations are likely to generate moderate, incremental growth.

From a local economic development perspective, an incumbent industry’s adoption of a sustaining innovation supplied by a major local employer can have a significant local economic impact. For example, the auto industry’s integration of embedded computing devices in cars, which accelerated in the 1990’s and early 2000’s, generated significant income for Freescale Semiconductor. Freescale is headquartered, and designs and manufactures a large number of these chips, in Austin. Therefore, the sustaining innovation of embedded computing devices in cars created a positive economic impact in Austin.

However, this positive impact was highly localized to regions, like Austin, where suppliers of embedded devices were located. The sustaining innovation of embedded computing did not catalyze new consumption of cars by people who previously did not purchase or drive and did not catalyze the emergence of a new market in consumer products.

As a general matter, while sustaining innovations may benefit particular regions with existing employers who win key supplier contracts, these innovations rarely generate explosive growth,
do not lead to the emergence of new market clusters and do not create broad macroeconomic growth.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Potential applications in sustaining innovations</th>
</tr>
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<tbody>
<tr>
<td>Solar PV</td>
<td>• Distributed PV owned by a vertically integrated utility located at substations or on roofs of buildings within the integrated utility’s service area</td>
</tr>
<tr>
<td>Batteries</td>
<td>• Electric vehicles</td>
</tr>
<tr>
<td></td>
<td>• Batteries coupled with distributed PV owned by vertically integrated utilities and sited at substations</td>
</tr>
<tr>
<td>Software</td>
<td>• Enterprise software applications – meter data management systems and distribution management systems</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>• Embedded devices in smart appliances, smart meters, LED lighting, electric vehicles.</td>
</tr>
<tr>
<td>LED technologies; optics</td>
<td>• LED lighting</td>
</tr>
<tr>
<td>Fuel cells</td>
<td>• Utility-owned generation located at the site of demanding customers with critical loads, such as hospitals and high technology manufacturing facilities</td>
</tr>
<tr>
<td>Wind turbines</td>
<td>• Wind farms</td>
</tr>
<tr>
<td>Biofuels</td>
<td>• Transportation fuels</td>
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</tbody>
</table>

Some frequently mentioned technologies are not included in the above list of technologies for sustaining innovations. In particular, this list does not include solar thermal or batteries among technologies and does not include solar hot water heaters and ground-mounted utility-scale solar arrays among potential products. These technologies and products do not meet the test for successful sustaining innovations: innovations that offer an improvement on a metric of performance that the industry’s most demanding customers will a premium to obtain.

Applications with disruptive potential
With the emergence of a dynamic new platform such as home and building management systems, these applications of new technologies hold the potential for creating disruptive innovations that catalyze new markets and the emergence of new market clusters.
<table>
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<tr>
<th>Technology</th>
<th>Potential applications in new market systems</th>
</tr>
</thead>
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| Solar PV         | • Distributed generation on roofs of homes and commercial/industrial buildings  
|                  | • Embedded PV in consumer products         
|                  | • Embedded solar PV in consumer applications (such as paints and roof shingles)  
|                  | • Integration into edge utilities systems |
| Batteries        | • Home vehicle charging with solar PV      
|                  | • Optimized distributed PV systems        |
| Fuel cells       | • Natural gas electric microgrid           |
| Software         | • Home and building management systems     
|                  | • Edge utilities                          
|                  | • Home apps that access smart appliance data |
| Networking technologies | • Home and building management systems  
|                  | • Edge utilities                          
|                  | • Demand aggregation                      
|                  | • Natural gas electric microgrid          |
| Semiconductors   | • Embedded devices that enable smart appliance data that can be accessed by home apps  
|                  | • Embedded devices that enable in-home and edge utility vehicle charging, including charging from solar PV and in-home batteries  
|                  | • Embedded devices in home health care services running over home management platforms.  
|                  | • Embedded devices in Internet of Things applications.  
|                  | *Semiconductors design and manufacturing is also a core expertise for solar PV and nano-solar PV applications. Therefore, regions with expertise in semiconductors have the potential to transfer this expertise (though not existing capital manufacturing equipment) to solar PV design and manufacturing.* |
| Wireless technologies | • Networking of premises and multi-tenant buildings for HEMS platforms, edge utilities and Internet of Things applications  
|                  | • Wireless electricity distribution        |
Cluster and job opportunities in the Austin-Round Rock region

Meaningful job growth has yet to occur from products and services integrating new energy and smart grid technologies. The requirements for new market development – an enabling platform, techno-economic paradigm and killer app – have yet to emerge. The lack of job growth has occurred largely because most new energy technologies have to date been deployed by incumbent firms (primarily utilities). As economic theory predicts and experience demonstrates, when incumbent firms deploy new technologies, they invariably deploy them to fit into their existing processes.

At best, incumbent-driven technology adoption results in sustaining innovations; frequently, though, this approach results in the phenomenon of cramming. Sustaining innovations result usually in modest, incremental growth, while cramming approaches – with their negative operational impacts – can result in (at best) moderate or even negative economic impacts.

Sustaining innovations that utilities have deployed include most prominently smart meters, which are improving distribution utility operational efficiency and have produced moderate positive economic impacts. Examples of cramming include utility-provided home energy management systems, utility-scale batteries and large utility ground-mounted solar farms. All of these technologies have tremendous potential in applications structured to achieve disruptive innovations, but when deployed into incumbent utility delivery models, the approach of deploying these technologies into incumbent utility processes “takes an innovation from a circumstance in which its unique features are valuable to a circumstance in which its unique features are a liability.”

As the preceding paragraph suggests, while job growth has largely underperformed, such an outcome is almost inevitable given the methods by which new energy technologies have been deployed. Core smart grid and new energy technologies have in fact experienced dramatic improvements in the past five years. In particular, the achievements by General Motors and Nissan in creating mass market electric-powered vehicles (the Volt and Leaf respectively) represents a monumental advance in battery and vehicle power management technologies.

Researchers have also produced significant advances in solar PV technologies, with significant and constant efficiency improvements in converting sunlight into electricity. In June 2011, a California firm announced at an IEEE conference that it had set a new conversion record by converting 28.2 percent of the sunlight hitting its PV panel into electricity. The emergence of products such as solar dyes and inks and Dow’s home solar PV roof shingles create the potential for disruptive applications integrating these technologies, particularly in emerging markets, in edge utility systems and as part of integrated vehicle charging systems.

Pecan Street’s research and evaluation of the Austin-Round Rock MSA region has resulted in these conclusions:

- The University of Texas has internationally significant research strength in supercomputing and battery, semiconductor and wireless technologies and significant research strength in engineering disciplines.
• The Austin-Round Rock MSA possesses internationally significant private sector expertise in semiconductor design and manufacturing, software development and services and medical devices. The region’s semiconductor expertise includes particular excellence in automotive embedded devices, low energy chip design and sophisticated chip design. The region also possesses a meaningful concentration of small and mid-sized battery companies.

• The region’s weaknesses include a comparative lack of solar PV research and design expertise compared to potential competitor regions. The region has the potential to overcome this shortfall in large part due to a relatively large market in distributed rooftop PV systems and significant sunshine.

• Given the region’s strengths in semiconductor design and manufacturing – particularly in embedded devices and low power chip design – the Austin-Round Rock MSA stands to benefit strongly from the growth of embedded devices in vehicles and smart appliances.

• An emerging risk factor for the region is the loss of semiconductor jobs.

• The region has significant local expertise in greenbuilding and energy efficient building practices. While greenbuilding represents a largely local set of services that do not make up global export-based industries, the significant pool of talent could help contribute to the development of new disruptive innovations deployed on HEMS platforms.

• The region has few comparative advantages in biofuels. Given that biofuels are a sustaining technology with high technical and cost barriers, this does not appear to be a promising sector for the Austin-Rock region to pursue relative to other opportunities.

• While the various retail, municipal, coop and investor-owned distribution utilities in the region have various strengths and weaknesses, utilities are inherently not participants in global markets and for the most part serve a local services function. The most important actions to support new market development that regional utilities can take include:
  • providing solar PV rebates for homeowners
  • installing advanced smart meters with two-way ZigBee radio and supporting ZigBee SEP 1.1 (and subsequently 2.0) communications
  • supporting (or not attempting to block) private sector demand aggregation and edge utility services within master metered buildings

• Actions that regional utilities might take that would fail to have any impact or that in fact could inhibit regional economic development efforts include:
  • attempting to block private sector vehicle charging services
  • providing utility-controlled home energy management platforms

Ultimately, the most promising scenarios for new market development depend on a development of a new platform. With such a platform – most likely a multi-use home and building management platform built on smart mobile device application stores, electricity, gas and water distribution management system, broadband Internet and home alarm system platforms – the most promising new markets for the Austin region to pursue or support development of would be –
• Home applications that leverage home energy and performance data
• Home vehicle charging with solar PV and batteries
• Edge utilities (particularly in apartments and multi-tenant commercial buildings) that integrate natural gas fuel cell electricity generation, thermal storage, rooftop solar PV, smart appliances, vehicle charging and building-wide energy management
• Integration of embedded computing into medical devices for home health care systems

**Pecan Street activities to advance industry and cluster development**

During the two-year grant period, Pecan Street went from a newly-formed corporation with no assets, no employees and no offices to a nine-employee research organization headquartered at The University of Texas that secured over $3 million in direct research funding to UT, established an industry-university research consortium, successfully recruited nine member companies, successfully deployed home smart grid systems, successfully deployed solar PV on over 130 homes, signed up 125 people to purchase electric vehicles, began data collection that will result in the nation’s deepest consumer energy usage database and began applied research on consumer smart grid platform development that includes technology, economic and behavioral research.

Pecan Street’s specific activities to advance the conditions for new market cluster development are as follows:

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<tr>
<th>Condition for new market cluster</th>
<th>Pecan Street action</th>
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| Identify and evaluate regional expertise                               | • Carried out research on regional companies and technology expertise.  
• Researched and prepared two white papers on clean energy and smart grid economic development.                                                                                                                  |
<p>| Research and understand customer needs                                | • Carried out baseline study on energy, gas and water usage in homes of volunteer participants.                                                                                                                                 |
| Focus on new market development                                        | • Pursued consumer-focused research that focused on deploying new technologies in peoples’ homes.                                                                                                                                 |
| Establish industry-university research consortium                     | • Established the Pecan Street Consortium and recruited nine companies as member (as of Aug. 20, 2011): Best Buy, Freescale, Intel, Landis + Gyr, LG Electronics, Oracle, Sony, SunEdison and Texas Gas. |
| Focus on global industries                                            | • Pecan Street’s applied research focused on home management platforms, and market, technical and informational interoperability of electric vehicle, smart appliance, solar PV and battery technologies on these platforms. |</p>
<table>
<thead>
<tr>
<th>Condition for new market cluster</th>
<th>Pecan Street action</th>
</tr>
</thead>
</table>
| Build efforts around a research university located in the region | • Established headquarters at UT.  
• Recruited and provided financial support and research project management to 10 UT faculty members and seven UT graduate students.  
• Recruited a UT researcher to co-lead consortium.  
• Hired the assistant chair of UT’s Electrical and Computer Engineering Department as Pecan Street’s Project Manager.  
• Hired Pecan Street’s first postgraduate fellow from UT.  
• Appointed UT architectural faculty to design the consortium’s interoperability research lab, which the consortium is developing to provide research opportunities for the UT-private industry consortium it created. |

| Support complementary assets such as technology incubators, joint industry-university research consortia and support networks for entrepreneurs | • Sponsored UT and ATI-UT conferences.  
• Provided direct financial support to ATI.  
• Supported Austin Technology Council.  
• Participated in Clean Energy Entrepreneur Network and Clean TX Foundation programming.  
• Put on weeklong course Smart.Clean.Energy to educate policymakers, entrepreneurs, individuals pursuing career changes and utility employees on best practices for creating sustaining and disruptive innovations.  
• Created Pecan Street Consortium. |

| Carry out applied research on platform development. | • Began vendor selection and field trials of HEMS platforms. Full deployment of the HEMS platforms is scheduled to go live in Spring 2012. |
Appendix A

This appendix lists all of the companies in the Austin region that Pecan Street has identified which have some role in clean energy or smart grid economic subsectors.
Endnotes


viii See Smilor, et al., at 215-16.

ix Smilor, et al., at 203.


xi Smilor, et al., at 204.


xiii George Kozmetsky, Frederick Williams & Victoria Williams, *New Wealth: Commercializing of Science and Technology for Business and Economic Development* x (Preface) (2004).


 xx Perez, at 10.

 xxi Perez, at 10 (emphasis added).


 xxv Christensen, et al., *Seeing What’s Next*, at 21-22.


 xxviii Christensen, et al., *Seeing What’s Next*, at 95.

 xxix Christensen, et al., *Seeing What’s Next*, at 96.

 xxx Christensen, et al., *Seeing What’s Next*, at 85.

 xxxi Christensen, et al., *Seeing What’s Next*, at 97-98.

 xxxii Christensen, et al., *Seeing What’s Next*, at 149.

 xxxiii Christensen, et al., *Seeing What’s Next*, at 149-50.

 xxxiv Christensen, et al., *Seeing What’s Next*, at 151.

 xxxv Christensen, et al., *The Innovator’s Solution*, at 43.


 xxxvii Christensen, et al., *The Innovator’s Solution*, at 104.

 xxxviii Christensen, et al., *The Innovator’s Solution*, at 60, 70, 74.

Christensen, et al., *The Innovator’s Solution*, at 104-05.

Christensen, et al., *Seeing What’s Next*, at 91.

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Christensen, et al., *Seeing What’s Next*, at 90-91.

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Porter, *Competitive Strategy*, at 223.


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Wunker, *Capturing New Markets*, at *729 of 4143*.

Gridwise Architecture Council Policy Team, *Introduction to Interoperability and Decision-maker’s Interoperability Checklist* v. 1.5 1 (Aug. 2010),

http://www.gridwiseac.org/pdfs/gwac_decisionmakerchecklist_v1_5.pdf.

Wunker, *Capturing New Markets*, at *441 of 4143*.

Wunker, *Capturing New Markets*, at *722, 747 of 4143*.

Wunker, *Capturing New Markets*, at *441 of 4143*.


Wunker, *Capturing New Markets*, at *502, 759 of 4143*.

Perez, at 11; Wunker, *Capturing New Markets*, at *1089 of 4143*.


Christensen, et al., *Seeing What’s Next*, at 76.

Christensen, et al., *Seeing What’s Next*, at 76.