2010 U.S. Smart Grid Vendor Ecosystem

Report on the companies and market dynamics shaping the current U.S. smart grid landscape

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I. Introduction

Key Takeaways

Market Takeaways:

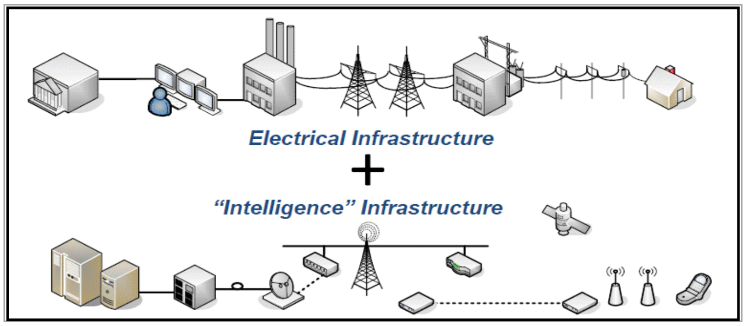
- The Smart Grid vendor ecosystem is an increasingly interdependent web of companies. Vendors of Advanced Metering Infrastructure (AMI) products (meters, communication units, and related software) have emerged as leaders in establishing cross-industry partnerships. Investments in AMI infrastructure have catalyzed new working relationships throughout the industry.
- There is strong “coopetition” playing out in the market between vertically integrated vendors and product specialists. Market dynamics are being reshaped by the entrance of new technologies and new companies. This results in vendor cooperation on some projects and competition on others.
- Acquisitions and consolidation are increasing and will continue to shape the landscape in the coming years. Large, established, global companies are expanding product portfolios to stretch across smart grid categories with the goal of providing end-to-end solutions to utilities and other large customers.
- $2.75B will be spent in 2010 on smart grid products in the core industry sub-sectors of Advanced Metering, Demand Response, and Distribution Grid Management. The market for spending on services in these markets, while not covered extensively in this report, is likely to be equal if not greater to this estimate of product spending.

Company Takeaways:

- The smart grid vendor landscape is more mature and geographically diverse than may be commonly thought. The market is populated not only by venture-backed startups, but by established public, and private companies. Many of these firms have substantial legacy businesses and are working to adapt to new, smart grid market requirements. In addition, while venture-backed companies are concentrated in a handful of states, there is significant geographic diversity to the full range of companies working in the smart grid sector.
- Different smart grid product sectors require different competencies - hardware vs. software, technology/product vs. services, and varying levels of skilled manufacturing. This has an important impact on how employees are distributed from product development through installation and ongoing services.
- The smart grid is composed of a vast landscape of companies touching a diverse range of related sectors. Demarcating the bounds of the smart grid is an increasingly arbitrary exercise. Understanding the development of the smart grid requires knowledge of technologies not only for electricity distribution, but for energy management within homes, buildings, and other industrial facilities, as well as technologies for the integration of a diverse range of new assets including vehicles, storage, and distributed renewables.

Background

Even before the Department of Energy's October 2009 Smart Grid Investment Grants[1] shined a bright, $3.4 billion dollar light onto the sector, "smart grid" was fast becoming a ubiquitous term throughout the utility industry and the broader clean technology world. The convergence of the nation's aging power system with a smart, IT-enabled control and communications layer – the basic essence of "smart grid" - had long been seen as an industry goal.



Source: EPRI Intelligrid Architecture

However, it was a goal that had been far enough on the horizon that pursuing it at top speed was not always viewed as a critical priority. While the benefits of managing the grid more efficiently were becoming increasingly well documented and the tremendous costs of outages were being felt, there continued to be significant regulatory, economic, and educational hurdles to overcome in the realization of the industry's smart grid goals.

The American Recovery and Reinvestment Act (ARRA) Smart Grid investments, and broader package of $11B for grid-related projects,[2] did not, and will not alone, solve the hurdles that stand in the way of smart grid deployments. However, this significant infusion of capital and – perhaps equally as important – sense of urgency and attention has proven to be an important catalyst in the development of the smart grid ecosystem. There are a myriad of industry associations, standards development organizations, government agencies, and policy think tanks actively providing critical input into the future of the grid, shaping standards via the NIST Smart Grid Interoperability Panel,[3] convening conferences and working groups, and influencing the dynamics of an evolving commercial landscape.

It is on this commercial playing field that a long and growing list of equipment companies – from venture-backed startups to global, multi-billion dollar enterprises – will compete. **Fundamentally, this report is a study on the state of those companies.** We have not set out to add to the tremendous wealth of literature providing technical guidance and recommendations on how to best proceed with smart grid deployments, nor do we intend to prognosticate precisely where the market is headed.

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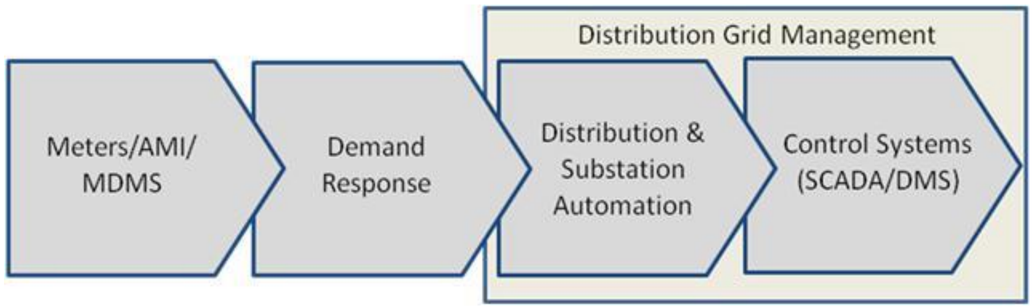
[1] http://www.energy.gov/news2009/8216.htm
[2] http://www.whitehouse.gov/assets/documents/Recovery_Act_Energy_2-17.pdf
[3] http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/WebHome

Rather, our goal is to provide a clear picture of the current vendor landscape across a number of leading sub-sectors of the commercial smart grid equipment market.

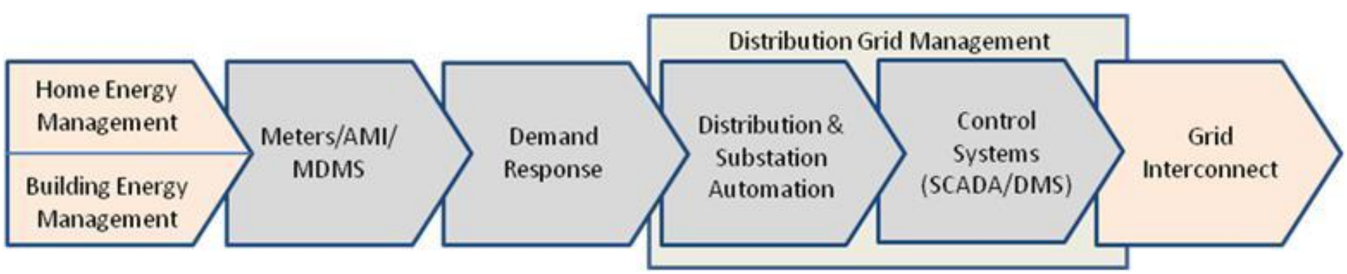
In order to accurately catalogue the companies engaged in developing the building blocks of the smart grid, we defined a simple set of product categories that would allow us to most easily bound and bucket active vendors within a limited set of categories.[4]



We examine three key areas in depth, providing market sizing, market share, and detailed commentary on the state of the vendor landscape:

(1) Advanced Metering • Meter • Communications • Meter Data Management Systems	(2) Demand Response • Curtailment Service Providers • Technology Enablers	(3) Distribution Grid Management • Feeder/Distribution Automation • Substation Automation • DMS Software

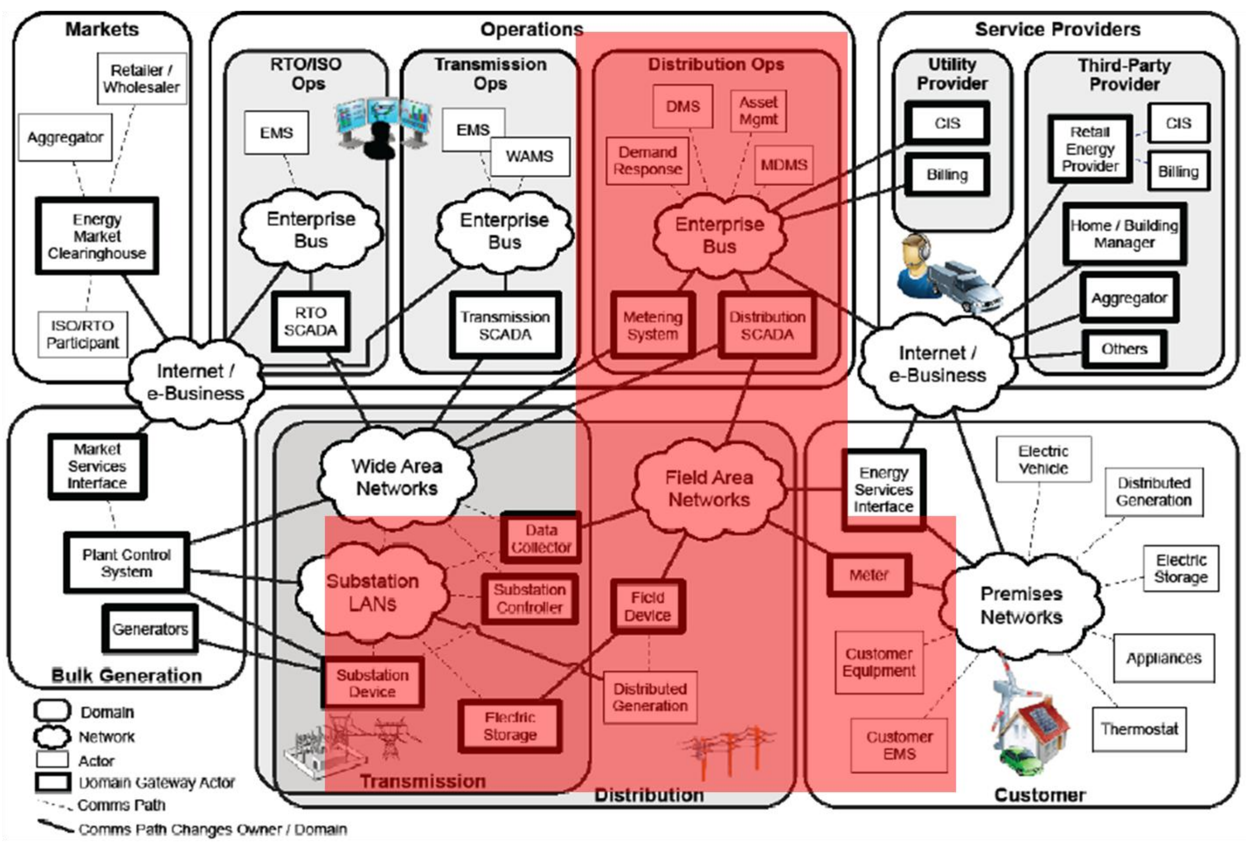
In addition to detail that we will provide on these three key sub-sectors, we will provide background and more concise commentary on a number of other critical demand and supply side sub-sectors:



[4] It could be argued that "Demand Response" is an application, not a product category. The lens of this report however is based on common market perceptions and we have tried to align our categories with how the market has tended to naturally segment itself. Demand Response has clearly emerged as a category unto itself with a unique set of vendors.

(1) Home Energy Management
(2) Building Energy Management
(3) Grid Interconnect

Our vendor-centric framework cuts across a number of sectors articulated in the NIST Smart Grid Conceptual Model[5] . The NIST model is one of the most widely circulated frameworks and focuses on seven key areas of the grid: Bulk Generation, Transmission, Distribution, Customer, Markets, Operations, and Service Providers. Given scope limitations, this report does not touch on all of these areas, but rather spans a number of them to highlight key product categories. Given widespread reference to the NIST Model, we felt that it would be instructive to locate our framework within this context. The highlighted region overlaid on the NIST model below is intended to convey the focal areas of our work.



Source: NIST Smart Grid Conceptual Model, Cleantech Group Analysis

Our analysis indicates that more than $2.75B will be spent on the three major smart grid product categories in the U.S. in 2010. Our analysis triangulates various information gleaned from vendor interviews, third party research firms, and our own calculations. As with any high growth market, there are various vendors attempting to position themselves to project momentum and utilities trying to

[5] http://www.nist.gov/smartgrid/

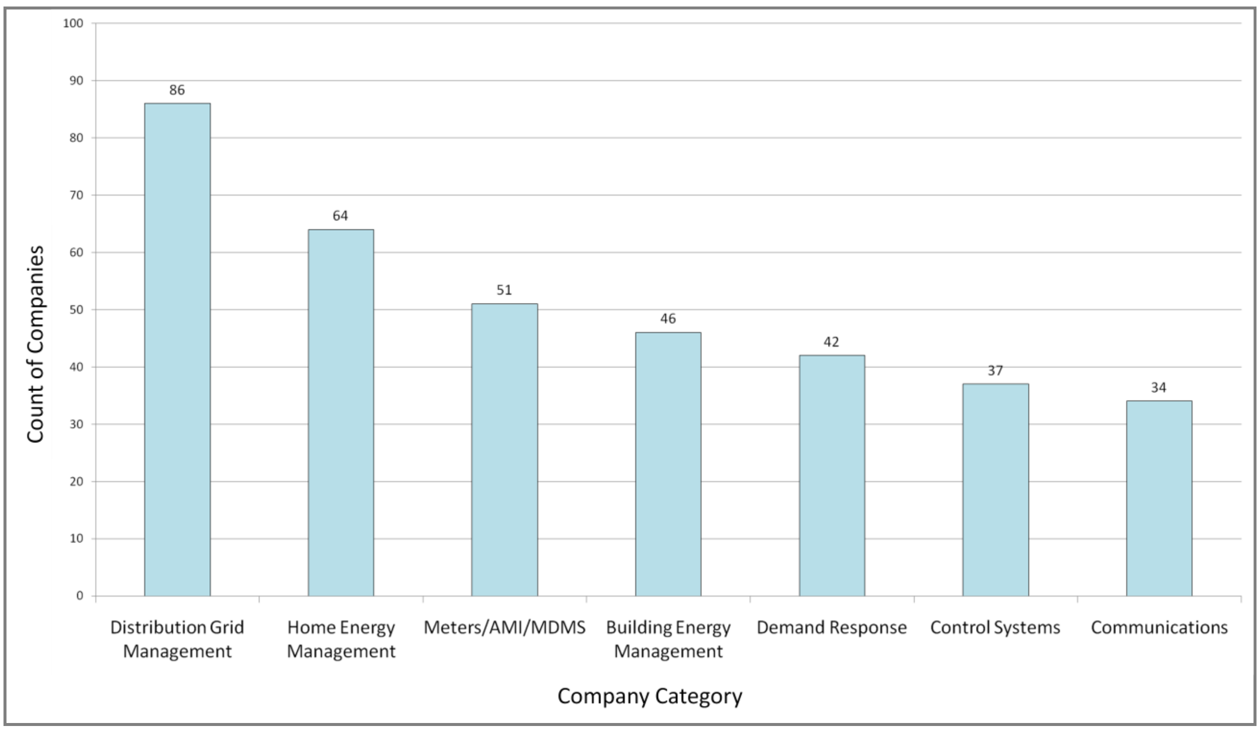
manage expectations, consequently actual deployment numbers are closely guarded. This analysis should serve as a foundation for dialogue, critique, and for continued industry discussion.

Sector	2010 Estimated U.S. Spend
Advanced Metering Infrastructure	$1.1B
Demand Response (Technology Products Only)	$0.15B
Distribution Grid Management	$1.5B

Source: Cleantech Group Estimates[6]

Our work categorized over 600 companies working across these six categories, plus some additional, adjacent categories.

Company Count By Category Analyzed



Source: Cleantech Group Smart Grid Database & Analysis

It should be noted that there are a number of categories that have not been covered extensively in this work. First, our report has focused primarily on the market for hardware and software products. We have tried to highlight the importance of services throughout our report, but we have not extensively

[6] Our estimates have been developed through our own research and through analyzing the data and estimates of leading market research firms such as Newton-Evans Research, Cognyst Advisors, and many others.

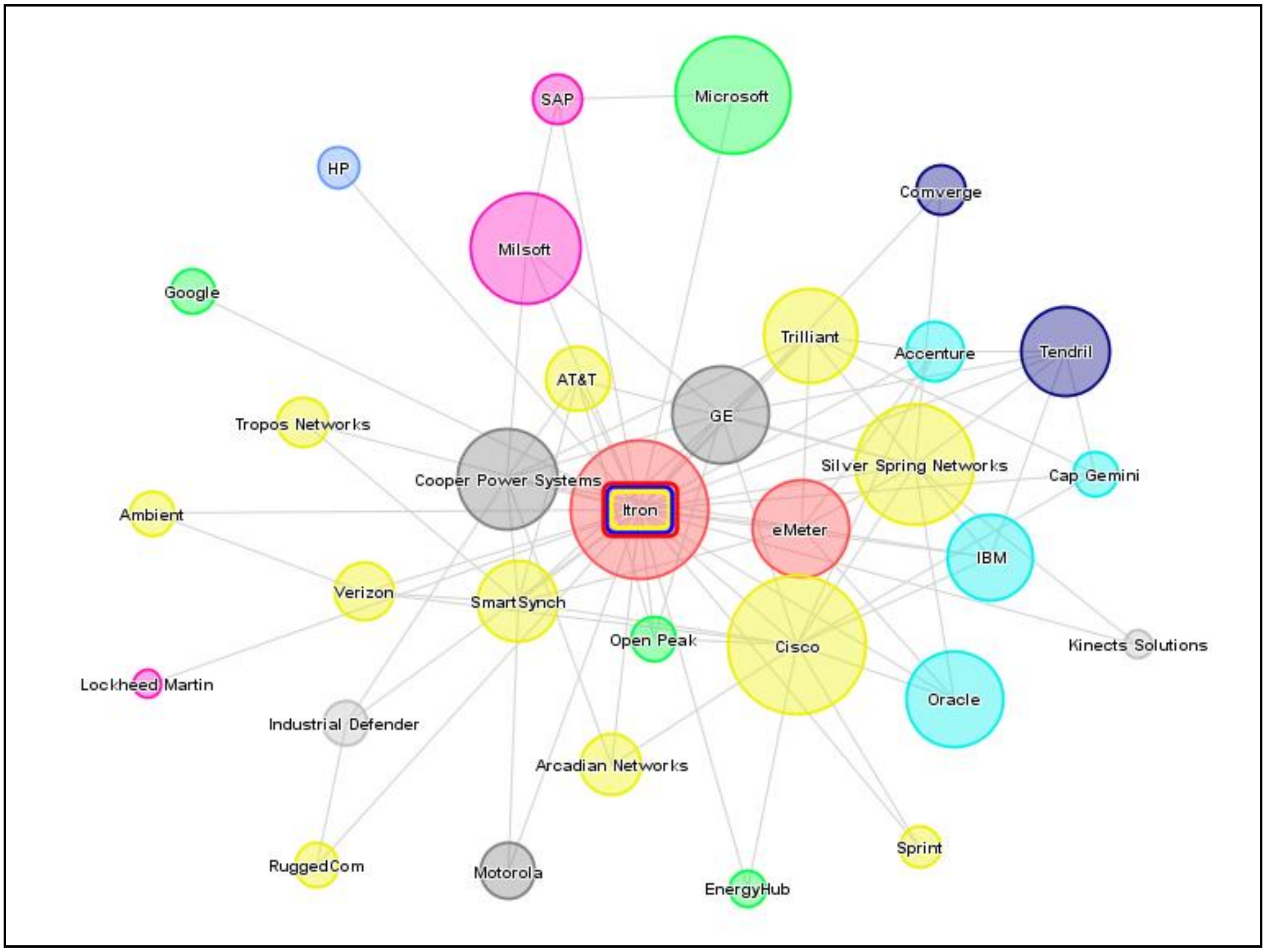
catalogued vendors involved in the installation, maintenance, and ongoing services of smart grid equipment. In terms of dollar costs, the services market is equal, if not larger, to the amount spent on smart grid products. Second, we have limited our focus primarily to the producers of finished goods. We have catalogued some of the more significant vendors of critical chipsets and other components, but there is a large second and third tier supply chain of vendors, producing everything from epoxy resins to steel enclosures, that are benefitting from smart grid spending.

While the following chapters will dive into deep discussions of particular sub-sectors, we believe that there are a number of key themes that are shaping the evolution of the smart grid vendor landscape.

Key Takeaways

1. The Smart Grid vendor ecosystem is an increasingly interconnected and interdependent web of companies; smart metering and communications vendors have been leaders in establishing connective tissue across multiple layers of the smart grid.

Itron: Smart Grid Relationships



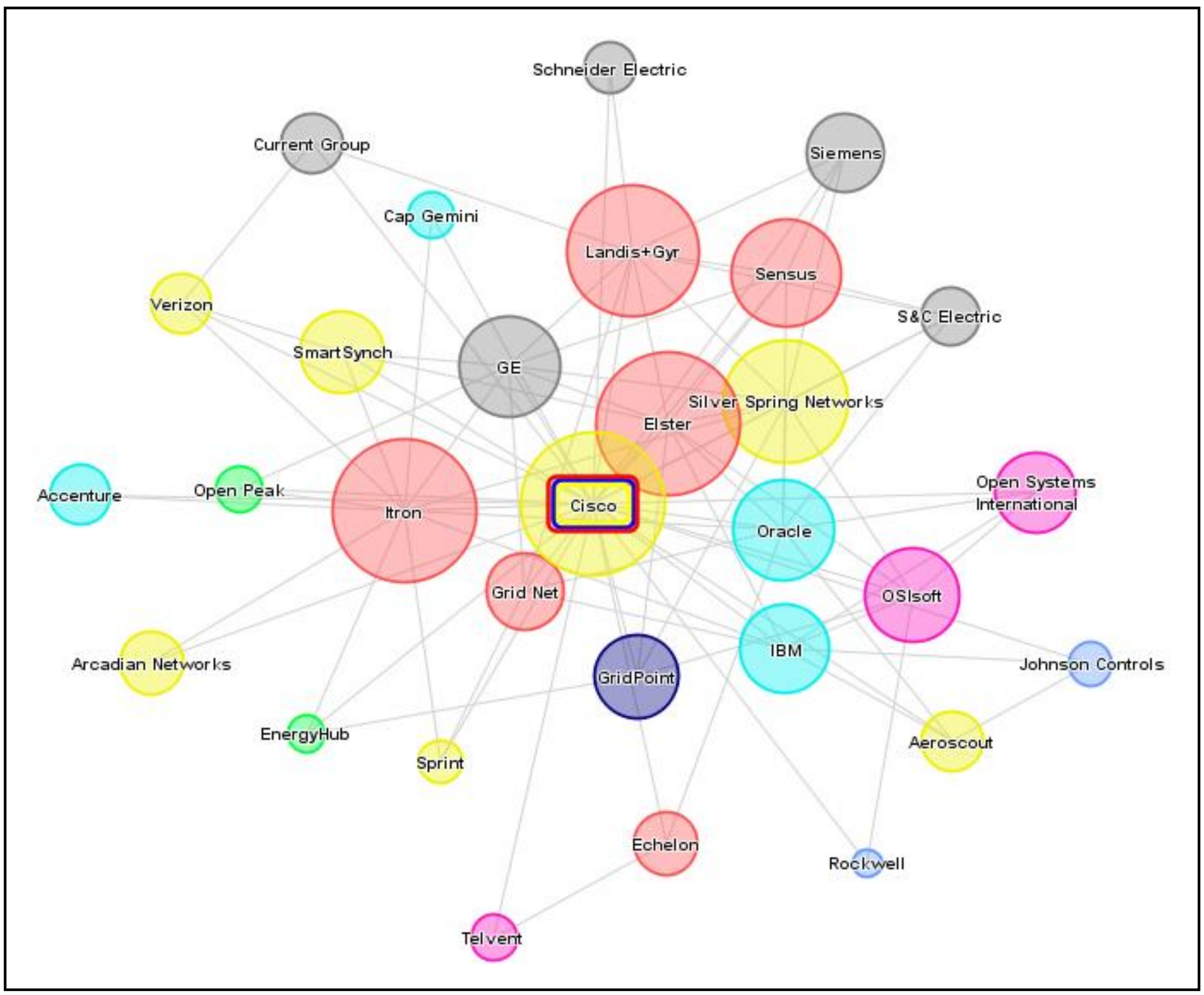
Source: Cleantech Group Smart Grid Mapping Model

One of the key questions that we set to answer with our research was how the smart grid vendor ecosystem was evolving as a living and breathing organism. In order to address this question, we built a network model based on industry connections (announced partnerships, press releases, public collaborations, etc.) and used a relationship mapping tool to visualize the industry.

This model reveals that AMI vendors (both meter and communication vendors) are forming a wide variety of relationships across the industry. As a great deal of new investment is being directed into AMI projects, it is logical to see vendors establishing these connections. Meter stalwarts such as Itron, Landis+Gyr, GE, Elster, and Sensus have long tentacles spread throughout the industry as do communications specialists such as Silver Spring Networks. This dynamism is beginning to touch the legacy power systems vendors as well, though they are bridging the market with a more methodical approach.

It should also be noted that there are a number of large vendors who have only recently entered the smart grid space from adjacent markets, but have rapidly built partnership hooks with a variety of firms. Cisco Systems is the best example of this phenomenon. While our model highlights the potential influence of these relationships in the future, these linkages are not correlated with the size of a company's current revenue base in the sector and should not be over-interpreted as a sign of industry prominence.

Cisco: Smart Grid Relationships

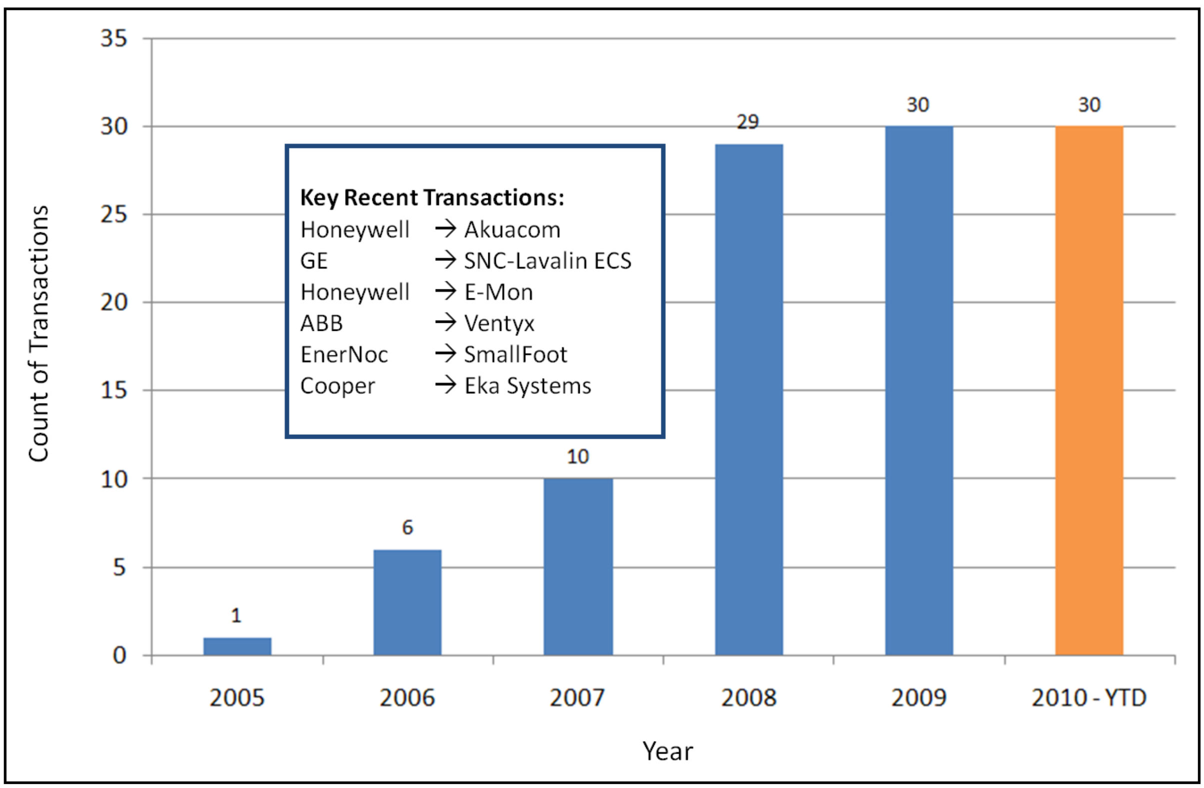


Source: Cleantech Group Smart Grid Mapping Model

2. There is strong competition and "coopetition" playing out in the market between vertically integrated vendors and product specialists. Acquisitions and consolidation will continue to shape the landscape in the coming years.

Across multiple smart grid segments there is a tension developing between vendors of broad solution suites and those with best-of-breed products and applications. Vendors such as Itron in the metering world and GE and ABB in the distribution grid management space have product sets spanning hardware, communications, and software that can be implemented as a single solution. At the same time, these same vendors are requested to integrate on certain projects with communications vendors like Trilliant or software vendors like Open Systems International (OSI). Legacy vendors such as Cooper Power Systems are moving to vertically integrate elements of the value chain through acquisitions (for example, Cooper's acquisition of communication specialist Eka Systems[7]) or GE's recent acquisition of SNC-Lavalin's Energy Control System's business[8]. At the same time, global leaders in adjacent markets such as Honeywell are moving to establish themselves as smart grid players through purchases (for example, Honeywell's recent acquisition of Akuacom and E-Mon[9]).

Smart Grid M&A Transactions



Source: Cleantech Group Analysis

[7] http://venturebeat.com/2010/04/13/cooper-grows-smart-grid-presence-with-eka-systems-buy/
[8] http://www.bizjournals.com/atlanta/stories/2010/08/02/daily3.html
[9] http://www.greentechmedia.com/articles/read/honeywell-buys-another-grid-company-e-mon/

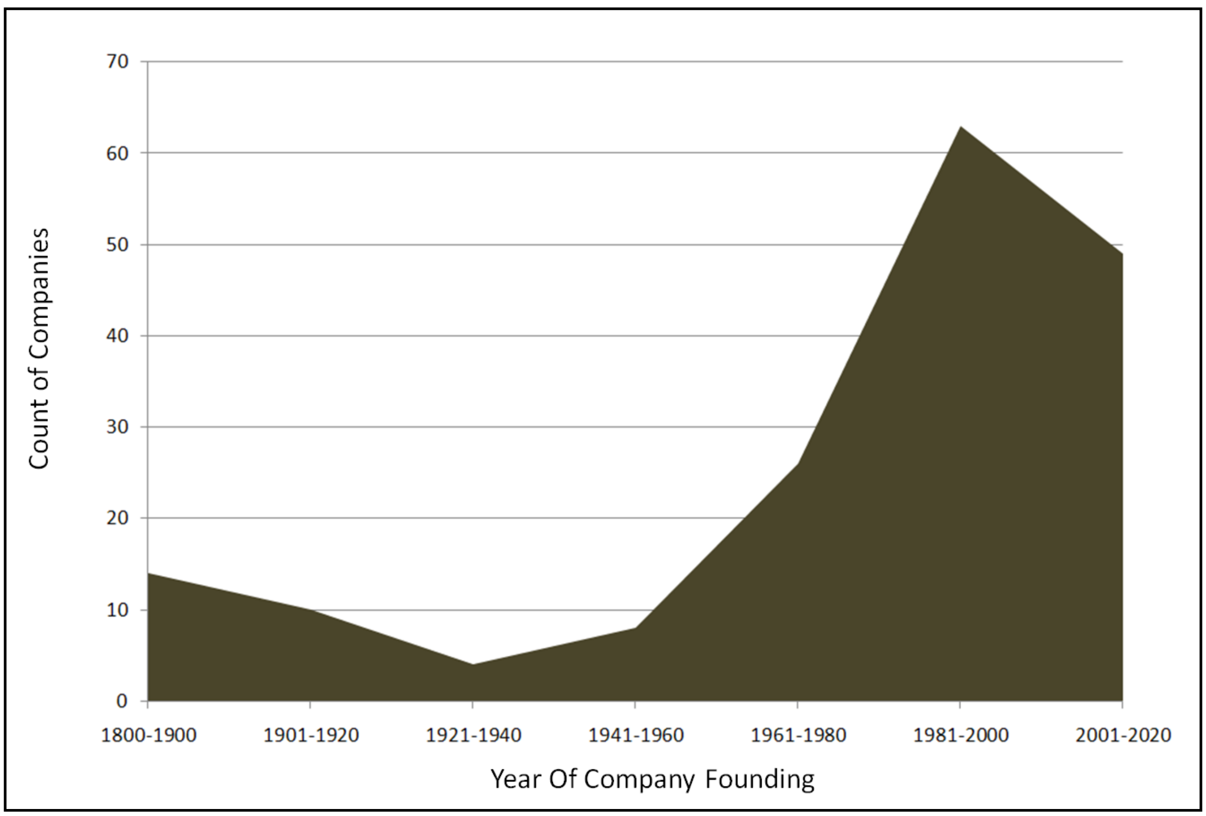
3. The smart grid vendor landscape is more mature and geographically diverse than may be commonly thought.

Elements of what is now known as the smart grid have been developing organically for the past two decades and consequently many of the companies that we have tracked in this market are well-established. While there clearly has been significant investment into new ventures in the space, we have found that the majority of companies involved in the sector are far from brand new.

Our data suggests that only 30% of the top 177 smart grid companies from our database were founded in the past decade. This means nearly 70% of companies involved in the sector were founded prior to 2000; 25% of this entire list of leaders was founded prior to 1980.

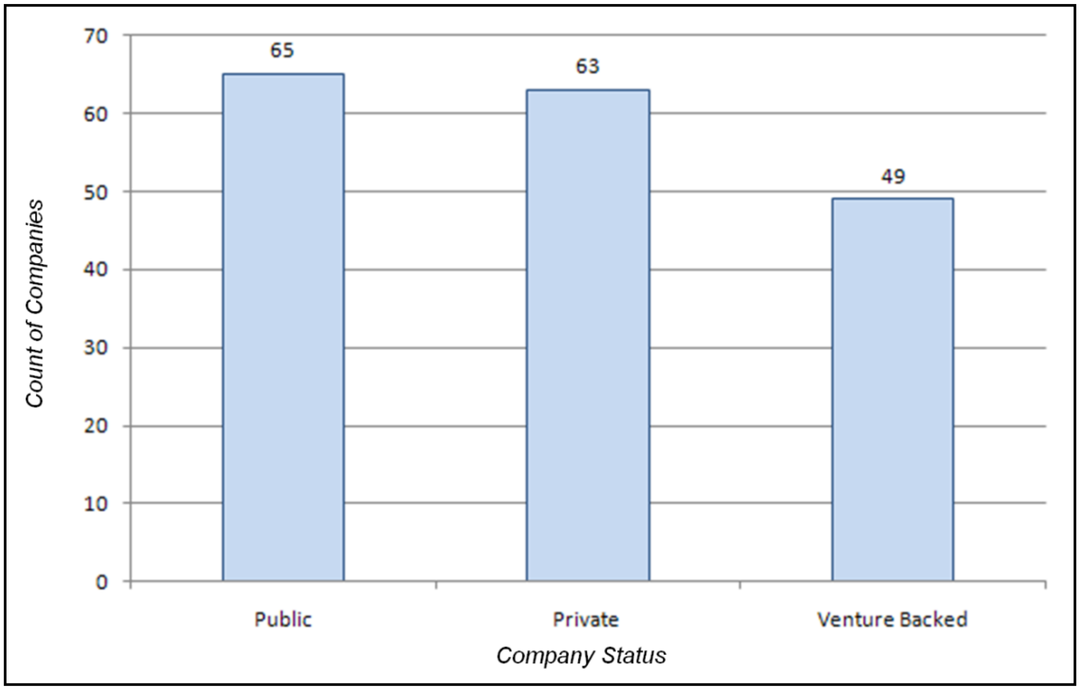
In addition, while there are indeed many venture-backed companies in this sample of smart grid companies, there are a large numbers of public firms and a substantial number of private firms that are operating without venture capital support.

Count of Companies By Year Founded



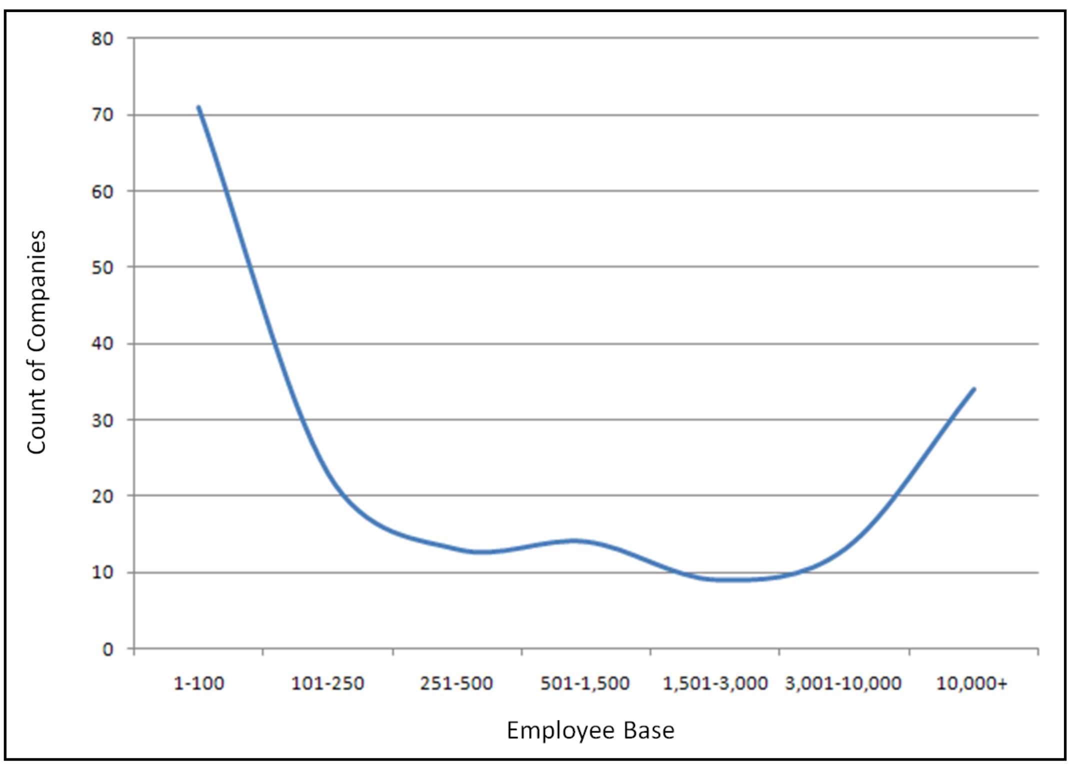
Source: Cleantech Group Analysis

Count of Companies By Status



Source: Cleantech Group Analysis

Count of Companies By Employee Base

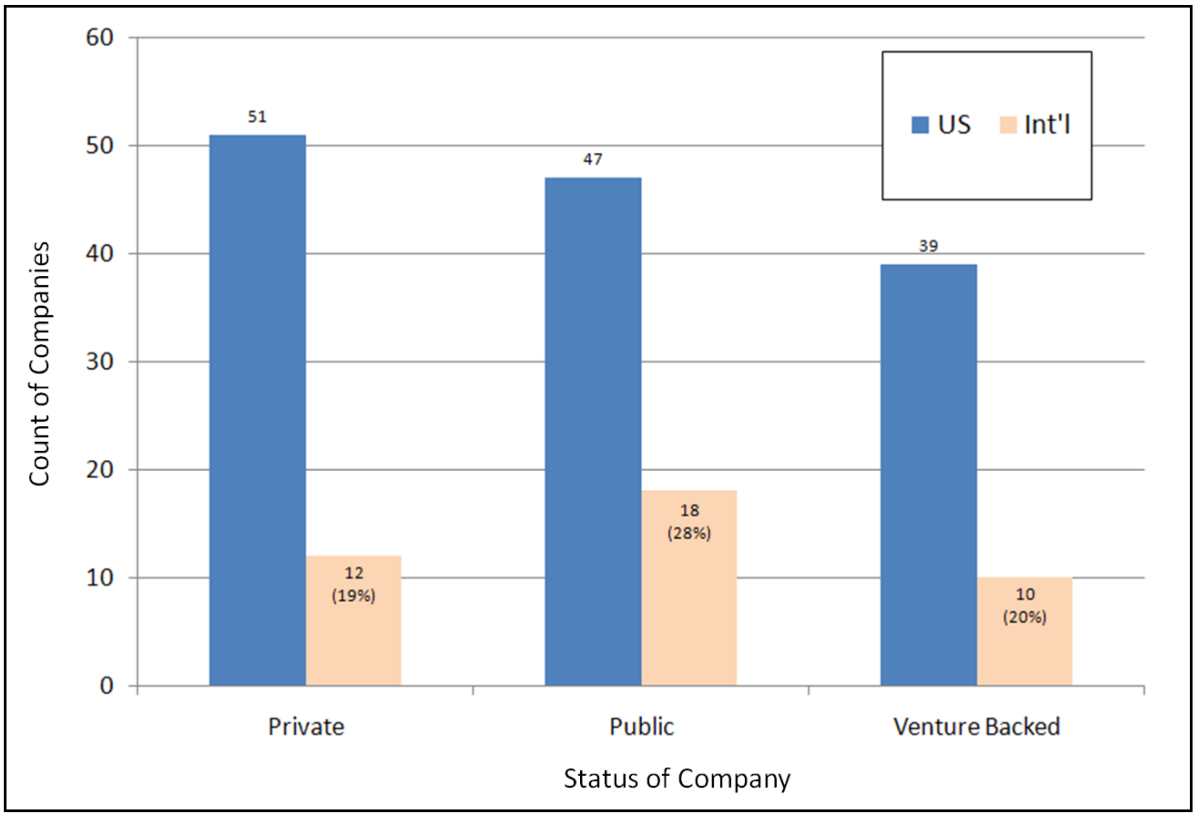


Source: Cleantech Group Analysis

We have also found that plotting companies by number of employees yields an interesting curve to the market. We find clustering of companies at the smallest and largest company sizes. We believe that this supports our findings around consolidation as one possible explanation for this curve is that successful mid-size companies are being acquired by larger, public firms.

Turning to geographic distribution, we find that that international companies made up 22% of our sample of top companies. International firms were better represented amongst large public firms than other categories indicating that while the U.S. continues to have a strong lead in the number of venture-backed companies, there are a substantial number of large, international competitors that are potential acquirers and market leaders.

Geographic Spread of Top Companies By Status



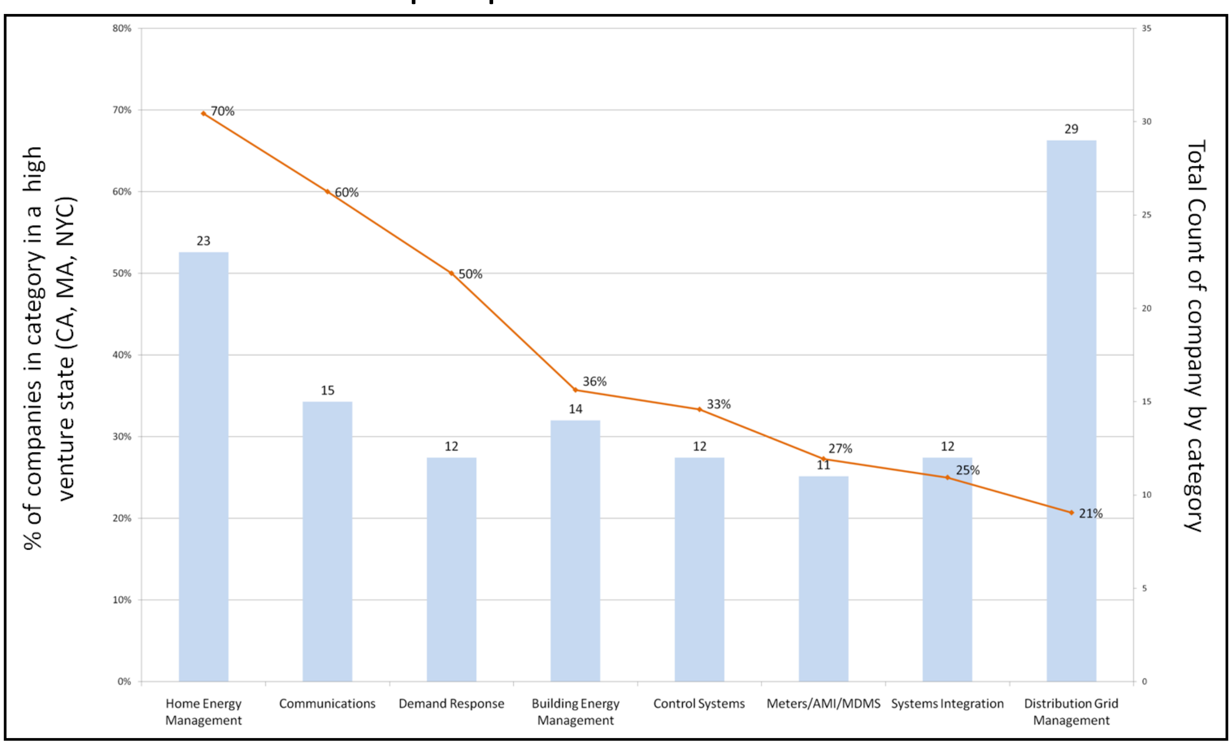
Source: Cleantech Group Analysis

When we drill down on the top U.S. companies (approximately 137 of the 177 companies in this sample), we find that they are also more geographically dispersed than would be typical for an "innovation industry". While the geographic concentration of startup companies involved in the smart grid market mirrors typical patterns for venture capital – with California, Massachusetts, and New York home to the vast majority of young companies – 30 of 50 states are home to the headquarters of at least one of the companies on our top list.

Headquarters of Top U.S. Smart Grid Companies

Source: Cleantech Group Analysis

Top Companies From "Venture States"



Source: Cleantech Group Analysis

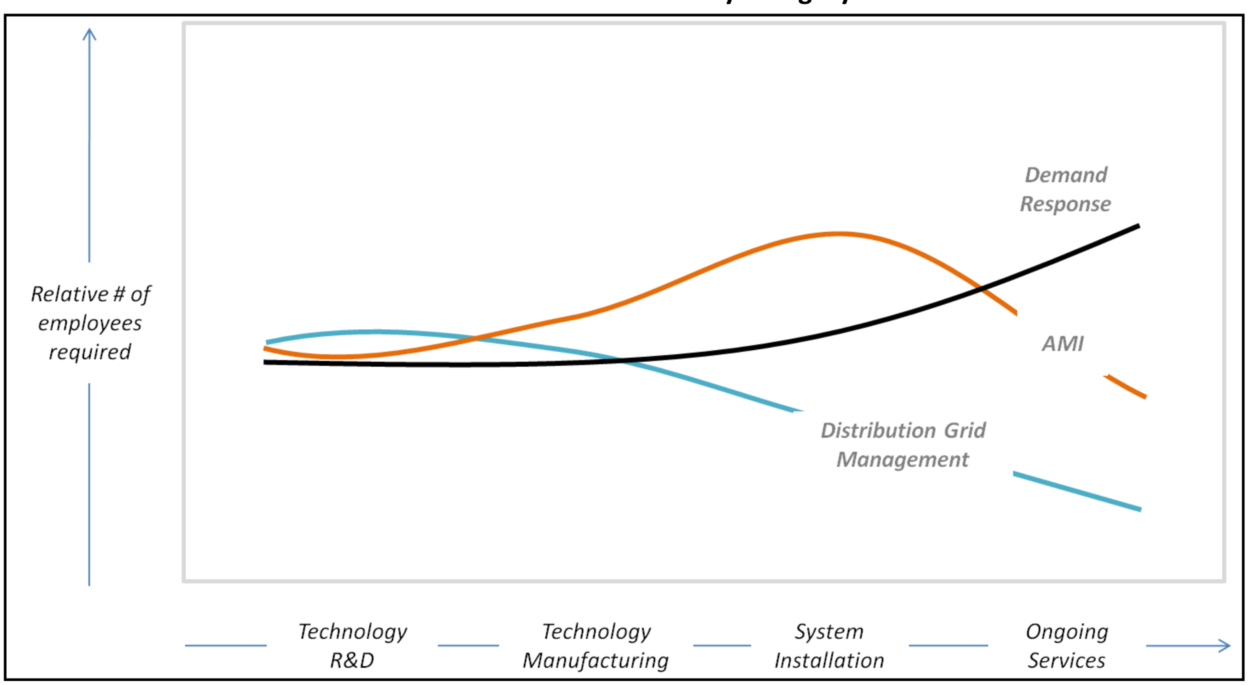
4. The smart grid is an increasingly vast landscape of companies that touches a diverse range of related sectors. Demarcating the bounds of the smart grid is an increasingly arbitrary exercise.

This report has primarily focused on the sub-sectors most commonly associated with the utility industry. Our discussion of smart metering, distribution grid management, and even demand response should be familiar to most who have been working in and around the power industry. However, it is becoming clear that as an increasing amount of energy intelligence gets pushed to the edges of the electric grid, companies involved in the manufacturing of products as diverse as air conditioners to vehicles will have a role to play in ensuring the stability of the grid. We have catalogued companies in categories such as home energy management, building energy management, and a more general grid interconnect bucket that are actively engaged in smart grid activities, but this web of companies will only continue to radiate outward in the coming years and should be closely monitored.

Areas for Further Study

1. Sizing the market for services and the impact of services firms: The scope of this study has primarily been on product sales. It should be noted that some sub-sectors may have low per unit costs, but high installation costs (for example, smart meters). Other sectors may have very high per unit costs, but fewer total units to install and consequently lower installation costs (for example, substation automation). Consequently, while the product sales estimates in this report may be similar for metering and distribution grid management, there may be a substantially higher services component, and hence jobs impact, for metering installations. The services component of smart grid projects should certainly be studied in greater depth.

Relative Job Distribution By Category



Source: Cleantech Group Analysis

2. Evaluating the landscape for second and third tier suppliers: As we alluded to earlier, there are a wide variety of second and third tier suppliers that provide materials and components to finished goods manufacturers. This is an area that certainly merits further analysis in order to understand the full halo effect of the growing smart grid market.

3. Evaluating the regulatory and incentive structure for non-AMI projects: This report has not addressed in detail the regulatory environment that plays a critical role in shaping the competitive landscape. While there appears to be a significant body of knowledge and industry discussion around the regulatory environment for advanced metering projects, our initial research suggests that there has been less work done to highlight the regulatory impediments for utilities to more aggressively pursue other grid efficiency and performance projects.

ACKNOWLEDGEMENTS:

We would like to thank Chuck Newton, from Newton-Evans Research, whose work is referenced in numerous sections of this report for his contributions and insights into the market particularly around distribution and substation automation. We would also like to thank Howard Scott, from Cognyst Advisors, as his communications unit data is invaluable to understanding the emerging AMI landscape.

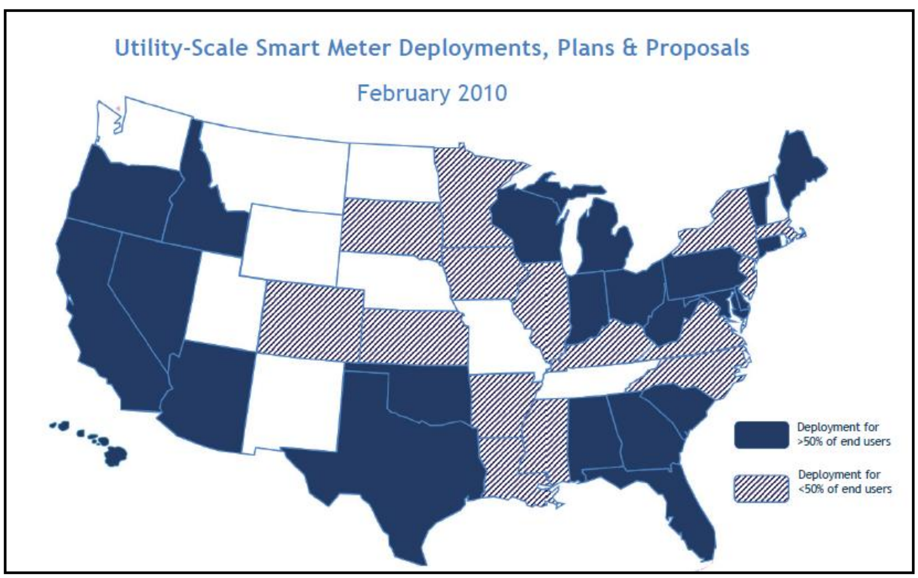
We would like to thank a long list of vendors that we interviewed throughout our information gathering process. We would like to specifically acknowledge the input and insights gained from the following vendors:

Oracle	ABB	Siemens	Tantalus
Landis+Gyr	GE	Echelon	ACS
S&C Electric	Cooper Power Systems	Schneider Electric	GridSense
Cisco	Silver Spring Networks	Ecologic Analytics	eMeter
Telvent	Lockheed Martin	Tendril	
Johnson Controls	EnerNoc	AT&T	

II. Smart Metering/AMI (Advanced Metering Infrastructure)

Key Takeaways		
• The deployment of smart meters has become the focal point for the majority of utility smart grid investments. • The U.S. advanced metering market will likely produce $1.0B in product spending in 2010 with the majority of revenue flowing to meter hardware vendors, followed by communication vendors, and meter data management software vendors. • The competitive dynamics of the industry are being shaped by the interplay between legacy vendors with end-to-end product portfolios and specialist vendors of communications equipment and data management platforms.		
Key Vendors		
• Itron	• GE	• eMeter
• Landis+Gyr	• Trilliant	• Oracle
• Sensus	• Cooper Power Systems	• Ecologic Analytics
• Elster	• Aclara	• Accenture
• Silver Spring	• SmartSynch	• IBM

It is not by coincidence that we begin our review of the smart grid ecosystem with the market for advanced metering solutions. The deployment of smart meters has become synonymous with the deployment of smart grid solutions. Much of this association has been driven by press attention to smart meter rollouts (both good and bad), government stimulus funding directed to the area, and large, well-publicized venture investments in metering communication vendors such as Silver Spring Networks and Trilliant. This attention however does mirror reality as the majority of utility smart grid projects are focused on smart metering.



Source: Edison Electric Institute[10]

[10] http://www.edisonfoundation.net/iee/issueBriefs/IEE_SmartMeterRollouts_update.pdf

According to data compiled by Newton-Evans Research on current smart grid deployments (approximately 160 projects), including those supported by federal stimulus dollars and those independently financed, 62% contain some aspect of smart metering[11]. This significantly outpaces other investment categories such as distribution automation, wide area control systems, and upgrades focused on facilitating integration of renewable and electric vehicles.

Area of Focus: Top U.S. Utility Projects

Advanced Metering	**62%**
Distribution Automation and Monitoring	31%
Communication Projects to Support AMI & DA	**20%**
Renewables Facilitation	20%

Source: Newton-Evans Research, Sample of 160 projects

This mirrors allocations made in the October 2009 Recovery Act Smart Grid Investment Grant Awards with a large majority of well-funded projects connected to metering deployments. The stimulus awards cover projects consisting of 18M smart meter installations with a stated goal of supporting 40M installations by 2015.[12]

Significant SGIG Grants Linked To AMI Deployments

Project	Stimulus Award	Meters
CenterPoint	$ 200,000,000	2,200,000
BG&E[13]	$ 200,000,000	1,100,000
Duke Energy	$ 200,000,000	1,400,000
Florida Power & Light	$ 200,000,000	2,600,000
Progress Energy Service	$ 200,000,000	160,000
PECO	$ 200,000,000	600,000
NV Energy	$ 138,000,000	1,300,000
Oklahoma G&E	$ 130,000,000	771,000
Sacramento Municipal	$ 127,506,261	600,000
EPB Chattanooga	$ 111,567,606	170,000
PEPCO	$ 104,800,000	570,000
Central Maine Power	$ 95,900,000	650,000

Source: DOE, Cleantech Group Analysis

Howard Scott, a leading researcher on AMI trends, sums up the shift in the market succinctly in his most recent 1Q 2010 report[14]:

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[11] Newton-Evans Research, Smart Grid Projects 2010

[12] http://www.whitehouse.gov/sites/default/files/administration-official/vice_president_memo_on_clean_energy_economy.pdf

[13] The BG&E Grant had been under DOE review given the Maryland PSC's original rejection of BG&E's smart meter plans. This project has now been conditionally approved.

"The 40 million Smart Metering units announced prior to 2009 grew by approximately another 10 million units in 2009, and the current (and anticipated) RFP activity will probably add another 30 million units. Thus, of the (approx.) 150 million electric meters in the U.S., approx. 80 million will be changed out to Smart Meters within the next few years. **Clearly, the electric utility industry has passed the "tipping point" for Smart Metering. The question is no longer whether the remaining electric utilities will deploy Smart Metering, but "when" will they do so."**

Interviews conducted for purposes of this study confirmed this trend, with vendors throughout the smart grid ecosystem reporting that metering projects were indeed taking precedence and influencing architectural decisions. However, the question of when these meters will be physically installed continues to be a source of ongoing industry speculation. Our estimates will attempt to pin down 2010 expectations.

Hand in hand with discussing market estimates, we will dive into the vendors shaping the smart metering landscape. Our study is not intended as an assessment of technology alternatives, but rather a review of the vendor landscape. Technology choices will certainly dictate winners and losers in this rapidly expanding market, but our goal is to give a snapshot of the current "state of play" and resist the temptation to speculate on future market direction.

In assessing the supplier landscape in the metering market, it is instructive to segment the market into three key areas:

(1) **Smart Meters:** The solid-state, customer premise hardware responsible for the actual metering function.

(2) **Communication Systems:** The network infrastructure for transmitting data from the smart meter to the utility head-end.

(3) **Meter Data Capture & Management Software:** The software layer(s) that compile meter data and other monitoring information produced by meter devices and allow for business applications (i.e. customer service, billing, etc.).

This report assesses the market at the macro, systems level. However, this market consists of various sub-systems and components vendors who serve as suppliers to many of the system vendors. We have focused on the overall market view, rather than a more granular analysis of each sub-system and component. Nevertheless, our AMI Vendor Ecosystem chart below provides more granularity on some of the sub-segments that contribute to our top level categorizations.

[14] The Scott Report, June 2010

	HW & Subsystems	Systems & SW	Services
Meter Data Management	**Servers/Databases** • Oracle • Microsoft • IBM	**Software/Applications** • Itron • Elster • Oracle • eMeter • Ecologic Analytics • Aclara • Tibco	**System Integrators** • IBM • Accenture • Cap Gemini
Communications	**Chips/Equipment** • Texas Instruments • Sierra Wireless • Qualcomm • Motorola • Cisco • Alcatel • Nokia Siemens	**Systems** • Silver Spring • Trilliant • Itron • Landis+Gyr • Sensus • Elster • GE • Aclara	**Network Operators** • AT&T • Verizon • T-Mobile • Sprint
Meters	**Chips/Components** • Ember Networks • Digi International • Zensys • Teridian • Freescale • Accent	**Systems/Units** • Itron • Landis+Gyr • Sensus • Elster • GE	**Services/Install** • Corix • UPA • VSI

Source: Cleantech Group Analysis

Many vendors in the meters, communications, and software segments pursue specialist strategies (i.e., participating in one segment of the market). However, there are numerous vendors providing integrated end-to-end solutions. Some vendors even pursue both these strategies in tandem in response to utilities who seek best-of-breed solutions in some cases, and single vendor solutions in others. In fact, nearly all of the integrated solution providers (e.g. Itron, Landis+Gyr, etc.) have explicit partnerships announced, or examples of collaborative deployments, with multiple communication vendors and back-end data management vendors.

Meter Vendor Differentiation

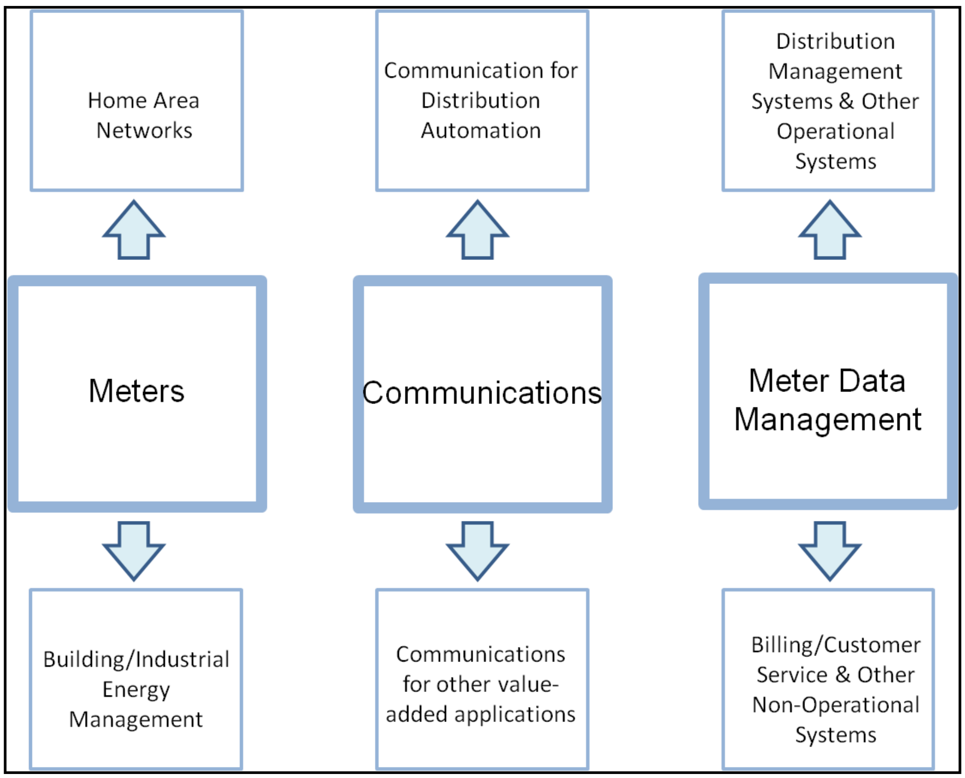
Specialists:	• Silver Spring Networks[15] (communications) • Trilliant (communications) • Ecologic Analytics (MDMS)
End-to-End Solutions:	• Landis+Gyr • Itron • Elster • Sensus

Source: Cleantech Group Analysis

[15] Silver Spring Networks has an expanded product portfolio that includes in-home energy management and other elements of an integrated solution, but is, today, best classified as a core communications vendor.

While these categorizations are useful to organize and clarify, it is important to recognize the market is complex and rapidly evolving, and therefore solutions blend into other adjacent segments of the smart grid landscape. For example, many of the firms providing communication solutions for meters are also attempting to position their technologies as the communication backbone for distribution and substation automation, as well as other forms of grid monitoring and control. Similarly, firms providing software to manage meter data are increasingly trying to integrate a wide variety of functionality that stretches into distribution management and outage management. Finally, some meter vendors are keen to move from outside to inside the home and a number of them are engaged in development efforts on home energy management devices and dashboards.

AMI Landscape: Vendor Adjacencies



Source: Cleantech Group Analysis

Market Size Estimates

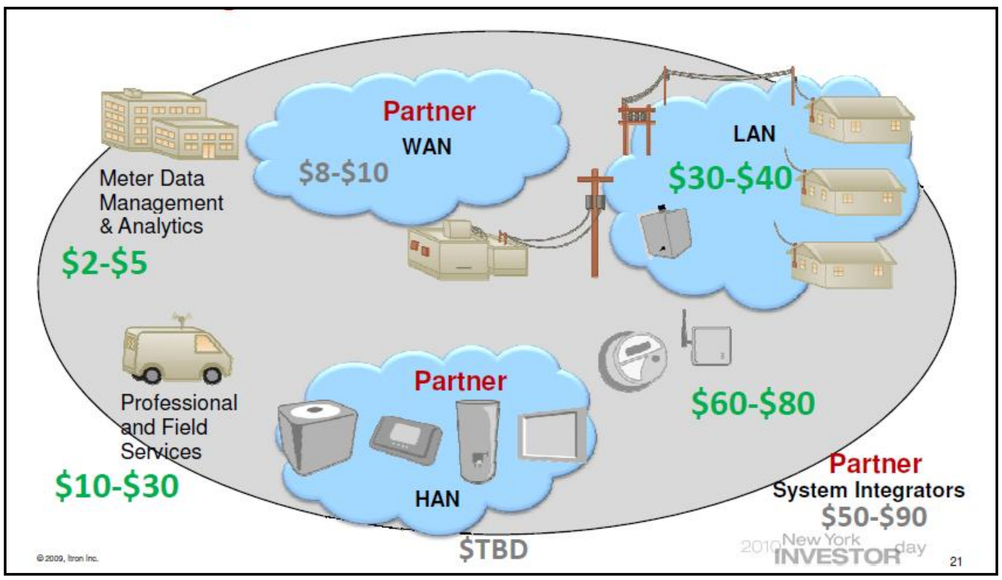
We estimate total U.S. spending across all three metering categories will be approximately ~$1.05B in 2010. This estimate is based on analysis of third party data, interviews, and our own internal analysis. We estimate the breakdown of this spending across these largest categories to be the following:

U.S. AMI Product Spending

Meters	$M	650
Communication	$M	350
MDM	$M	100
Sub-Total	**$M**	**1,100**
*Services *(not covered in this report)*	$M	700+

Source: Cleantech Group Analysis

Our market size estimates are primarily drawn from the deployment and shipment data that we will cover in this section of the report, as well as cost data that we have observed in the market. The following chart, included in a recent Itron investor presentation, highlights various elements of the meter supply chain and related costs. These per customer estimates ($60-$80 per meter, $30-$40 for communications infrastructure, $2-$5 for MDM software) are consistent with data points collected through our primary research activity and are a driver of our overall market estimates. While this report does not dive deeply into the services component of these deployments, it is clear that field services and system integration can be 50% or more of the total cost of an AMI deployment.



Source: Itron, Investor Day Presentation, June 2010[16]

As we will see from our specific market share data, this $1B+ AMI market opportunity has attracted the attention of large, established equipment vendors and well-financed venture-backed companies with substantial revenue and teams.

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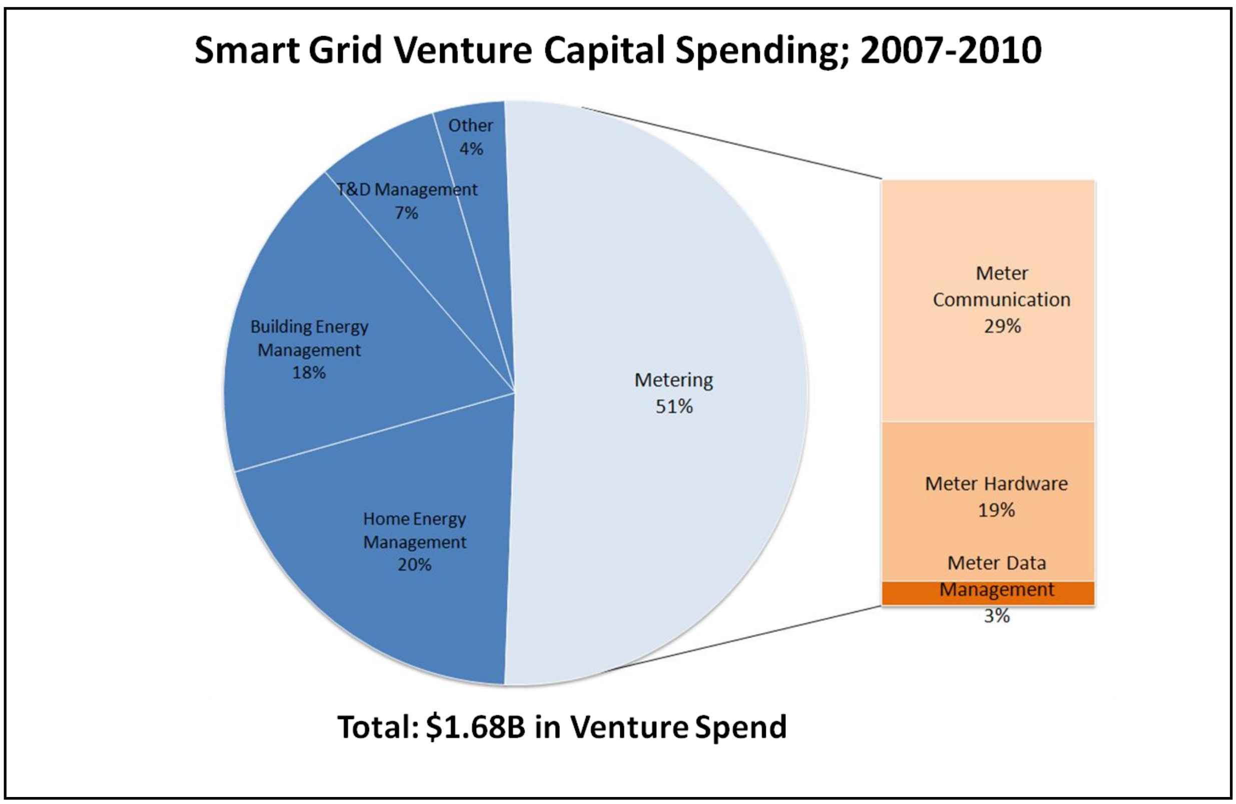
[16] http://files.shareholder.com/downloads/ITRI/971108004x0x376612/742ADC2B-8BD7-4C9A-8BA1-0F84C8508117/2010_Investor_Day_Consolidated_Slides_Webcast.pdf

Major AMI Vendors

	Headquarters	Revenue (est.)	Employees
Itron	Liberty Lake, WA, US	$1B-$10B	3,000-10,000
Landis+Gyr	Zug, Switzerland	$1B-$10B	3,000-10,000
Sensus	Raleigh, NC	$.5-$1B	3,000-10,000
Elster	Essen, Germany	$1B-$10B	3,000-10,000
GE	Atlanta, GA	$10B+	10,000+
Aclara	Hazelwood, MO	$20M-$100M	501-1500
Cooper Power	Waukesha, WI	$1B-$10B	1,500-3000
Silver Spring	Redwood City, CA, US	$100M-$.5B	250-500
Trilliant	Redwood City, CA	$20M-$100M	250-500
eMeter	San Mateo, CA	$20M-$100M	100-250
Ecologic Analytics	Bloomington, MN	$1-$20M	1-100
Oracle	Redwood Shores, CA	$10B+	10,000+

Source: Cleantech Group Analysis

The market has also been the recipient of the vast majority of venture capital dollars allocated to smart grid companies over the past 4 years. Venture financing data show that more than 50% of the money invested into smart grid firms has gone to metering companies.



Source: Cleantech Group Venture Data

Metering & Communication

We will review in parallel the current state of the vendor landscape for both meter hardware and communication systems. Because these two markets are so intimately intertwined – there is a communication unit needed for every meter installed – we will study these two segments together. Our review relies on data from Howard Scott of Cognyst Advisors[17] who compiles the industry's most comprehensive dataset on AMI communication unit shipments. This data only covers communication units however and we have developed our own estimates for meter hardware for purposes of this report.

As our review will demonstrate, the market for metering hardware is dominated primarily by a small set of incumbent, global-scale vendors. The retail market for electricity has always required a system capable of recording usage and billing customers. Consequently, while advanced metering has grabbed many recent headlines as a big piece of grid modernization, the meter market is a century old business.

While advances in technology have yet to catalyze the entry of major new competitors for meters themselves, there has been significant innovation at the communication layer that has sparked changes in market share and competitive dynamics for the underlying meters. These shifts have been primarily driven by new communications vendors that are capable of working with multiple meter suppliers. We will review the nature of these shifts taking place amongst vendors and some of the underlying drivers.

Current State of the Market: Installed Electricity AMR Base

It is helpful to begin with a snapshot of a broader, current state of the meter and communication unit market. For purposes of this study, our baseline of market share will be drawn from the current installed base of all electricity meters capable of automated meter reading (AMR). Loosely defined, AMR meters are capable of integrating a communication unit to transmit data, *in at least one direction*, that has been collected – even if only a few feet to a handheld device. Note, using this definition, AMR can also broadly include new AMI or "smart meter" deployments that can send data in two directions.

While AMI is relatively new to market, early forms of AMR are not at all a new phenomenon and equipment for drive-by or handheld reading has been rolling out in the field for the past two decades. As data on the annual shipment of AMR meter communication units demonstrates, there has been a steady advance of AMR units in the marketplace over the past decade.[18]

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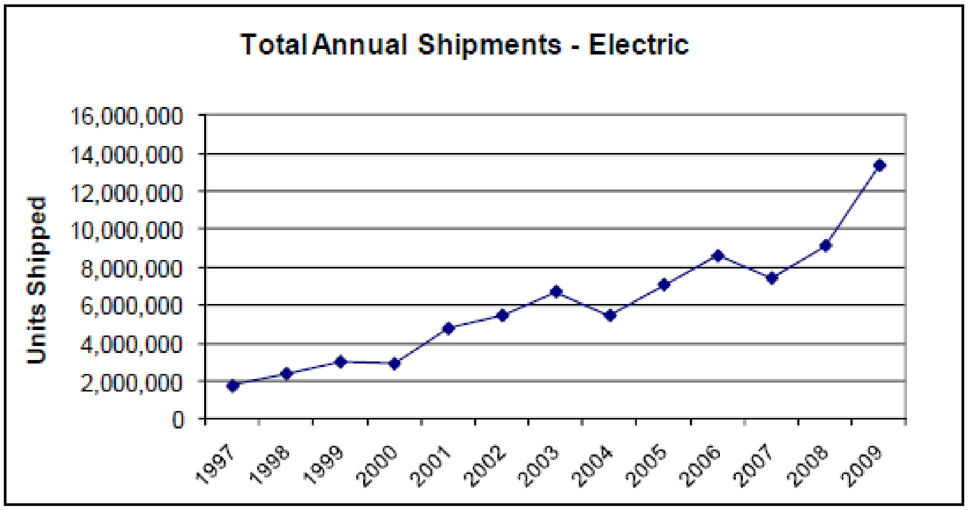
[17] http://www.thescottreport.com/publications.html
[18] Ibid. Note that this chart is for all North America, however US units make up 95%+ of this total.



Source: The Scott Report 13th Edition, Worldwide AMR Deployments

Data indicates that there were more than 82 million cumulative communication units shipped through 2009 for all electricity AMR applications, including AMI, in North America (with the vast majority in the United States). [19] These communication shipments were concentrated amongst a handful of vendors:

Shipments to Electric Utilities

	Share of Cumulative AMR Communication Units Through 2009
Itron	41%
Landis+Gyr	23%
Aclara	16%
Sensus	6%
Elster	5%
Silver Spring	5%

Source: The Scott Report, Cleantech Group Analysis

Silver Spring Network's presence on this chart is revealing as the company provides only AMI communication units. The fact that it has achieved meaningful market penetration of greater than 5% in 24 months of shipments against the backdrop of a market that has been shipping for decades is notable. We will see more of the company's impact as we dive deeper into AMI specific data.

Our own analysis of meter hardware associated with these communication units produces a similar picture. These findings are not surprising given that, traditionally, an AMR communication unit was associated with a meter itself from the same vendor. In addition, while the AMI market has driven a

[19] The Scott Report, 1Q 2010

proliferation of communication units in multiple places in the network, AMR communication units should ship near one-to-one with meters.

As our estimates demonstrate, the meter hardware market has revolved around a small set of key players with Itron dominating the installed base of AMR meters and Landis+Gyr coming in a strong second position. There is little question in the market that Itron, based in Liberty Lake, WA, has historically dominated the U.S market for meter hardware and has become a global leader in the field. Most public estimates of the total installed base of AMR units in the US fall somewhere between 75M and 80M units, or more than 50% of all ~150M electric meters.

Market Share of Installed Electric AMR Meters

	Share of All Installed AMR Meters Through 2009
Itron	50%
Landis+Gyr	28%
Sensus	6%
GE	6%
Elster	5%

Source: Cleantech Group Analysis

Most of these cumulative AMR meters and communication units shipped through 2009 were first generation; meaning that they were capable of communicating data, but only over short distances to a mobile unit that would then download data to a central server. These communication networks send usage data in one-direction, but are not capable of any other form of communication or control (technically, some of these meters can receive a signal from a central collection device, but it is a signal that simply tells the meter to send a reading).

As this communication layer has evolved, we have begun to see divergence from the legacy advanced meter reading units into the category that we have come to call “smart meters”. “Smart meters” or AMI units are capable of sending richer meter data over longer distances and bi-directionally over a fixed network. This eliminates the need for mobile reading in the field, allows for rapid retrieval of data at regular intervals, enables service provisioning from a central control center, and vastly improves monitoring of conditions at the customer end point. It is primarily the communication layer that makes this all possible.

Innovation at the communication layer is being driven by two camps of vendors. The legacy meter vendors including Itron, Landis+Gyr, Sensus, Elster, and GE all have their own AMI communication technologies which they are selling into the market alongside their own meter technology, and in partnership with each other’s meters. For example, it is conceivable to pair a Landis+Gyr meter with Elster’s EnergyAxis communications system or an Itron meter on Landis+Gyr’s Gridstream communication infrastructure. While this highlights that vendors are working together in a variety of ways, this should not be interpreted as widespread standards-based interoperability. These are primarily customer-driven integrations at the request of utilities.

Communication Capabilities Of Leading Metering Vendors

Vendor	Communications Brand	Technology
Itron	OpenWay	RF Mesh
Landis+Gyr	Gridstream & 2 Way PLC	RF Mesh & PLC
Sensus	FlexNet	RF Tower-based
Elster	EnergyAxis	RF Mesh

Source: Cleantech Group Analysis

At the same time, there have been many communication focused vendors such as Silver Spring Networks, Trilliant, SmartSynch, and Eka Systems (now a division of Cooper Power Systems), that have raised substantial amounts of venture capital in an effort to aggressively enter the market. These companies partner with the legacy meter vendors and are dependent on supplies of meters as an underlying component of their system.

Venture-Backed Communication Vendors

Vendor	Network Topology	Total Venture $ Raised
Silver Spring Networks	RF Mesh	$247,300,000
Trilliant	RF Mesh	$146,000,000
SmartSynch	Cellular	$30,000,000
Eka Systems (now Cooper Power)	RF Mesh	$31,000,000
Tantalus	Hybrid	$14,000,000
Tropos Networks	Metro WiFi	$81,800,000

Source: Cleantech Group Analysis

The combination of these communications specialists and a growing mandate from utilities that networks need to be open for multiple meter vendors is driving open platform development by many of the meter hardware vendors. Landis+Gyr, who has been a partner to Silver Spring on a number of large deployments, has aggressively designed its meters in support of communications partnerships. The web of partnerships between meter and communication vendors has grown increasingly intertwined. As we will see later in the chapter when we examine a handful of large utility projects, we see a tapestry of vendor choices being knitted together.

These communication vendors and new entrants have had a meaningful impact on market share in the communication unit and metering market for smart meter or AMI upgrade projects. Cumulative communication unit shipments through the first quarter of 2010 for just AMI architectures (a subset of the larger AMR market) to electric utilities provides a different market share picture:

Cumulative AMI Communication Units For Electric Utilities

	Share of Cumulative AMI Communication Units Through Q1 2010
Sensus	23%
Silver Spring	21%
Elster	18%
Landis+Gyr	16%
Itron	7%
Trilliant	6%
Cooper Power Systems	5%
Aclara	5%

Source: The Scott Report, Cleantech Group Analysis

These market share figures cover approximately 23 million communication units shipped through Q1 of 2010 classified as AMI. As a subset of the approximately 86 million total AMR units shipped through Q1 2010, AMI communication units are already greater than 25% of all AMR shipments.

It is also worth noting that this is a rapidly shifting competitive landscape capable of changing from quarter to quarter based on the pace at which individual utilities decide to deploy communication networks (for example, legal and consumer challenges to PG&E's California rollout could impact project vendors such as Landis+Gyr, GE, and Silver Spring[20]). Similarly, regulatory decisions may impact rollouts that may be moving toward contract. For example, the Maryland PSC's recent denial of BG&E's smart meter deployment plan temporarily had put on hold a large number of units. While this deployment is now back on track after revisions to the BG&E plan[21], it is an instructive case that highlights the impact of regulatory decision-making.

A closer look at the data for just the first quarter of this year, demonstrate how relative share can change quite quickly:

[20] http://online.wsj.com/article/SB10001424052748703946504575470211788200600.html

[21] Silver Spring Networks has been selected as the vendor on this project: http://www.marketwatch.com/story/baltimore-gas-and-electric-company-selects-silver-spring-networks-for-smart-grid-initiative-2010-09-01

AMI Communication Unit Shipments to Electric Utilities

	Comm. Units Q1 2010
Silver Spring	28%
Sensus	27%
Itron	22%
GE	11%
Landis+Gyr	9%
Aclara	5%
Elster	4%
Trilliant	3%

Source: The Scott Report, Cleantech Group Analysis

Translating these communication units into corresponding meter units is not a straightforward exercise in the new competitive landscape. Silver Spring, for example, now commands a significant market share of communication units, but works with a number of meter vendors including GE, Landis+Gyr, and Itron.[22] Similarly, Trilliant and Eka (included in the Cooper statistic) integrate with third party meters.[23] In addition, keep in mind that not all communication units are destined for meters – some will be deployed in a tiered, relayed topology within AMI data concentrators and others will be used for grid monitoring and control and distribution automation. Finally, the shipment and subsequent installation of a complete meter system may lag the shipment of a communication unit, so a one-to-one mapping is not accurate.

The number of shipped and installed smart meters is a source of great industry speculation and is often shrouded in secrecy with vendors wary of exposing competitive positioning. While much of the publicity around smart meter vendors is generated by contract announcements, there is a huge gap between contracts announced and meters shipped. This gap could be years and the number of units awarded to a vendor can change significantly over time – for this reason, estimating the current state of the meter market is akin to hitting a moving target.

The last widely cited industry benchmark of installed smart meters is 8 million as of January 2009.[24] This number relies heavily on FERC's 2008 Demand Response & Advanced Metering Survey which will be updated later this year. [25] Our analysis indicates that this number has likely risen in the subsequent 18 months to approximately 15-16 million meters installed though Q2 of 2010. We believe that this translates into a market for approximately 10 million meters to be shipped in 2010. It is important to reiterate that there is a lag between meter shipments and installations.

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[22] http://www.silverspringnet.com/partners/advanced_metering.html
[23] http://www.trilliantinc.com/partners
[24] http://www.whitehouse.gov/sites/default/files/administration-official/vice_president_memo_on_clean_energy_economy.pdf
[25] http://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp

U.S. Meters: Shipped & Installed

	Meters Shipped	Total Meters Installed (cumulative)
2008		8M
2009	7M	12M
2010	10M	20M

Source: Cleantech Group Analysis

Our research has led us to market share estimates for the installed base of meters through Q2 2010, as well as a market share of shipments for 2010 that will have a more material impact on market share of installed meters in 2011.

U.S. Meter Market Share

	Market Share of Installed AMI Meters Through Q2 2010	**Market Share of AMI Meters Shipped in 2010**
	Assume 15M Installed	*Assume 10M shipped*
Landis+Gyr	25%	19%
Sensus	24%	20%
Itron	20%	33%
Elster	15%	10%
GE	15%	17%

Source: Cleantech Group Analysis

These estimates are consistent with some of the few public data points. Itron is a public company (NYSE: ITRI) and consequently reports quarterly data on the number of smart OpenWay meters that it ships per quarter. In its most recent Q2 2010 filing, it reported that it had shipped 1.2M total OpenWay units in Q2 on top of 1M units shipped in Q1.[26] A majority of these units are headed for the U.S. electric market and we estimate that they will ship just short of 3.2M units to the U.S. for the year. Sensus files publically as well (though only issues public debt, not equity), but it reports all of its data in endpoints as opposed to meters. In its most recent presentations it refers to 7M smart endpoints installed worldwide.[27] A portion of these projects are in Europe and a portion are for gas and water utilities (which we have excluded from our analysis). Assuming half of these endpoints have gone directly into meters installed by U.S. electric utilities would lead us to an estimate of 3.5M Sensus meters (in line with what our market share estimates would suggest).

[26] Itron Q2 financial filing; add proper reference

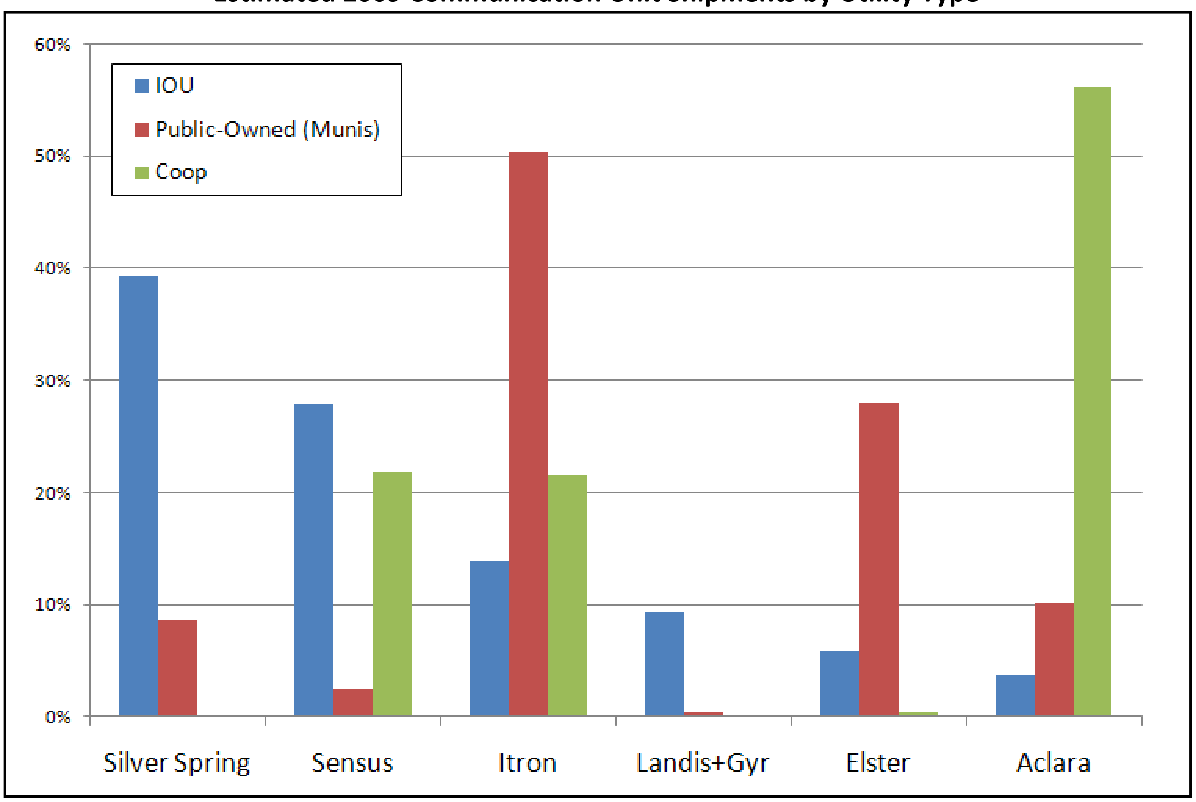
[27] http://www.sensus.com/SensusPresentation_DeutscheBank2010-05-12.pdf

Itron's reassertion of its leadership position is an important development. The company has a substantial backlog of meter orders and is moving back toward its historical position as market leader. While it may not establish the same dominance that it commanded in the legacy AMR world, it is back in a very competitive position. GE is making similar competitive strides as its relationship with Silver Spring Networks has clearly been beneficial to its ability to quickly gain market share in the meter hardware market. GE has broad aims in the smart grid space as evidenced by recent announcements of products for in-home energy management and vehicle charging, as well as a $200M grant competition for smart grid related ventures.[28]

Breakdown by Type of Utility

It is also instructive to analyze the market segmented by the type of utility customer: Investor Owned (IOU) vs. Public Owned (Muni) vs. Cooperatives. Using The Scott Report's estimates for communication unit shipments in 2009 by utility type,[29] we can compute a market share by vendor by utility type. Note again that these are communication unit shipments, not actual meters.

Estimated 2009 Communication Unit Shipments by Utility Type



Source: The Scott Report, Cleantech Group Analysis

[28] http://earth2tech.com/2010/07/13/ge-pledges-200m-for-smart-grid-unveils-electric-vehicle-charger/
[29] The Scott Report notes that this level of granularity is an extrapolation of data only available through the first half of 2009

We see that Silver Spring had garnered early mindshare with large IOUs engaged in AMI rollouts, Itron held a dominant position with public-owned utilities, and Aclara has built a commanding market share with co-ops. Aclara's dominance in the co-op market is explained by the category's overwhelming choice of powerline communication technology – an area of leadership for Aclara. Silver Spring had been the beneficiary of spending by forward-thinking IOUs, but as we will see in a review of vendors by major projects, this market is quickly becoming competitive.

Meters and Communication: Strategic Summary

Having assimilated communications-centric entrants, the vendor landscape for meters and AMI communications infrastructure is now entering a mature period of competition. The market is likely to move in the near term via wins and losses amongst the vendors named in this section, rather than the entrance of brand new competitors. There may be long term entry and price pressure from foreign hardware manufacturers, but the current state play is being shaped by the relatively small number of vendors enumerated in this report.

Meters and Communication: Related Vendors

Most discussions around meter hardware involve the meter unit vendors – Itron, Landis+Gyr, GE, Sensus, and Elster. While a number of these vendors rely on in-house chipset and component design and manufacturing, others rely on chipsets from semiconductor manufacturers such as Teridian, Freescale, and upstarts such as Accent[30]. In addition, the need for meters to communicate in an open, standards-based way to home devices is fast becoming an important market requirement. The on-going NIST SGIP work has both a domain expert working group (DEWG) focused on home-to-grid, as well as an identified Priority Action Plan (PAP) focused on home integration issues.[31] In response, most vendors are incorporating short range communication chipsets (primarily ZigBee) from vendors such as Ember Networks, Atmel, and Texas Instruments.

We should also note that while we are not examining the market for services, a large majority of project cost and labor ultimately flows into meter installation conducted by firms such as Corix Utilities, Utility Partners of America, and VSI Meter Services. These companies are engaged for project management and installation expertise, and are growing quickly in response to smart meter rollouts. Corix, based in Vancouver, Canada, has expanded to over 2,000 employees (it has 315 employees alone installing meters for Southern California Edison), and will generate over $500M in 2010 services revenue.[32] This is

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[30] http://www.smartgridnews.com/artman/publish/Technologies_Metering_News/Why-the-Smart-Metering-Business-Just-Changed-Forever-2285.html
[31] http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/H2G
[32]http://www.vancouversun.com/business/Corix+emerging+leading+utilities+service+provider+North+America/3302155/story.html

clearly big business and a large portion of labor allocated to smart grid deployments is associated with these firms. Further study of the services component of the smart grid supply chain is certainly warranted in future work.

Similarly, the market for communications infrastructure is not confined to the vendors deploying systems. While the current spotlight on the communications market tends to focus on firms like Silver Spring, Trilliant, and incumbent vendors such as Itron, Sensus, and Landis+Gyr, there is a supporting ecosystem of incumbent communication equipment vendors such as Cisco, Motorola, and Nokia Siemens Networks that are increasingly carving out their own high profile role. Module, semiconductor, and chip vendors such as Teridian and Digi International also have an important supply role in this market. Finally, the major telecom service providers, including AT&T, Verizon, Sprint, and T-Mobile have all articulated smart grid strategies and are looking to leverage their network assets by promoting cellular technology for both backhaul and direct connection to field devices and meters.

Meter Data Management

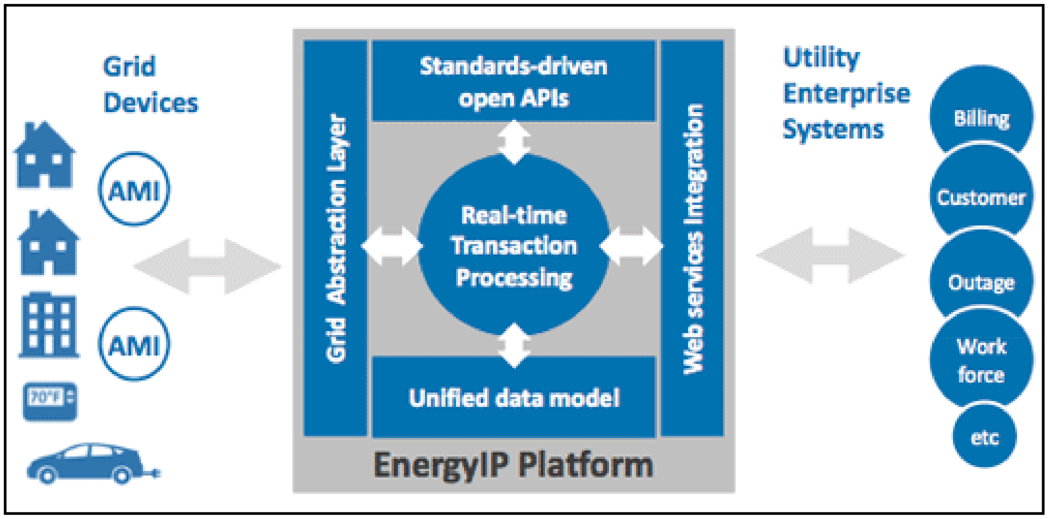
As is evident from the data on AMI meter and communication deployments, there is a proliferation of devices capable of generating a vast amount of new, real-time usage data. For a traditional utility IT system architected to accept a meter reading once a month, a stream of data at 15 minute intervals is a vast, new IT challenge. In order to handle this new stream of information, a category of software called Meter Data Management (MDM) has been rolling out steadily. Increasingly, industry participants indicate that utilities are making MDM software procurement a foundational step in broader smart meter rollouts and selecting an MDM vendor prior to selecting network and meter components. As we will see in our analysis of the vendor landscape, this procurement strategy can benefit pure-play software vendors such as eMeter and Ecologic Analytics.

MDM software can be used to provide a number of mission critical functions in an AMI deployment. The software serves as an integration layer, capturing and standardizing meter data from all customer endpoints; an increasingly important function for utilities that are deploying meters from multiple vendors, sending data over multiple network technologies, and deploying equipment across different customer sets and geographies.[33] An MDM package will also typically employ Validation, Estimation, & Editing (VEE) algorithms in order to correct for missing datapoints. On top of this integration and data cleansing layer, an MDM system may provide applications like billing natively or provide for integration with installed billing and CIS systems.

[33] http://www.intelligentutility.com/article/08/10/are-all-meter-data-management-systems-created-equal

As utility IT environments become increasingly complex, the MDM category will be fluidly defined. It remains an open question whether MDM will become an application layer, a middleware layer, or both. The middleware function, consolidating data and feeding it to other IT systems, is clearly a mission critical capability. MDM vendors may begin to see this layer as a platform play with a winning strategy focused on how to enable access to data via application programming interfaces (APIs). eMeter's Energy IP is a move in this direction and the company is positioning the product as an integration platform:

Meter Data Consolidation as Middleware/Integration Layer – eMeter Energy IP



Source: eMeter Product Literature

Categories in this area are still loosely defined, as evidenced by a number of vendors selling billing and customer service applications under the banner of MDM. Older billing systems are often incapable of handling dynamic pricing schemes and the larger amounts of data being produced by smart meter deployments. Consequently utilities must rely on new system vendors or custom programming by system integrators.

Meter Data Management Vendors

Pure-Play:	eMeter, Ecologic Analytics
End-to-End Solutions:	Itron, Elster, Aclara, Oracle
System Integration:	IBM, SAP, Accenture, Cap Gemini

Source: Cleantech Group Analysis

Much as we saw a split in the metering and communications world between pure-play and integrated vendors, so too do we see this division in the MDM systems market. It is also worth noting that the deployment of MDM software is typically linked to a larger systems integration project that assists a utility in ensuring that all of its back office IT applications are functioning in concert. While this study is focused on hardware and software products (not services or custom built applications), this is an area of the market that cannot be overlooked as a piece of the strategic value chain.

Estimating market share and market size statistics for the emerging MDM market requires triangulating a variety of industry datapoints. Our market share estimate comes from our own internal analysis, industry conversations, and evaluation of third party data. We believe that the U.S. market for stand-alone MDM software solutions will be near $100M[34] in 2010 with the following vendor breakdown:

2010 U.S. MDM Software Market Share

	Share of MDM Software Sales
eMeter	15%
Itron	13%
Elster (EnergyICT)	10%
Ecologic Analytics	10%
Oracle	8%
Aclara	8%

Source: Cleantech Group Analysis

According to a recent report issued by IDC Energy Insights, the majority of MDM contracts (80%) are currently awarded by large utilities.[35] For mid-size and smaller utilities, stand-alone MDM installations may be burdensome and these utilities may rely on MDM solutions that are scaled-down (essentially just data collection) or custom-built that we have not included in our market size estimate. This same IDC study cites typical large utility costs of $2M-$4M per MDM installation.[36] This IDC pricing is consistent, albeit at the top end, with our research in the market. While these costs are meaningful in terms of dollars, they are quite small in comparison to the tens, if not hundreds, of millions of dollars spent by large utilities on the procurement of meters and communication systems. While no dataset will be perfect in terms of analyzing market sizes and shares, it is clear that the majority of dollars flowing into metering projects are earmarked for metering hardware and communication infrastructure, with a smaller portion allocated for meter data management software.

Conclusions: Overall Market Momentum and Dynamics

While a snapshot of each of the subsectors (meters, communication, software systems) has provided insight into important market dynamics and the current state of vendor share and positioning, it is also instructive to examine the market going forward, with a particular emphasis at the utility project level.

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[34] There have been a number of recent industry estimates published. IDC Energy Insights estimated that the North American MDM market was $240M in 2008 growing at 29.4% year over year. Newton-Evans has published a more conservative estimate of $110-$125M in 2010 revenue (that includes installation costs).

[35] http://www.idc-ei.com/getdoc.jsp?containerId=prUS22181810

[36] Ibid

Using a variety of available data sources and our own secondary research, we have compiled a database of major projects and announced vendors associated with these deployments.

Note that this analysis is not intended to be overly-predictive. Our methodology relies on press releases, industry conversations, and estimates. Vendors announced for pilot stages of a project may not win full-scale deployments. In addition, vendors, eager to gain mindshare in the market, routinely announce vendor contracts for even minor project participation.

Even with these caveats, we believe that examining these projects and announced vendors provides support for the key trends highlighted in this chapter. First, we have color coded projects, yellow for those relying on primarily a single vendor solution and pink for those deploying a multi-vendor environment. As we have discussed, there is an ongoing tension in the market between these approaches; if this dynamic is tipping, it is tipping in the direction of more open, multi-vendor configurations. Second, the vendors announced on all of these projects are the major vendors catalogued in this chapter confirming maturity in the competitive set of players.

Smart Grid Utility Projects & Announced Vendors

Utility & Deployment Size		Announced Vendors		
Company Name:	**Endpoints**	**Meters**	**Communications**	**MDMS**
Southern California Edison Co	5,300,000	Itron	Itron	Itron/eMeter
Pacific Gas & Electric	5,100,000	GE/Landis+Gyr	Silver Spring	Ecologic Analytics/eMeter
Florida Power & Light	4,400,000	GE	Silver Spring	Itron
Southern Company	4,300,000	Sensus	Sensus	Itron
DTE	4,000,000	Itron	Itron/SmartSynch	Elster
Oncor	3,000,000	Landis+Gy	Landis+Gy	Ecologic Analytics/eMeter
Center Point Energy	2,200,000	Itron	Itron/GE	eMeter
Pepco Holdings, Inc	1,900,000	GE/Landis+Gyr	Silver Spring	
San Diego Gas & Electric	1,400,000	Itron	Itron	Itron
NV Energy	1,300,000	Sensus	Sensus	
Ameren	1,100,000	Landis+Gyr	Landis+Gyr	
Wisconsin Power and Light	1,000,000	Sensus	Sensus	eMeter
Salt River Project	935,000	Elster	Elster	Elster
Portland General Electric	850,000	Sensus	Sensus	
Arizona Public Service	800,000	Elster	Elster/KORE	Aclara
Oklahoma Gas & Electric	771,000	GE	Silver Spring	Elster
Central Maine Power Company	650,000	GE/Landis+Gyr	Trilliant	
Sacramento Municipal Utility District	620,000	Landis+Gy	Silver Spring	Itron
Peco Energy Company	600,000	GE	Silver Spring	Sensus
Idaho Power	475,000	Aclara	Aclara	Aclara
Hawaii Electric	450,000	Sensus	Sensus	

Source: Cleantech Group Analysis; data on endpoints collected from various sources including Edison Electric Institute

III. Demand Response

Key Takeaways
• Curtailment service providers (CSP) have been the key intermediary providing a wide range of demand response (DR) options and expanding the number of capacity providers (customers), including small and medium commercial and industrial (C&I) facilities and residential home owners. • DR has grown beyond the earliest one-way, direct load control programs offered by utilities to a more dynamic, multi-stakeholder relationship that may involve the utility, an Independent System Operator (ISO)/Regional Transmission Organization (RTO), a CSP, and the retail customer. • DR has primarily been a services model commanding $1.1B in revenue in 2010. We estimate that $150M of this market is spent on technology products to enable DR applications. • The increasing complexity of DR and the desire for more automated, transparent access to curtailable loads is leading to growth in technology-enabled DR platforms. These platforms will help utilities provision DR services more effectively. • The DR vendor landscape is perhaps the most dynamic of all smart grid markets with large building automation vendors, major CSPs, power systems vendors, and upstart technology companies all converging on the opportunity.
Key Vendors
• Comverge • EnerNOC • CPower • Energy Curtailment Specialists • EnergyConnect • Honeywell • Carrier • Cooper Power Systems • Siemens • Schneider Electric • General Electric • Johnson Controls • EnergyHub • Tendril • OpenPeak • OPower • eMeter

Is Demand Response the "killer application" for the smart grid, as suggested by Federal Energy Regulatory Commission Chairman Jon Wellinghoff?[37] Indeed, the ability to curtail up to 188 GW of power in 2019, or about 20 percent of the country's overall peak energy use, by turning down power in commercial, industrial, and residential loads is an attractive alternative to building the equivalent in new generation.[38] In this section, we will walk through the progression of the DR value chain from its origins to where it is going, with specific focus on vendors, partnerships, and innovations.

Unlike the markets for smart metering or distribution grid management which have established, defined technology product categories, DR has primarily been a services market. Only recently have we

[37] http://www.smartgridtoday.com/public/1686.cfm
[38] FERC A National Assessment of Demand Response Potential Staff Report June 2009

witnessed a growing technology-enabled component of the DR sector. For this reason, this section will be more of a study in market evolution, rather than an inventory of market sizes and market shares. We will certainly address the size of the market and the key players, but we will do so by fitting them into a market story that continues to unfold.

The DR value chain involves multiple stakeholders. First and foremost, customers must enter into a demand response contract indicating interest in helping to shave demand during peak periods. Originally, utilities (and in some instances, the ISO/RTO) contracted directly with a small handful of large C&I customers to reduce load. In some instances this transaction was automated through use of remotely controlled thermostats or load control receivers manufactured by vendors such as Honeywell and Cooper Power Systems. To cover a larger pool of C&I demand response capacity, many utilities ceded customer acquisition and load management to the emerging curtailment service providers (CSP) – namely Comverge, EnerNOC, and a handful of other national-scale demand response aggregators.

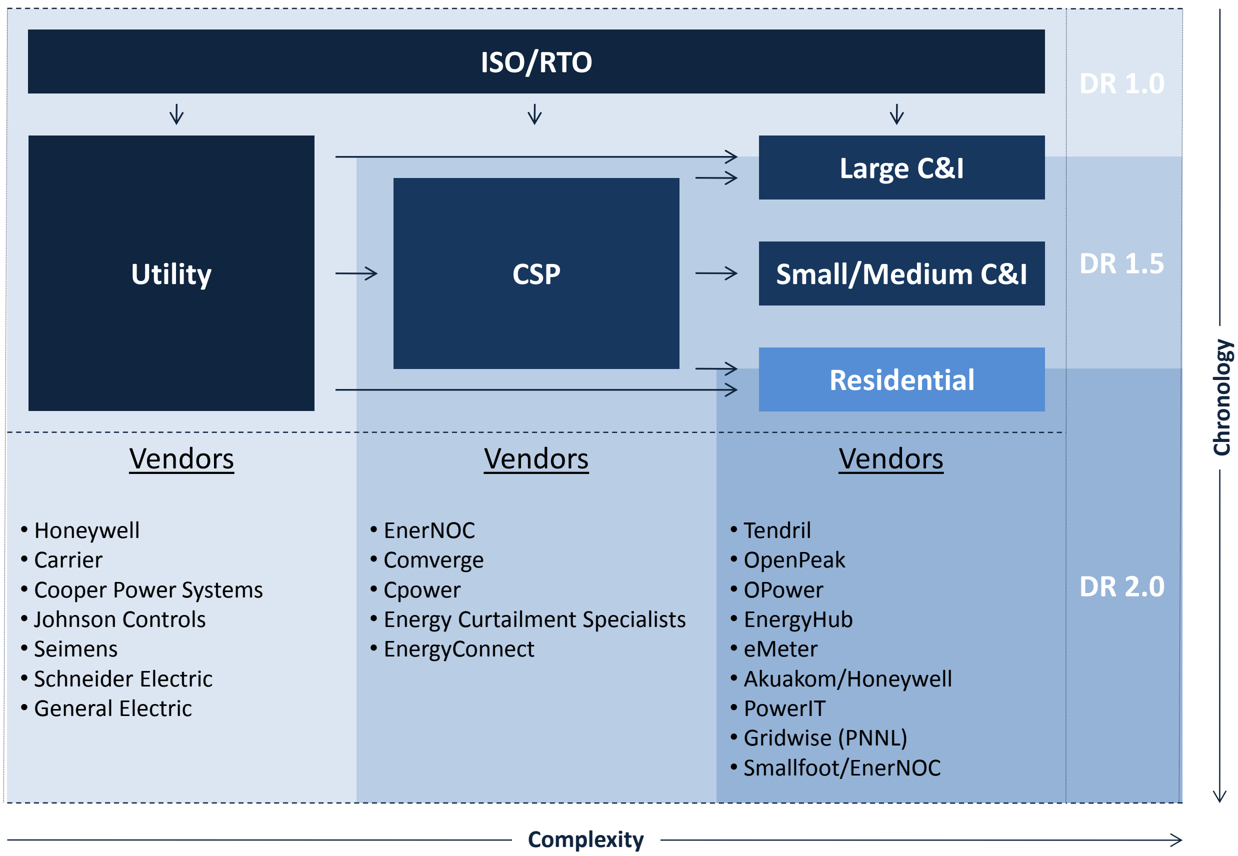
The CSPs provide a single point of contact for a utility to request multiple MWs of power during a peak event and it is then incumbent on them to deliver this reduction through direct or indirect control of customer loads. Once a service relationship has been established, either directly with a utility or via an aggregator, there is a technology layer required that will allow a utility to send a DR signal to a customer alerting him or her that a reduction in usage is required. In the past, this technology layer has been as a simple as a phone call, a text message, or an email. This manual notification remains the norm, though some more advanced signaling and automation is now being employed. Technology for communicating DR signals in the residential sector is being rolled out by venture-backed startups such as Tendril Networks and OpenPeak. Finally, monitoring, control, and automation systems are required on the premise side of this transaction to interpret pricing signals and to reduce energy use.

This portion of the study is primarily concerned with technologies up to the edge of the building & home though we will summarize vendors engaged in building automation and home energy management in Sections V and VI. That said, a discussion of DR vendors would be remiss without addressing evidence of emerging consolidation and competition between the traditional building management systems (BMS) players (e.g., Honeywell, Johnson Controls, Siemens, Schneider Electric), the major CSPs (e.g., EnerNOC, Comverge) and the startups edging into this domain (e.g., eMeter, Tendril Networks).

The DR Landscape (By Chronology and Complexity) – With Indicative Vendors

We see the demand response market increasing in complexity over time as the DR participation pool expands to include small to medium sized C&I customers and residential homeowners. To properly serve these new customers, the ISO/RTO, utility, and the CSP must adopt new technologies that provide better communication and intelligence. We have broken this evolution of DR into three categories, which we identify as **Demand Response 1.0 (DR 1.0)**, **Demand Response 1.5 (DR 1.5)**, and **Demand Response (DR 2.0)**.

DR 1.0 will address the initial forms of demand response, prior to the emergence of CSPs as an important intermediary. DR 1.5 introduces the role of the CSP, which greatly expanded the DR end market to include both small and medium sized C&I customers and some residential homeowners. Finally, we look at DR 2.0, which broadens the DR pool to include all networked residential homes and also introduces new DR products and services such as ancillary services and software solutions that enable the utility to bypass CSPs.



Source: Cleantech Group

Demand Response 1.0: The Origins of Demand Response

In many ways, demand response has been around in one form or another for several decades. The DR market was originally built on the simple premise that curtailing energy use at large commercial and industrial (C&I) customers during peak periods can reduce strain on the electrical grid and avoid outages. C&I customers would opt into a program that allowed utilities to interrupt power in return for a reduced rate. When demand strained the grid, the utility would make a phone call to

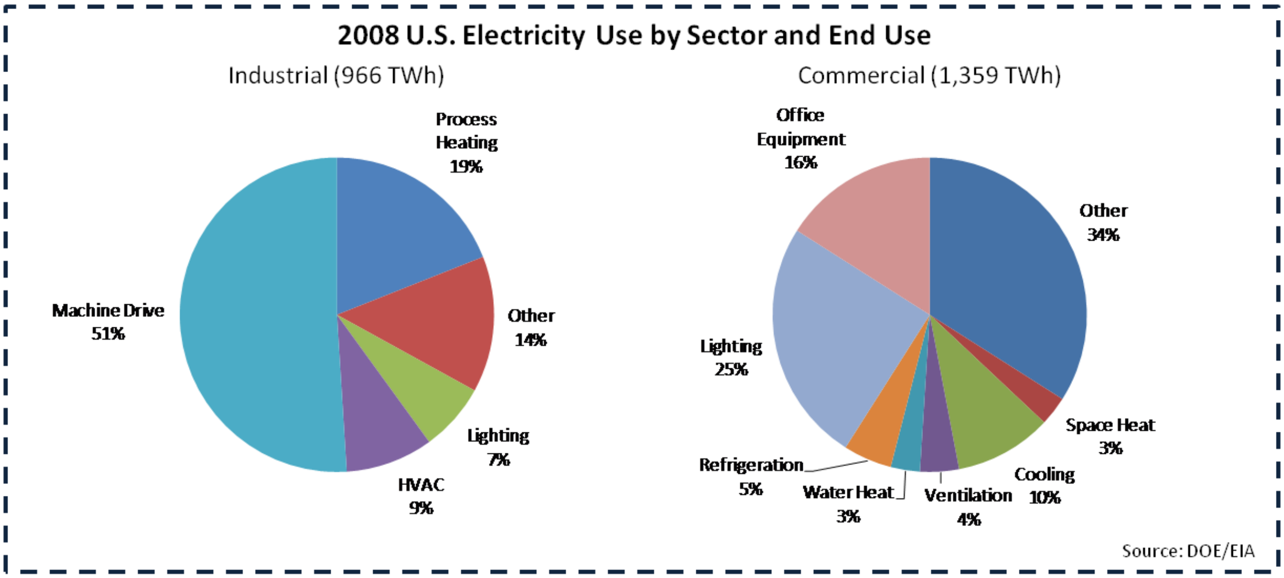
Examples of Commercial and Light Industrial Curtailable Processes

Air handlers	Internal lighting
Anti-sweat heaters	Irrigation pumps
Chiller control	Motors
Chilled water systems	Outside signage
Defrost elements	Parking lot lighting
Elevators	Production equipment
Escalators	Processing lines
External lighting	Pool pumps / heaters
External water features	Refrigeration systems
HVAC systems	Water heating

Source: EnerNOC

the building operators at the C&I customer premise and request that they turn down their air conditioning or some other interruptible load. The building managers would volunteer to reduce load in exchange for the reduced rates, or pay a penalty. Manufacturers of thermostats, HVAC systems, heat pumps, and building management systems (BMS) such as Honeywell, Schneider Electric, Siemens, and GE were, in a way, enablers of this rudimentary DR, which we'll call Demand Response 1.0 or DR 1.0.

In C&I environments there are multiple end points where DR can play a significant role in energy curtailment without materially disrupting the course of business. For many C&I customers, the largest curtailable processes can be adjustments to the HVAC system, a reduction of lighting, or slowing down variable speed motors. In addition, if appropriate, some large C&I customers can temporarily shift load towards on-site generation, which would reduce electrical demand on the grid.

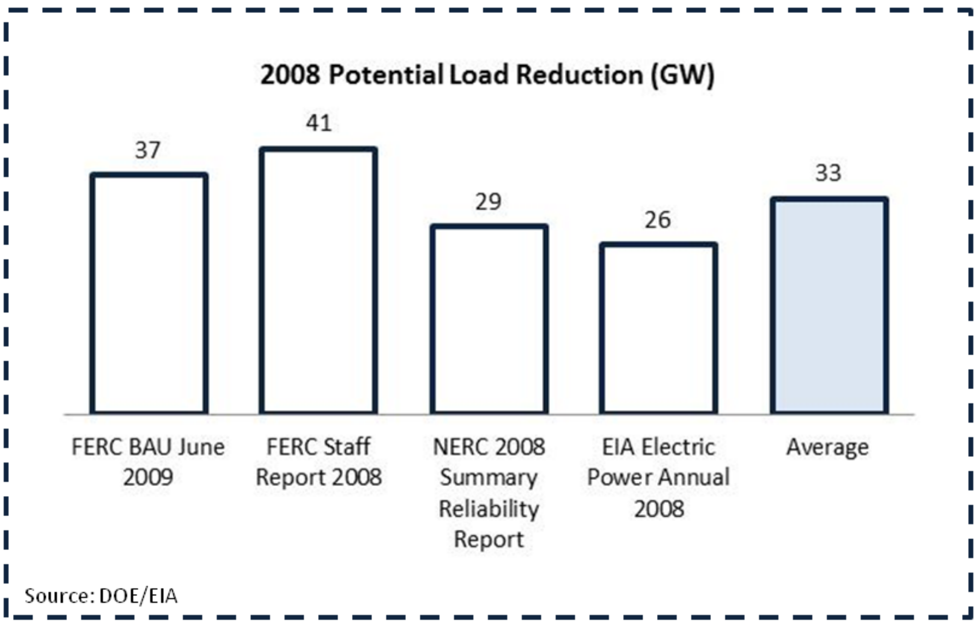


As electrical demand continued to outstrip new generation, however, utilities began relying more on these ad-hoc interruptible loads to relieve the grid. Many see two catastrophic events as the catalyst of modern-day DR. The 2000-2001 blackouts in California and the 2003 blackouts in the Northeast generated nation-wide interest in DR as an alternative to new generation. Some believe that with sophisticated DR solutions in place, the respective utilities could have better responded to price volatility and grid reliability.

Demand Response 1.5: The Emergence of Curtailment Service Providers

While in the past, large C&I customers coordinated directly with utilities, as DR programs became more widely adopted in the C&I space, the role of a curtailment service provider emerged as a trusted third party intermediary. We call this development Demand Response 1.5, or DR 1.5. Venture capitalists noticed this trend and made the bulk of their investments in demand response in companies like Comverge, EnerNOC, and CPower between 2006 to 2008 though the CSPs had been in operation since as early as 2001. C&I customers enjoyed using CSPs because they streamlined the DR logistical process compared to dealing directly with the utility. Utilities liked CSPs because they now had one point of contact to manage their DR programs. In addition, CSPs broadened the customer base of DR participants by aggregating small to medium sized load C&I customers (e.g., 200kW or less) and residential customers who could not participate in prior DR programs.

Estimates vary between organizations tracking the volume of potential load reduction from demand response (see chart below). The Energy Information Administration (EIA), a data and analytics agency within the Department of Energy, estimates that approximately 13GW of actual peak load was reduced in 2008.[39] With an approximate 33GW of potential load reduction in 2008, this means that the nation exercised less than 40% of its capacity.[40] Moreover, with national demand response participation at 1.5% right now, there is a great deal of untapped capacity.[41]

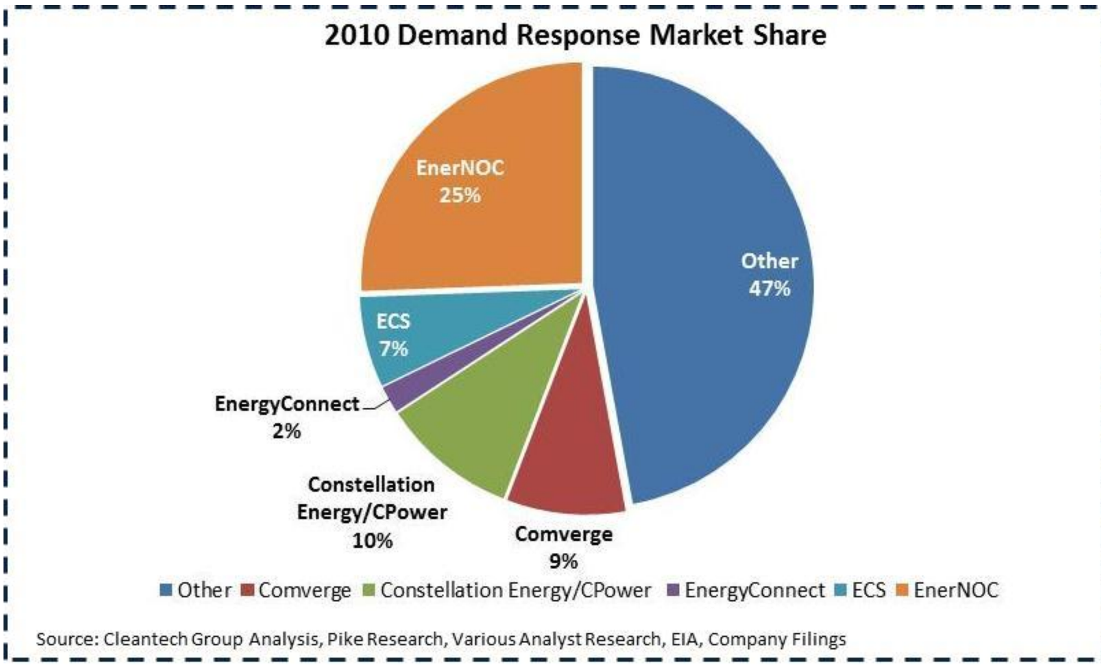


The Cleantech Group estimates 2010 demand response managed (either by the utility/ISO/RTO or CSP) to be approximately 15GW, up 2GW from 2008, for an approximate total market size of $1.1B.[42] This DR (including C&I and residential) market is largely dominated by a few major aggregators. From our estimates, Comverge and EnerNOC have captured almost 35% of actual demand response peak load reduction. Constellation Energy, with the acquisition of CPower, now represents 10% of demand response. The other major CSPs, including Energy Curtailment Specialists (ECS), and EnergyConnect represent approximately 9% of actual peak load reduction. The remaining ~7GW in the other category

[39] EIA Electric Power Annual 2008, January 2010
[40] Cleantech Group Analysis
[41] DOE Smart Grid Report July 2009
[42] Cleantech Group Analysis. Estimates from third party research firms vary from $1.0B to $1.5B.

is likely a combination of smaller CSPs and direct load controls from major C&I customers to the utility/ISO/RTO.

The revenue associated with this market is primarily services revenue – CSPs earn a margin on payments made to customers. As we have discussed, the technology product market associated with this revenue is still quite small. Interactions between utilities, CSPs, and customers are generally facilitated using equipment already installed on a customer premise. **We estimate that current U.S. technology spending in this market is approximately $150M in 2010.**

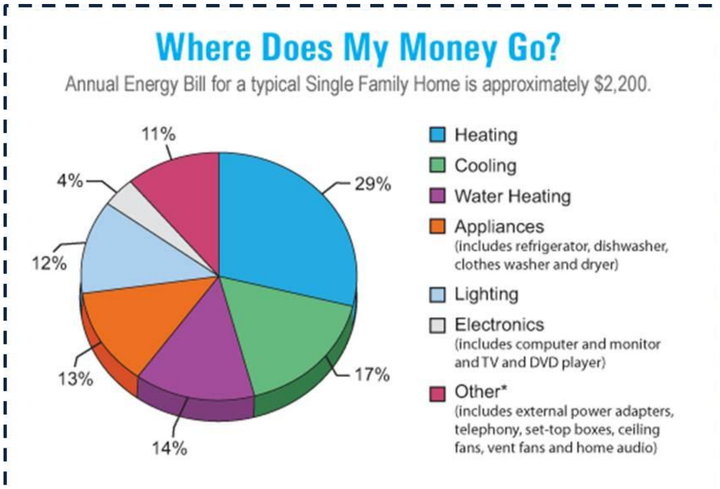


The Rise of Residential Demand Response

At first blush, the emergence of residential DR seems like a natural extension of the services offered to commercial and industrial customers. Residential energy use represents approximately one-third of all total electricity usage in the United States.[43] Like C&I customers, residential customers also have some low-hanging fruit in energy curtailment. For example, more than 45% of home energy use is in heating and cooling.[44] During peak summer periods, cooling becomes an even more important source of energy curtailment, especially in geographies like the Southwest and Southeast. Comverge was one of the first to go after residential customers, with their PacifiCorp program in Utah in 2003.

[43] EIA, 2008.

[44] Energy Star, 2009



Source: Energy Star, 2009

In order to target the larger DR customer base and to make the offering more appealing and comprehensible to residential customers, technology must be rolled out that gives consumers more control, but continues to give direct visibility to utilities. One of the key drivers to residential DR will be the continued deployment of AMI smart meters, which enable two-way communication between the meter and the utility. The Cleantech Group estimates that total installed AMI smart meters has grown from 8 million meters in 2008 to nearly 20 million meters at the end of 2010. The proliferation of smart meters gives utilities better real-time insight into power consumption and can theoretically allow for immediate acknowledgement of load curtailment during a DR event.

For CSPs, there are significant differences in the DR business case between C&I and residential customers. While a typical large C&I load is 200kW or up, many residential homes have loads of only 1kW-2kW. To reach critical mass in residential loads, a CSP will have to aggregate multiple households. As a result, the capital requirements for residential DR differ greatly from C&I DR. EnerNOC reports that C&I customers have a capex cost of $3-$5/kW and are utilized throughout the year. Residential customers, on the other hand, can have costs ranging from $150-$500 per kW and are usually only utilized in the summer and winter months. In spite of these logistical and financial headways, residential DR continues its robust growth.

FERC estimates that there is approximately 6GW of potential residential demand response. Comverge appears to the market leader with approximately 650MW of residential DR load under management.[45] However, there is evidence that equipment manufacturers such as Honeywell and Carrier may also be facilitating significant DR deployments in the US. Honeywell claims over 950,000 load control device (usually programmable thermostats) installations in the US[46] while Carrier claims more than 80,000 2-

[45] Comverge 10-Q Quarterly Report, Q2 2010, pg. 16
[46] http://www51.honeywell.com/honeywell/news-events/case-studies-n3n4/energy_savings.html?c=36

way thermostat installations.[47] Many of these installations are in conjunction with CSPs who own the primary customer relationship. Nevertheless, it is important to note the hardware vendors are often the incumbents in building and home energy management, essentially owning the physical "socket," and should not be overlooked even if they are not explicitly managing major DR programs today.

The emergence of CSPs also led to the creation of differentiated DR products/services catered to the utility (reliability vs. price) and end customer (incentive vs. price). Reliability-based DR is often associated with emergency conditions on the grid, such as an impending blackout, whereas price-based DR is triggered by anticipated high energy prices. The DOE has identified nine distinct demand response options, categorized as either a price-based option or incentive-based program (see below).

Profiles of Demand Response Options[48]:

Demand Response Options

Price-Based Options

- *Time-of-use (TOU):* a rate with different unit prices for usage during different blocks of time, usually defined for a 24 hour day. TOU rates reflect the average cost of generating and delivering power during those time periods.
- *Real-time pricing (RTP):* a rate in which the price for electricity typically fluctuates hourly reflecting changes in the wholesale price of electricity. Customers are typically notified of RTP prices on a day-ahead or hour-ahead basis.
- *Critical Peak Pricing (CPP):* CPP rates are a hybrid of the TOU and RTP design. The basic rate structure is TOU. However, provision is made for replacing the normal peak price with a much higher CPP event price under specified trigger conditions (e.g., when system reliability is compromised or supply prices are very high).

Incentive-Based Programs

- *Direct load control:* a program by which the program operator remotely shuts down or cycles a customer's electrical equipment (e.g. air conditioner, water heater) on short notice. Direct load control programs are primarily offered to residential or small commercial customers.
- *Interruptible/curtailable (I/C) service:* curtailment options integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties maybe assessed for failure to curtail. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers.
- *Demand Bidding/Buyback Programs:* customers offer bids to curtail based on wholesale electricity market prices or an equivalent. Mainly offered to large customers (e.g., one megawatt [MW] and over).
- *Emergency Demand Response Programs:* programs that provide incentive payments to customers for load reductions during periods when reserve shortfalls arise.
- *Capacity Market Programs:* customers offer load curtailments as system capacity to replace conventional generation or delivery resources. Customers typically receive day-of notice of events. Incentives usually consist of up-front reservation payments, and face penalties for failure to curtail when called upon to do so.
- *Ancillary Services Market Programs:* customers bid load curtailments in ISO/RTO markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. If their load curtailments are needed, they are called by the ISO/RTO, and may be paid the spot market energy price.

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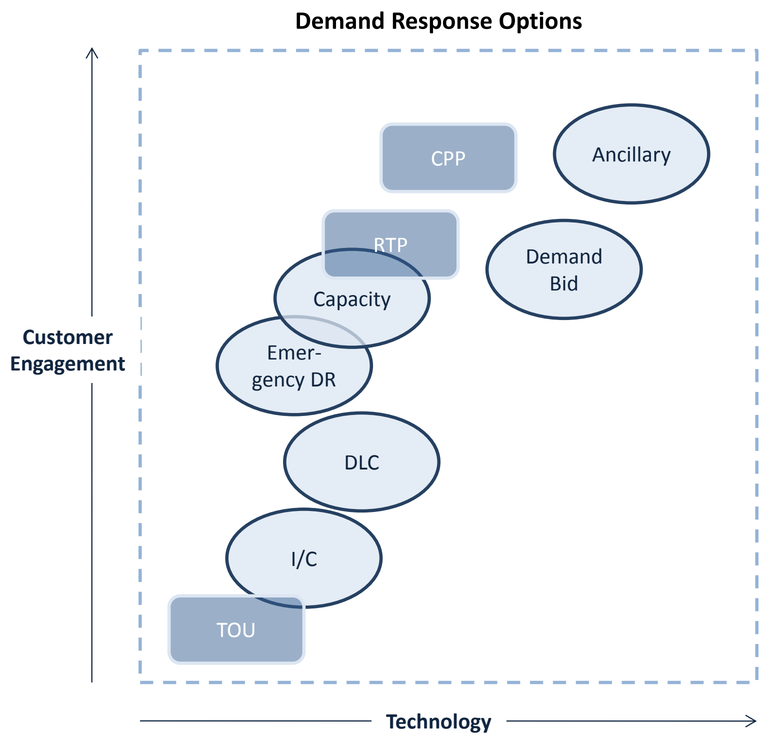
[47] http://www.silverspringnet.com/partners/company_profile_carrier.html

[48] DOE Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them, February 2006

A FERC study found that in 2008 slightly over 1% of all customers received a dynamic pricing tariff, with nearly the entire amount represented by time-of-use tariffs.[49] Many believe that dynamic pricing is highly correlated with increased DR participation. As such, in order to enable dynamic pricing and other higher touch customer engagement DR options for the ISO/RTO and utility, new technologies and applications were introduced initially by the CSP and later, by more vertically integrated energy management companies. In the next section, we will briefly explore each DR option along with the corresponding enabling technology or device.

Demand Response Options and the Corresponding Enabling New Technologies and Devices[50]:



Time of Use (TOU) Pricing and Interruptible/Curtailable Load: No new equipment although some devices may benefit from a load control receiver, usually from a hardware vendor like Johnson Controls.

Direct Load Control (DLC): Residential consumers in a direct load control program require a remote switch controllable by the utility to the power supplies of appliances, which in many instances is a two-way smart thermostat. Companies like Cooper Power Systems offer a load control receiver and Carrier offers a two-way smart thermostat.

Emergency DR: Consumers require an interval meter to provide a record if the consumer reduces load during a shortfall. Vendors that provide interval meters include Itron, Landis & Gyr, GE, Sensus, and Elster.

Capacity Market: In addition to requiring an interval meter, to account the load as system capacity, the consumer must also have a real-time communication channel that demonstrates the curtailment to the

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[49] DOE Smart Grid Report July 2009
[50] Cleantech Group, Assessment of DR Options for BPA (Global Energy Partners, LLC, The Brattle Group)

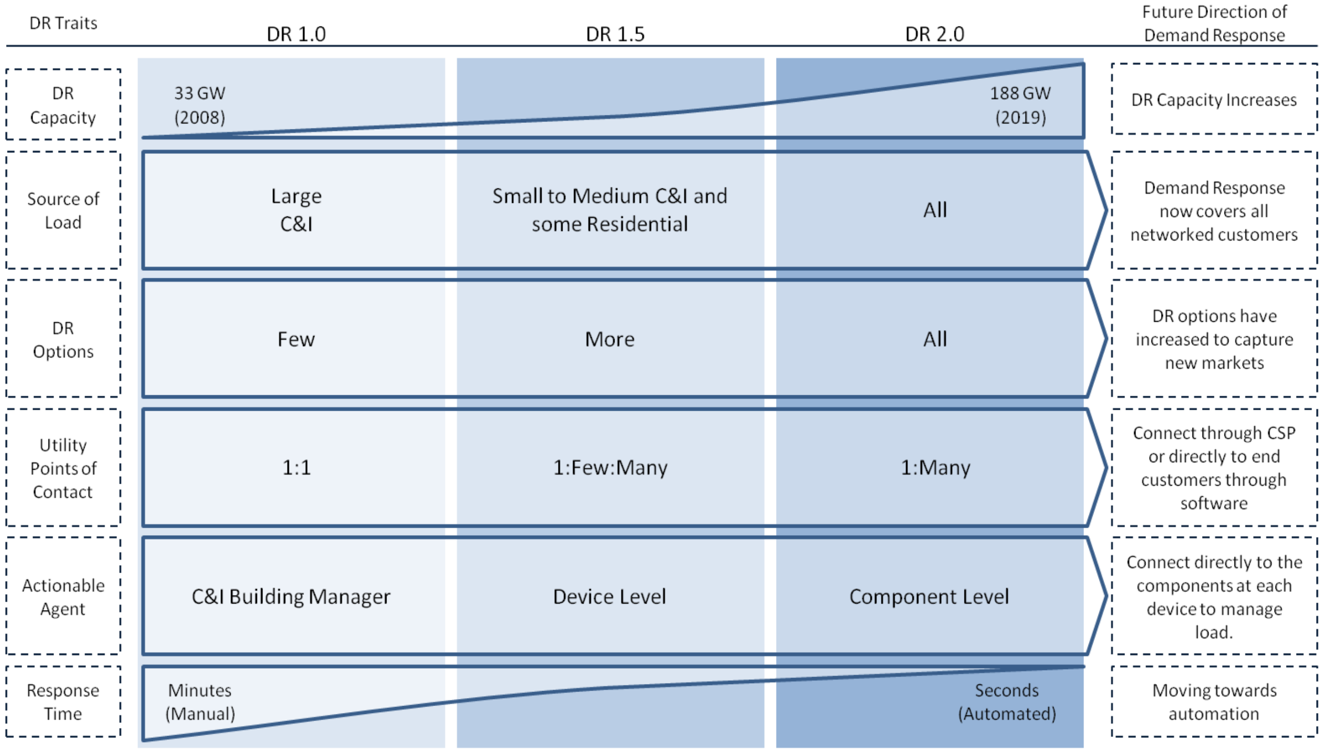
utility during the DR event. Consequently, new AMI communications vendors like Silver Spring Networks, Trilliant, and SmartSynch have emerged as enablers of this solution.

Real-Time Pricing (RTP) and Critical Peak Pricing (CPP): Some commercial and industrial customers are already affected by dynamic pricing in certain geographies. As a relatively new market for residential customers, an AMI Meter will be necessary for dynamic pricing. Residential customers will also likely require a Home Area Network (HAN) hub connected to the meter so they can manage their energy use in real time. With the development of automated DR (ADR) protocols, DR curtailments can be automatically triggered (whether by the utility or the end consumer) based upon specific DR events. HAN providers like Tendril Networks and Gridpoint give residential homeowners the tools to participate in these pricing schemes.

Demand Bidding / Buyback Programs and Ancillary Services: Commercial and industrial customers with significant loads require advanced metering and communication to participate. Companies like Viridity Energy are enablers of these demand response options.

Demand Response 2.0: The Convergence of Energy Management with Demand Response

With more DR options for the utility and/or ISO/RTO, the vendor landscape is trending towards more complexity in product offerings. The Cleantech Group has mapped out the evolution of DR through various change agents and where we see DR going, which we call Demand Response 2.0 or DR 2.0 (and beyond).



Source: Cleantech Group Estimates, FERC Assessment of Demand Response Potential June 2009

Overall, the general trend is that with more DR capacity, the response time to reliability or price driven events will decrease until it is almost instantaneous and automated. The following demand response traits have seen significant change in the evolution of DR:

Source of Load: CSPs brought DR out of large C&I customers to small and medium C&I customers until it finally reached residential loads.

DR Options: ISOs/RTOs and utilities have moved beyond the early DR options price and incentive-based options such as interruptible/curtailable DR. DR options such as ancillary services and critical peak pricing have higher customer touch, which requires new intelligence in customer engagement. In some geographies, the local utilities commission is mandating near real-time pricing transparency to customers by a certain date. The combination of increased DR options and increased response time has led to the development of Automated Demand Response (ADR) across multiple vendors. ADR programs will translate DR event information (from reliability to pricing signals) from the utility or ISO/RTO and automate a pre-programmed DR strategy across the interruptible and curtailable end-use devices such as the HVAC or lighting. Companies like EnerNOC (PowerTalk) and Echelon (i.LON SmartServer) offer ADR solutions into their respective customer bases.

California has had ADR programs since 2005, working with integration providers like Global Energy Partners, and now manages about 70MW of DR capacity.[51] In 2007, a pilot program with 81 PG&E service commercial and industrial accounts reduced approximately 22MW of demand, saving capacity and energy. A key takeaway from this ADR pilot was that the majority (67%) of the reduction came from industrial customers making adjustments in their process system. The remaining reductions came from HVAC in combination with lighting adjustments (18%) and HVAC adjustments alone (15%).

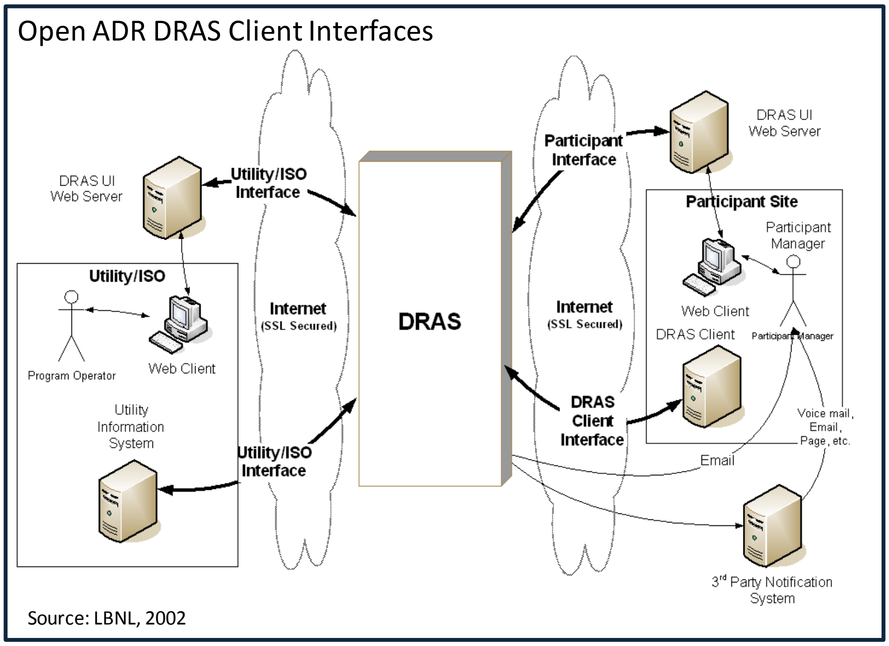
Traditional BMS companies are also actively looking at ADR as an entrant into the DR market. Honeywell recently acquired Akuacom, whose server technology is based on the Open Automated Demand Response (OpenADR) protocol, which is developed by the DR Research Center (DRRC) which is managed by Lawrence Berkeley National Laboratory (LBNL). OpenADR is intended to encourage the collaboration and adoption of a common standard and protocol for ADR. Companies like Tendril Networks have already adapted their service offerings to be compliant with OpenADR. Utility Integration Solutions (UISOL) is already working with LBNL to develop the OpenADR into an open source platform for real world applications.

Initially starting out as a research project borne out of the California energy crisis of 2002, the OpenADR data model now services multiple DR programs in California. The role of OpenADR is specifically outlined by the DRRC/LBNL[52]:

> The intention of the data model is to interact with building and industrial control systems that are pre-programmed to take action based on a DR signal, enabling a demand response event to be fully automated, with no manual intervention. The standard is a highly flexible infrastructure design to facilitate common information exchange between Utility/ISO and end-use participants. The concept of an open standard is intended to allow anyone to implement the signaling systems, providing the automation server or the automation clients.

In the OpenADR data model, a Demand Response Automation Server (DRAS) sits between the Utility/ISO interface and the Participant interface and interprets price and reliability messages from the Utility/ISO to the Participant and manages the consumption of energy at the Participant site according to parameters set by the Participant including load reduction end uses, exemptions, etc.

[51] http://eetd.lbl.gov/news-archives/news-honeywell.html
[52] DRRC LBNL Open Automated Demand Response Communication Standard Public Review Draft 2008-Revision 2



Other ADR standards being discussed include OpenSG, IEC TC57, NAESB, and EnerNOC's PowerTalk instant messaging protocol although it appears OpenADR is the leader in the space and is the only smart grid demand response protocol recognized by NIST in Release 1.0 of " Recognized Standards for Inclusion In the Smart Grid Interoperability Standards Framework."

Utility Point of Contact: Originally, utilities only had a few singular points of contact with large C&I customers in order to curtail a small amount of load. With the emergence of CSPs, the points of contact expanded slightly, but the CSPs aggregated a significantly larger amount of demand from many smaller customers that were logistically out of reach from the utility. In DR 2.0, utilities are reaching out to even more customers as more C&I customers and residential customers become logistically feasible through new vendors providing technical solutions.

One new way for utilities to gain visibility directly into customers is through a demand response management system (DRMS). CSPs such as EnerNOC and Comverge have their own in-house operations centers that leverage similar technology, but to-date they have primarily employed these tools for their own aggregation and benefit. The DRMS is a utility-facing system that provides a granular view into demand response loads.

These systems are still quite new and not widely deployed, but could hypothetically communicate directly to an end device such as a smart thermostat or load control receiver or could integrate on top of a meter data management system to provide specific DR analytics and controls. Comverge's Apollo , Lockheed Martin's SEEload, Cooper Power's Yukon, and UISOL's DRBizNet are the best current examples of this emerging product category. With DRMS, utilities may be able to better manage some DR programs without the need for a third party aggregator.

In addition to new models enabled by technology platforms such as DRMS, we also see new entrants emerging as potential utility points of contact. BMS players such as Johnson Controls, Honeywell, and Siemens may have less in-house capability for demand response, but they already own a central building control point for demand response applications and understand how to curtail loads at the premise as well as anyone in this value chain. It may be possible for BMS companies to roll up existing customers into a DR program.

EnergyHub Products

Source: EnergyHub

To round out the market, Home area network (HAN) start-up companies such as Tendril Networks and EnergyHub are beginning to provide residential customers energy usage intelligence and two-way communication, thus enabling demand response options as well. CSPs like Comverge had previously only targeted HVAC systems for demand response, particularly at the thermostat level. These new HAN companies are introducing new end points into residential DR, including smart outlets and in-home displays.

For many residential loads, simply deploying a customer energy engagement (CEE) program that provides visibility into energy usage can be enough to curtail significant peak demand. Companies like eMeter and OPower are passing CSPs and working directly with utilities in engaging the customer by showing them detailed energy consumption data and suggestions for conservation through an online platform. OPower estimates 1.5%-3.5% in average energy savings across their targeted residential base. While these programs are solely oriented around presenting data and analytics and are not operational in nature, they do open up a door for future use of these platforms as a DR channel.

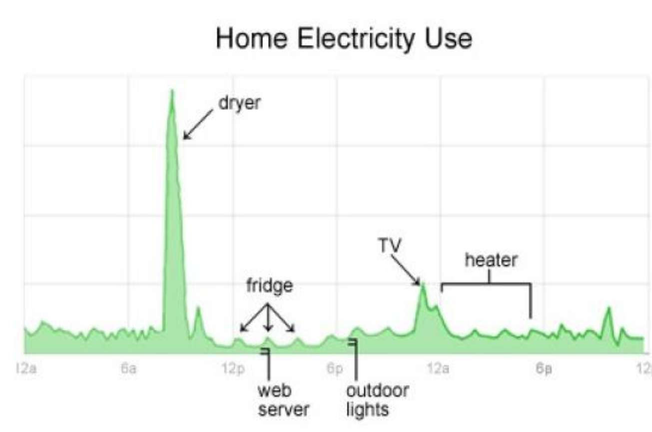
In these instances, the CEE may be separate from the supplier of the meter and the curtailment enabling device. In the PowerCents DC Program, Pepco DC sourced smart meters from Sensus, smart thermostats from Comverge, and utilized eMeter’s Energy Engage platform to educate customers on their energy use. CSPs are not sitting still however as these new entrants are moving into their space. EnerNOC recently acquired SmallFoot to target the small commercial DR market and Comverge introduced their in-home display in 2008.

Actionable Agent: In DR 1.0, when the utility recognized the grid was in distress, it had to make a phone call to someone on the premise side, like the C&I building manager, in order to shed load. With the emergence of CSPs in DR 1.5, CSPs provided a communication layer onto the curtailable process (often a load control receiver) or energy management intelligence for indirect demand response. These solutions greatly broadened the DR capacity as well as shortened the response time. Many of these solutions can be easily retrofitted into the existing built environment and industrial processes.

With DR 2.0, we are now seeing traditional equipment manufacturers develop intelligence directly into the component level of their appliances, which enable DR as well as other "smart grid" functions, such as frequency control. For the purposes of this study, the appliance/device (the terms are interchangeable) is hardware that an end customer can directly (or indirectly) interact with while a component is found in an appliance/device. The Gridwise project out of the Pacific Northwest National Labs (PNNL) is attempting to automate demand response applications at the component level with the Grid Friendly Appliance Controller[53]:

> "The Grid Friendly Appliance controller developed at PNNL senses grid conditions by monitoring the frequency of the system and provides automatic demand response in times of disruption. Within each of three vast interconnected areas of the North American power grid (East, West and Texas), a disturbance of the 60-Hz frequency is a universal indicator of serious imbalance between supply and demand that, if unarrested, leads to a blackout. This simple computer chip can be installed in household appliances and turn them off for a few minutes or even a few seconds to allow the grid to stabilize. The controllers can be programmed to autonomously react in fractions of a second when a disturbance is detected, whereas power plants take minutes to come up to speed. They can even be programmed to delay restart instead of all coming on at once after a power outage to ease power restoration."

With the introduction of demand response and energy management at the component level, appliances can automatically sense a grid disturbance and shut off/cycle restarts at different times, thereby shedding load when necessary to avoid a blackout or brownout and possibly maintaining the health of grid assets like transmission lines and substations. While not significant at each individual device, if the component found within a household appliance like a dryer can be aggregated, the amount of load can be staggering, as seen on the chart to the right.



Source: Secretary Steven Chu, "Investing in our Energy Future," DOE

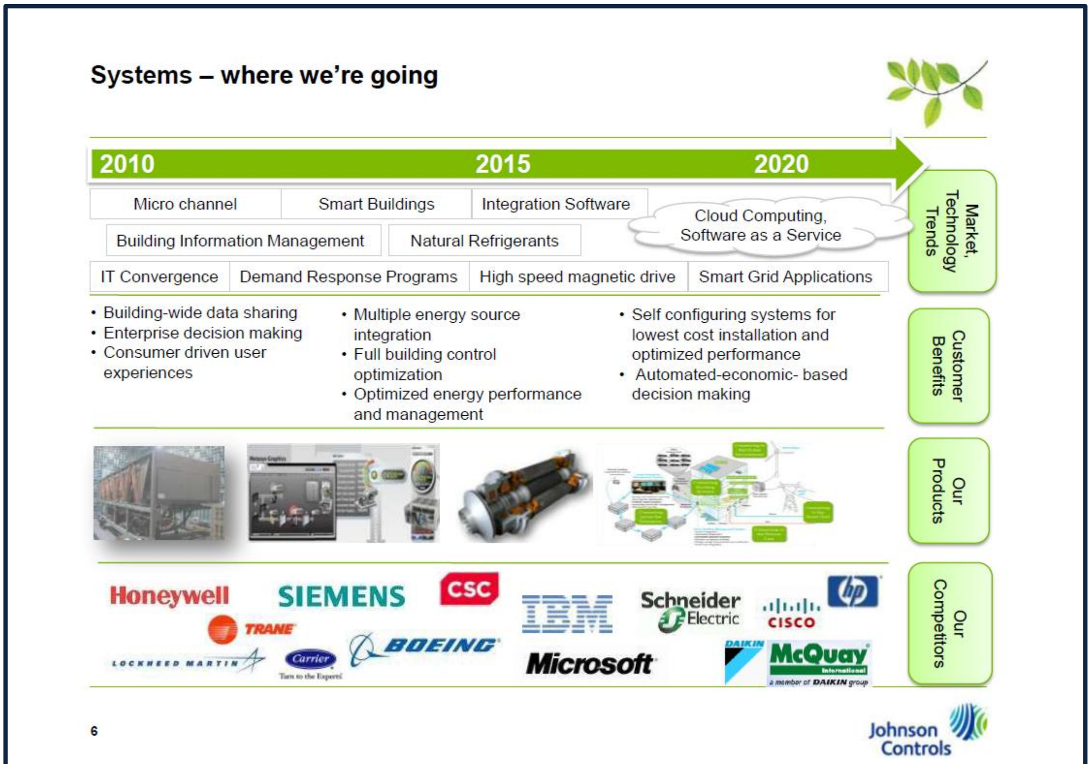
[53] http://gridwise.pnl.gov/technologies/transactive_controls.stm

"White goods" appliance makers like GE and Whirlpool have already developed pilot smart appliances that place demand response capabilities into the device itself. Whirlpool's smart dryer was recently introduced at the 2010 International Builders' Show and the Company has committed to produce 1 million smart appliances by the end of 2011. GE is aggressively moving into the smart appliance market, having already developed a smart water heater for a Kentucky pilot in 2009.

The Vertical Integration of Demand Response

As DR has evolved from 1.0 to 2.0, new entrants have come into the demand response ecosystem, enabling new services with advanced technologies or fulfilling a niche that was largely ignored by the original vendors. For the utilities, this provides many new demand response options across a wider variety of vendors. For some end customers, utilities, and ISOs/RTOs, this is viewed positively as this creates pricing competition among the different vendors at each leg of the demand response value chain, such as in the PowerCents DC program. Other customers prefer a single-sourced vendor to provide a comprehensive and robust demand response program.

Johnson Controls, for example, is layering smart grid applications, including demand response, onto a wide product suite of building and industrial controls and sensors. In a case study with Saint Clare's Health System in New Jersey, JCI estimates that through a 15-year performance contract, operations and maintenance agreement, and a service agreement, Saint Clare's will recognize energy and operational savings of more than $17 million. A major component of the arrangement with Saint Clare's was the upgrade of various JCI HVAC and energy management appliances, such as air handling systems and lighting retrofits, as well as the implementation of JCI's BMS, Metasys. Through these upgrades and systems, JCI can centralize a customer's energy management needs and can potentially manage demand response programs. We see this trend continuing amongst all the major BMS vendors, including Schneider Electric, Honeywell, and Siemens.



Source: Johnson Controls, 2010 "Building Efficiency Technology Overview"

The pace of mergers and acquisitions (M&A) in the demand response ecosystem has also increased as many once "pure-play" shops look to widen their breadth of products and services. One can look at EnerNOC's recent acquisition history as an example of a traditional CSP looking to expand beyond demand response.

EnerNOC Acquisition History

Date of Acquisition	Acquisition	Acquired Product/Service
March 2010	SmallFoot	Wireless demand control for small commercial buildings
December 2009	Cogent Energy	Monitoring-Based Commissioning (MCBx) services
June 2009	eQuilibrium Solutions	Enterprise carbon management and energy efficiency SaaS
September 2007	MDEnergy	Energy procurement service and ancillary services

Source: Company Press Releases

The general trend we are seeing is a vertical integration of the demand response value chain. Vendors are recognizing value in owning the customer at the device level and layering on top additional services beyond demand response.

Conclusion: What is Demand Response 3.0?

FERC Chairman Jon Wellinghoff may be correct in that Demand Response is the killer application of the Smart Grid. No other product or service from the Smart Grid has been as well received by the retail customer while providing immediate economic value to utilities and ISO/RTOs. In addition, it is worth noting that it is the only pure-play smart grid application category that has successfully raised public capital, namely the initial public offerings of venture-backed Comverge (NASDAQ: COMV) and EnerNOC (NASDAQ: ENOC).

As we are seeing from the trend of M&A in the space towards vertical integration, demand response may be opening the door to numerous Smart Grid applications. The increasing adoption of DR in the commercial, industrial, and residential markets will introduce more “smart” devices and increased market acceptance of dynamic pricing and energy management services. By introducing these devices and concepts into the market, DR will be a key driver for adoption of smart grid technologies. Given its importance, it is entirely possible that that Demand Response 3.0 may be better known as Smart Grid 2.0 when the market evolution is complete.

IV. Distribution Grid Management

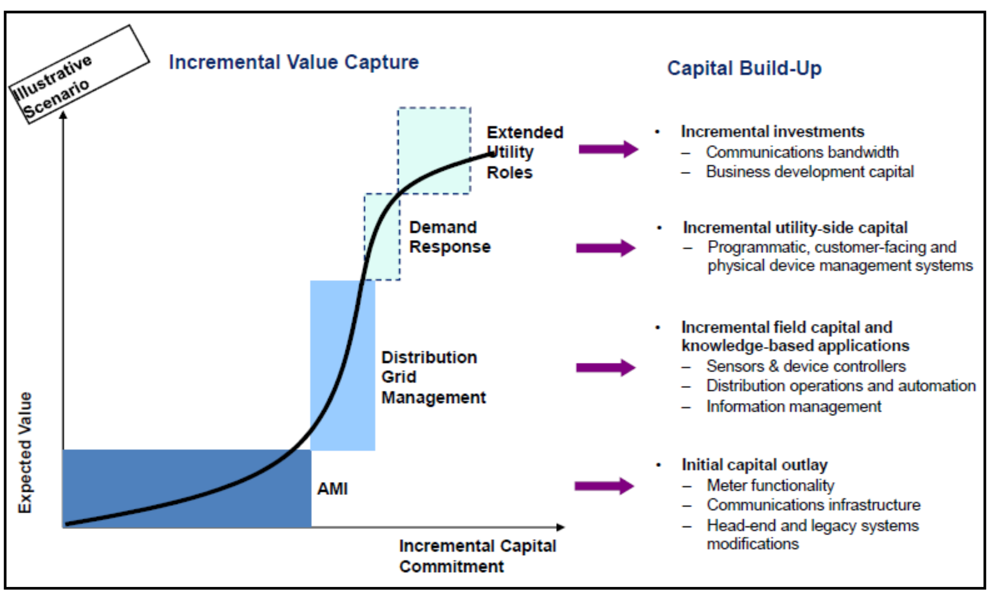
Key Takeaways

- Innovation in the distribution system is being driven primarily by legacy, power systems vendors developing equipment and applications that improve efficiency, performance, and control of the distribution system.
- Key distribution system improvements include feeder and substation automation, and distribution management systems (DMS) installed to control and optimize applications.
- We believe there is a $1.4B U.S. market in 2010 for distribution system products that directly enable more intelligent grid management. The market for all power systems elements is even larger.

Key Vendors

GE	Siemens	Telvent
ABB	Thomas & Betts	ACS/EFACEC
Cooper Power Systems	NovaTech	OSI
S&C Electric	G&W Electric	RuggedCom
Schweitzer Engineering	Beckwith Electric	Cisco
Schneider Electric	Subnet Solutions	Motorola

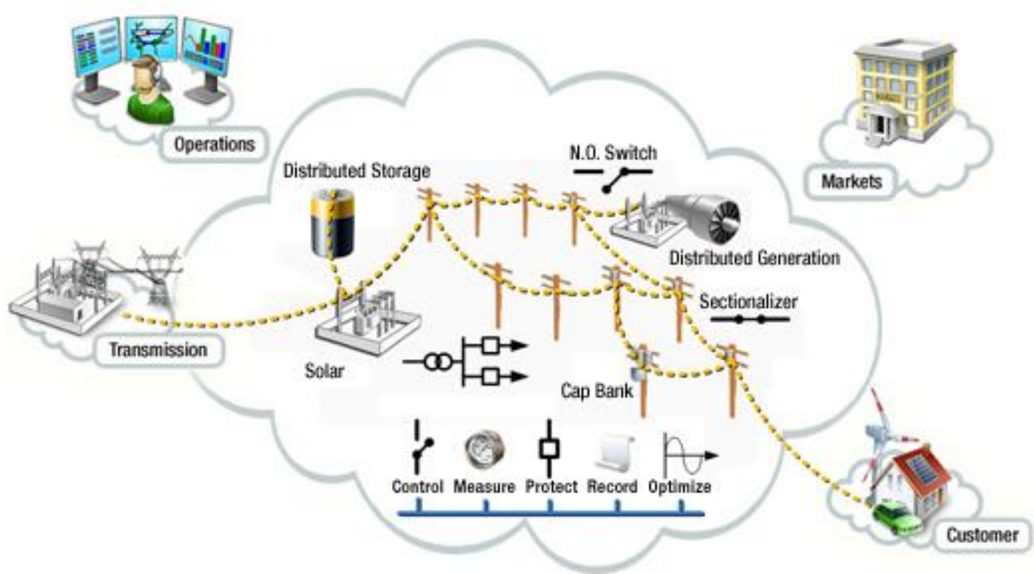
While smart metering and communications have captured much attention and venture finance, there is a vast opportunity for adding intelligence to the network of more than 100,000 substations and millions of miles of electrical line that make up the country's electricity distribution system. Smart meters and home energy management systems may be easier to grasp and may appear more tangible than distribution system concepts such as Volt/VAR control and feeder automation, but improvements in core distribution technology can have tremendous impacts on efficiency.



Source: Doug Houseman, Enernex, Connectivity Week 2010 Presentation

In fact, for all of the benefits of AMI installations, some analysts believe better distribution grid management will represent an even greater expected value with less required incremental capital.

For purposes of this report, we will use Distribution Grid Management (DGM) as an umbrella term to refer to communication and data-enabled improvements across all elements of the electrical distribution system. This term encompasses substation upgrades (commonly referred to as "substation automation") where an increasing amount of monitoring and control is being enabled by intelligent electronic devices (IEDs) and faster data networks; as well as a range of equipment and applications being deployed outside of the substation fence along distribution and feeder lines (commonly referred to as "feeder automation" or "distribution automation").

<table>
<tr><th colspan="4">Distribution Grid Management: Major Applications</th></tr>
<tr><td>"Substation Automation"</td><td colspan="3">"Distribution Automation"</td></tr>
<tr><td>Equipment Monitoring, Load Balancing, and Optimization</td><td>Volt/VAR Control</td><td>Fault Detection, Isolation, and Recovery</td><td>Feeder Monitoring, Maintenance, & Load Balancing</td></tr>
<tr><th colspan="4">Distribution Grid Management: Conceptual Diagram and Components</th></tr>
<tr><td colspan="4">


Visual Source: NIST Smart Grid Conceptual Model
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The benefits of DGM have not been lost on utility executives who have made distribution and substation automation investments a top priority. As we saw in our earlier analysis of major utility projects, distribution automation ranks behind metering as the second largest source of project expenditures. Further, a significant number of recently funded SGIG grants have flowed to utilities seeking to implement more advanced DGM functionality:

Area of Focus: Top U.S. Utility Projects

Advanced Metering	62%
Distribution Automation and Monitoring	**31%**
Communication Projects to Support AMI & **DA**	**20%**
Renewables Facilitation	20%

Source: Newton-Evans Research, Sample of 160 projects

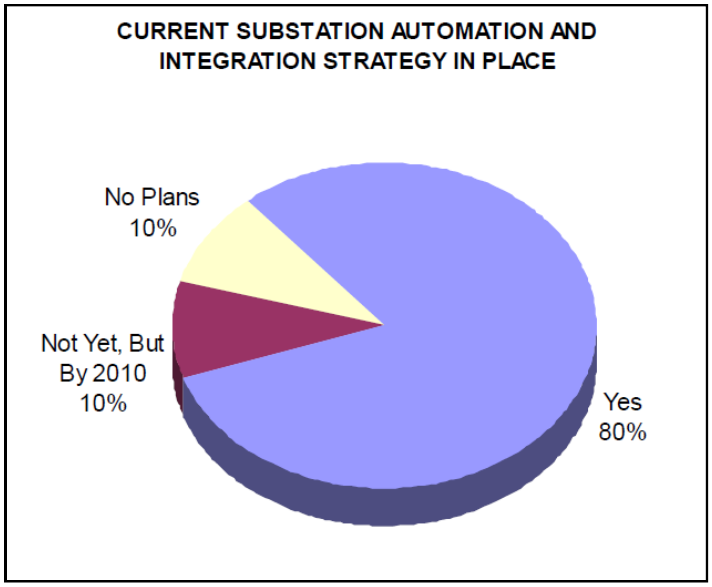
Major SGIG Grants Linked To Distribution Grid Management

Project	Stimulus Award	Project
Florida Power & Light	$ 200,000,000	Substation automation, IEDs, communications
PECO Energy	$ 200,000,000	Substation automation
NV Energy	$ 138,000,000	Distribution automation
Con Edison New York	$ 136,170,899	Distribution/Substation Automation
Avista	$ 20,000,000	DMS implementation, Outage mgmt
PPL Electric Utilities	$ 19,054,516	DMS implementation
Atlantic City Electric Co.	$ 18,700,000	Automation, monitoring, and load balancing
Snohomish Country PUD	$ 15,825,817	Substation automation, communications

Source: DOE, Cleantech Group Analysis

Much as there had been a “Version 1.0” of meter communication (i.e. first generation AMR read by drive-by RF systems), monitoring and automation in the distribution system is not an entirely new phenomenon. Utilities have long been deploying remote terminal units (RTUs) in substations for basic connectivity and monitoring. Many of these first generation RTUs were deemed “dumb RTUs” as they facilitated only basic monitoring and were not integrated with IED’s or digital controllers within the substation. Nonetheless, a 2008 study by Newton-Evans research indicated that 90% of utilities had deployed some form of substation automation or had a strategy in place to implement one by this year.

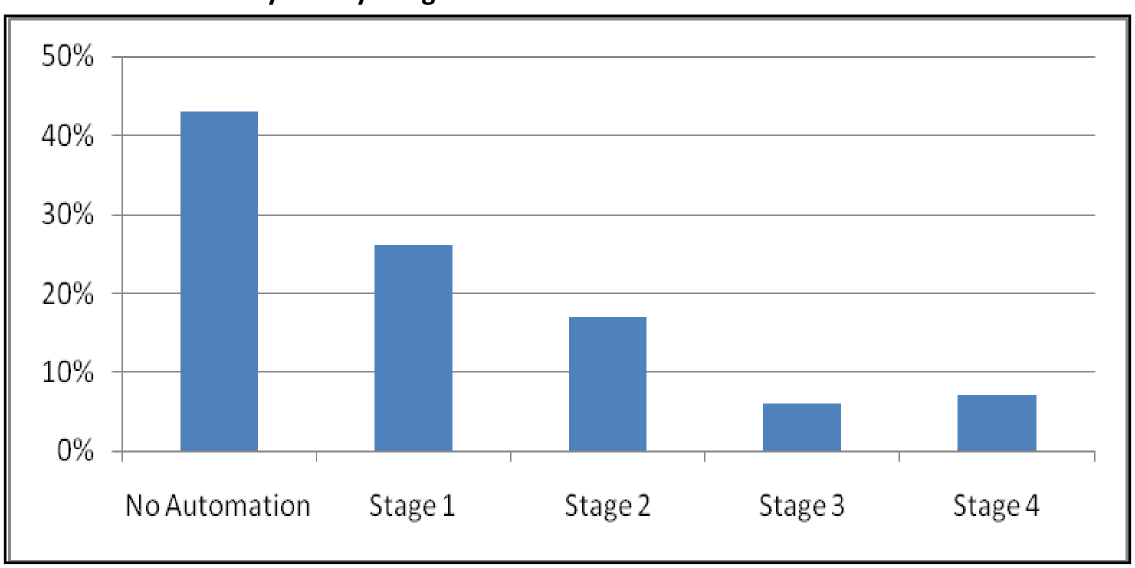
Utility Survey: Substation Automation



Source: Newton Evans, 2008 Substation Automation Survey

This figure is slightly skewed by more widespread deployment of automation into transmission substations. Deployment into distribution substations has slightly lagged this figure, with the same report indicating that only 56% of distribution substations were reporting automation at even the most basic level. Unlike the advanced metering world where we can build a binary sense of "deployed" or "not deployed," the rollout of DGM is an iterative, continual process that continues to be calibrated and improved with multiple potential stages of adoption. For example, the 56% of distribution substations with some form of automation are spread amongst a variety of increasingly sophisticated stages of adoption:

Utility Survey: Stage of Distribution Substation Automation



Source: Newton Evans, 2008 Substation Automation Survey

Beyond the substation, there is a significant opportunity for more thorough penetration of distribution automation throughout the grid. A more recent Newton-Evans study from early in 2010 indicates meaningful traction in distribution automation projects with large investor-owned utilities leading the way; between 10-20% of utilities will be conducting or completing work in 2010 on some form of distribution automation.

Utility Survey: Distribution Automation Plans

Table 1. Percent of Utilities with DA Projects Underway or Completed: 2010-2014

Type of Utility	2010	2011	2012	2013	2014
Investor-Owned-TOP 50	20%	24%	30%	35%	40%
Investor-Owned – Other 150	20%	26%	33%	40%	45%
Public Power Large – TOP 25	15%	15%	20%	20%	22%
Public Power –Other 1000	15%	15%	15%	18%	19%
Cooperatives-Large TOP 25	25%	27%	30%	32%	35%
Cooperatives – Other 900	10%	11%	14%	16%	18%

Prepared by Newton-Evans Research Company March-2010

While most utilities have established basic connectivity with substations and some are pursuing distribution automation projects, the percentage of utilities pursuing projects does not tell the full story of a market in continual evolution. We will focus our attention more on the yearly spend on DGM and the vendors that are the beneficiaries of this spending. There is a great amount of technical research into the benefits of DGM applications such as Volt/VAR control; consequently our goal is not reiterate these benefits or to analyze technical merits, but rather to inventory the vendors that inhabit the market for supplying the hardware and software that make these applications possible.

Framing the DGM vendor landscape is a bit different from our analysis of the metering or demand response markets. Both of the metering and DR markets are generally focused on the addition of new equipment to the grid or the wholesale replacement of older technologies. Most new AMI activity requires new meters[54], a new communication network, and a new meter data management system. Similarly, demand response markets are generally dependent on new programmable thermostats, energy management systems, and utility-side software.

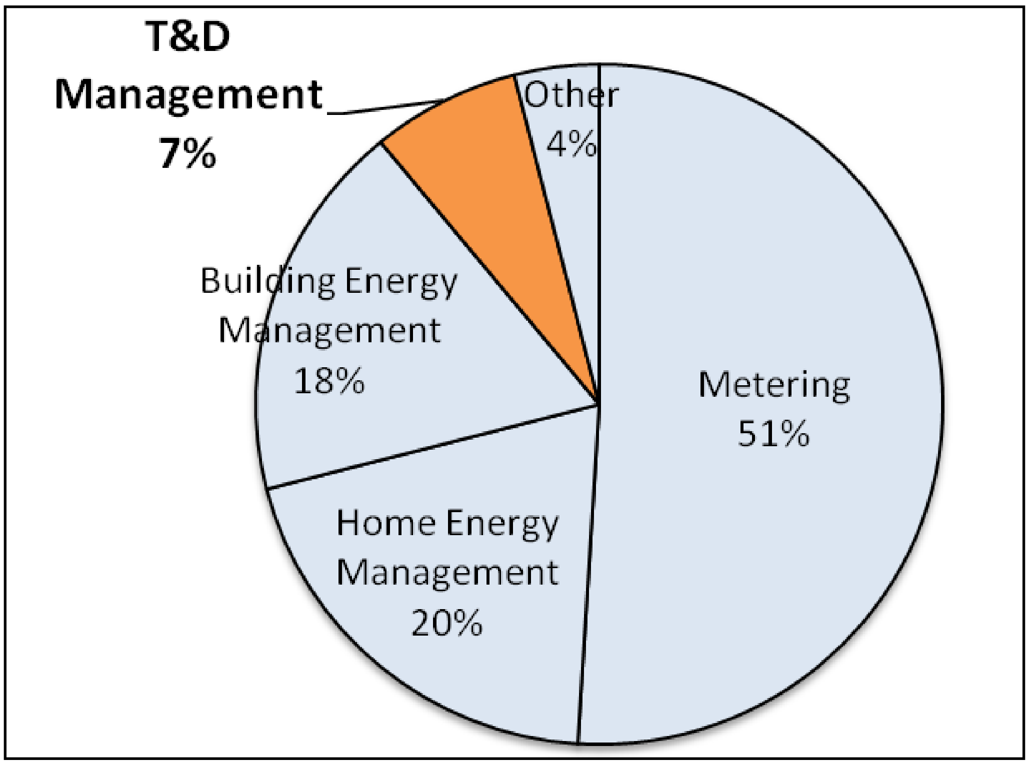
The DGM market is different. To use a well-worn business expression, the DGM market is a bit like "building an airplane in flight." The distribution system consists of tens of thousands of substations connecting to millions of distribution transformers and field devices. While there is a normal

[54] There are attempts to make use of older, drive-by RF meters as elements of upgraded smarter deployments by using RF to transmit to an internet-connected device in the home or business.

replacement cycle for many of the underlying power systems elements that make up the distribution grid, many DGM applications are built on the premise of adding intelligence to installed field equipment in order to more effectively monitor, maintain, and optimize performance. From installing IEDs (intelligent electronic devices) on transformers and retrofitting reclosers with digital controllers, to upgrading substation communication platforms, investments in the distribution system must be careful and methodical to not disrupt live, mission critical grid elements.

Another aspect of the DGM market that is quite different from the metering and demand response world is the relative paucity of new entrants and venture-backed companies.

Smart Grid Venture Capital: 2007-2010



Source: Cleantech Group Venture Data

Only 7% of venture finance dollars that have flowed to smart grid companies since 2007 has been allocated to firms working on applications for the distribution or transmission portion of the grid. Even this 7%, which accounts for $113M, is misleading as it has gone primarily to two firms, Current Group and BPL Global.[55]

Most, if not all, of the companies involved in advanced technology for the distribution system, are the same companies developing legacy grid equipment. Many of these are global, diversified industrial

[55] Current Group also raised $130M in 2006 which is not included in this timeframe

firms such as ABB, GE, Cooper Power Systems, and Schneider Electric, but a significant number are domestic power systems suppliers such as S&C Electric, Schweitzer Engineering Laboratories (SEL), Beckwith Electric, and NovaTech, all of which have been in the business of keeping the grid running decades before "smart grid" became an attractive, well-publicized growth industry.

Parsing out components of DGM that should be classified as "smart grid" may be a semantic exercise, but it is critical in order to assess incremental investment in the distribution system. Across the industry there are varying methodologies for what is counted in spending figures for distribution automation. Some executives and analysts choose to lump some, or all, of the underlying distribution hardware elements (reclosers, sectionalizers, capacitor banks, transformers, circuit breakers, etc.) into a distribution and substation automation number. Others attempt to segment only equipment with embedded intelligence or the related digital controllers.

	Distribution Automation	Substation Automation
Software Management & Control Systems	Distribution Mgmt System (DMS) & SCADA/DMS • Telvent • ABB • OSI • ACS • Siemens • Survalent	
Communication	DA Networking Equipment • GE • Landis+Gyr • Silver Spring • Sensus • Arcadian Networks • Trilliant • Itron	Substation Routing & Switching • RuggedCom • GarrettCom • GE • Hirschmann • Cisco • Motorola • Alcatel-Lucent
Automation Platforms & Controllers	Digital Controllers, Pole Top RTU, • SEL • Cooper • Schneider Electric • Telemetric • Thomas & Betts • GE • ABB • S&C • NovaTech	RTUs/IEDs & Substation Platforms • GE • Telvent • ACS • Siemens • DAQ • Schneider Electric • Rockwell • Cooper • Novatech • Subnet Solutions
Field Equipment *(with embedded intelligence)*	Reclosers, Sectionalizers, Cap Banks, etc. • GE • ABB • Cooper • S&C Electric • Siemens • Howard • Vishay • Beckwith • SEL • Qualitrol	Transformers, Circuit Breakers, Switchgear, etc. • ABB • GE • S&C Electric • Siemens • ADD

Source: Cleantech Group Analysis

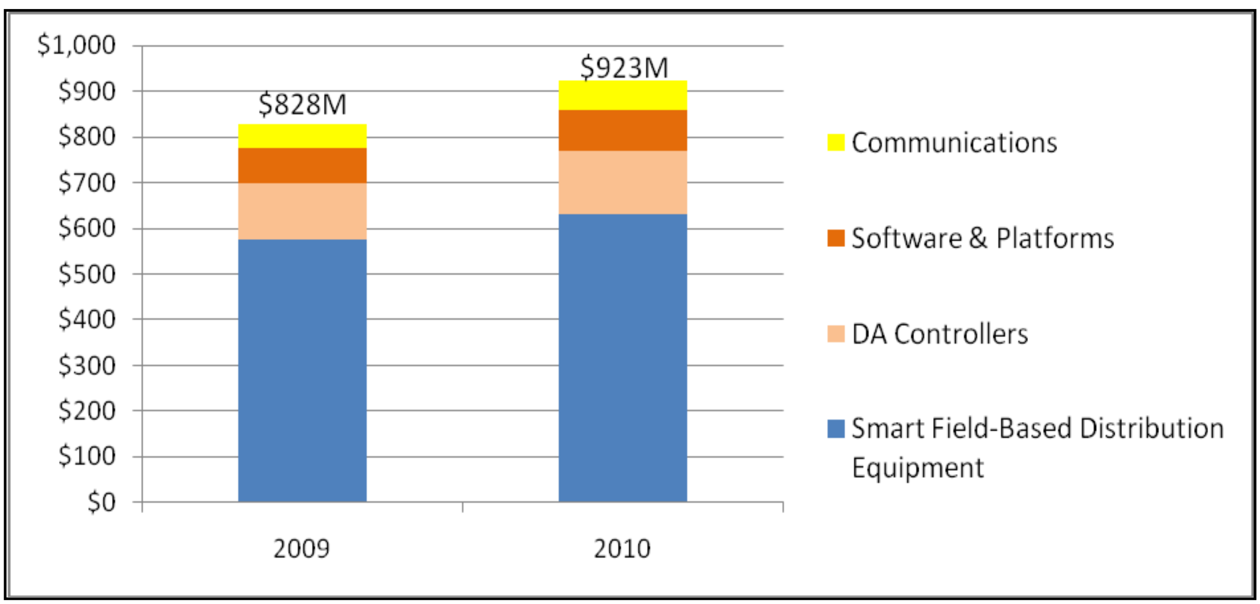
Clearly there is not a single perfect approach to this market. We will break the market down into three key pieces: (1) distribution automation (or feeder automation), (2) substation automation, and (3) distribution management systems (the software layer that provides control for both 1 & 2). Much of the following market sizing analysis and our thinking about vendors in this sector relies on data and input from Newton-Evans research, a firm that has distinguished itself for its leading work on distribution and substation equipment markets.

Distribution Automation

We will first address the market for distribution automation. This market primarily revolves around the deployment of intelligent devices along distribution and feeder lines in order to facilitate one of three major application categories: (1) Volt/VAR control, (2) Fault Detection, Isolation, and Recovery (FDIR), and (3) Monitoring for load balancing and proactive maintenance. Each of these applications generally requires: (1) a controllable field device (either a field device fitted with a digital controller or a field device with embedded intelligence), (2) a communications unit, and (3) a software management layer to monitor and, when required, intervene in decision making and configuration. The exception is equipment designed to embed programmable intelligence within the field, negating the need for communication back to a central control center and allowing for actions to be taken within seconds, or even microseconds, of an event or fault. For example, S&C Electric's pulse-reclosers act as a network of self-aware nodes and provide FDIR functionality without central processing.[56]

We estimate that the total 2010 U.S. market for distribution automation equipment is likely to be near $1.0B. Newton-Evans Research published a January study on the DA market that estimated 2009 DA spending at $828M with the majority of this spending in the smart field-device market.

U.S. Electric Utility Investment in Distribution Automation



Source: Newton Evans, March 2010 Distribution Automation Market Trends

[56] http://www.sandc.com/products/intellirupter/default.asp

The following equipment markets accounts for the bulk of both the smart field-based equipment market and DA controller market:

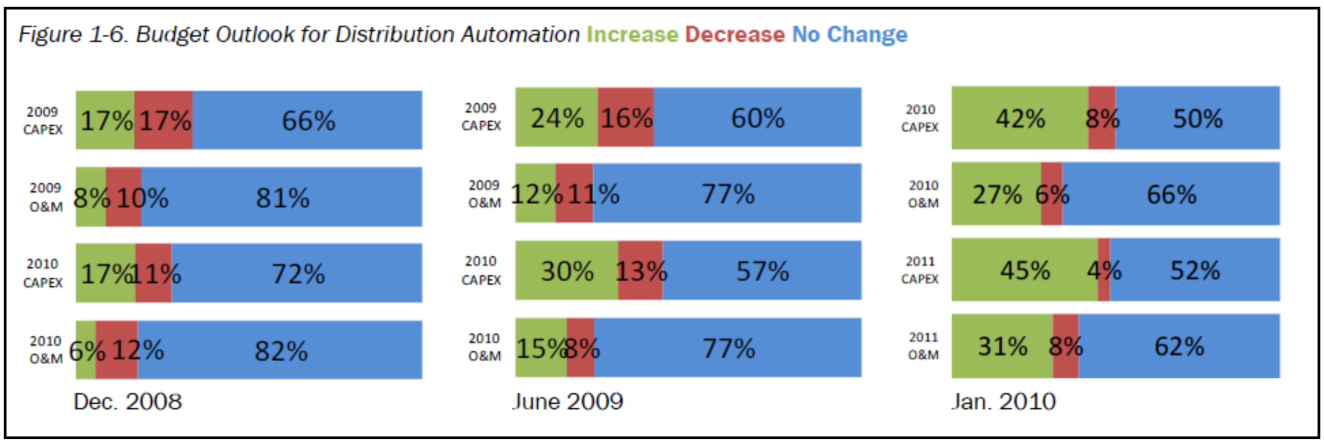
Distribution Automation Hardware

Smart Field Apparatus *(classified as smart field-devices)*	• Overhead Switches • Sectionalizers • Reclosers
Other Field Devices/Controllers/Sensors *(classified as either smart field-devices or DA controllers)*	• Capacitor Bank Controllers • Fault Indicators • Pole Top/Pad Mount RTUs • Voltage Regulators • Line Sensors

Source: Newton-Evans Research, Cleantech Group Analysis

Newton-Evans also confirmed through recent survey work that budgets for DA appear to be either growing or, at minimum, remaining constant:

Utility Capex Survey



Source: Newton-Evans Research, Utility Capex Study, January 2010

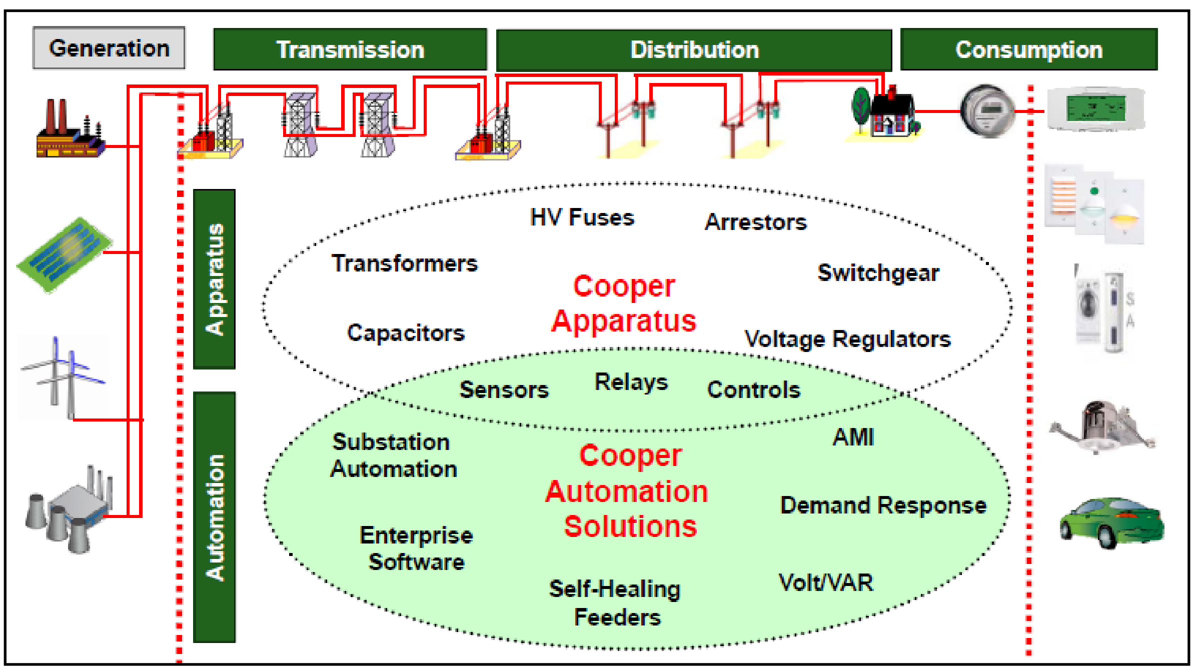
It should be noted that there continue to be large markets for distribution equipment that is not classified in our category of DGM. For example, the distribution transformer business continues to be a multi-billion dollar business in the U.S., but is not a smart grid category.

In addition to looking at this $1.0B in distribution automation spending from the perspective of equipment, one can also analyze it from the perspective of applications. We would estimate that investment is split nearly evenly across Volt/VAR control, FDIR, and more general grid monitoring, resulting in a market for each of $300-$350M.

Accurately parsing out the vendor landscape in this market also presents some unique analytical challenges. Because every vendor is building its own picture of what is considered “smart” vs. legacy power apparatus, there can be conflicting information as to the size of businesses in this space. The leading vendors in this space also tend to be either large, diversified industrial manufacturers (ABB, GE, Siemens) who are, understandably, careful about public reporting of revenue data and present numbers only at a business unit level; or large, private firms (S&C Electric, Schweitzer Engineering Laboratories) who need not present detailed, public reporting. Some estimates may overinflate the magnitude of a “smart” offering by accounting for much of the underlying power systems equipment. There is nothing inherently wrong with any specific vendor categorization, but each simply places a different lens on the market which makes market share comparisons difficult.

However, some vendors are offering public breakdowns of legacy vs. smart businesses in clear terms. For example, Cooper Industries breaks down its Power Systems business ($1.1B in total 2009 revenue) into a legacy business and a new Energy Automation Solutions (EAS) business which houses its smart grid offerings ($200M in 2009 revenue). The following chart, produced by Cooper, presents a clear picture, of the split between legacy apparatus and an intelligent, automated control layer. The Cooper EAS business is growing rapidly and making notable acquisitions (e.g. Eka Systems, an AMI communications vendor, in March of 2010), yet it is still a fraction of the Cooper Power Systems portfolio. This picture is consistent with the thinking that has gone into our breakdown of the DGM market. This split is not unique to Cooper and we posit that the other diversified vendors in this space are seeing 10-20% of legacy power systems spend directed toward new, smart solutions.

Cooper Power Systems Product Portfolio



Source: Cooper Industries

Rather than making a specific market share calculation for DA spending, which could vary depending on what is “in” or “out” of the calculation, we have chosen to segment vendors based on our estimate of the relative size of the businesses competing in this space. We break the market down into two categories of vendors. One category is “integrated vendors” who have broad product suites that address most aspects of a full DA solution and consequently produce larger revenues in the sector. The other category is equipment specific vendors, who have built defensible positions in specific equipment categories (i.e. reclosers or OH switches, etc.). Given the size and acquisitive nature of many of the firms in the DA market, it is likely that further consolidation will occur.

Distribution Automation (Equipment and Controllers): Vendor Breakdown	
Integrated Vendors (likely $50-$100M+ in U.S. DA revenue)	• ABB • GE • Cooper Power Systems • Siemens • S&C Electric
Equipment Specific Vendors (likely $5-$50M in U.S. DA revenue)	• SEL • Schneider Electric • Chance/Hubbell • Thomas & Betts • G&W • ACS/EFACEC • NovaTech

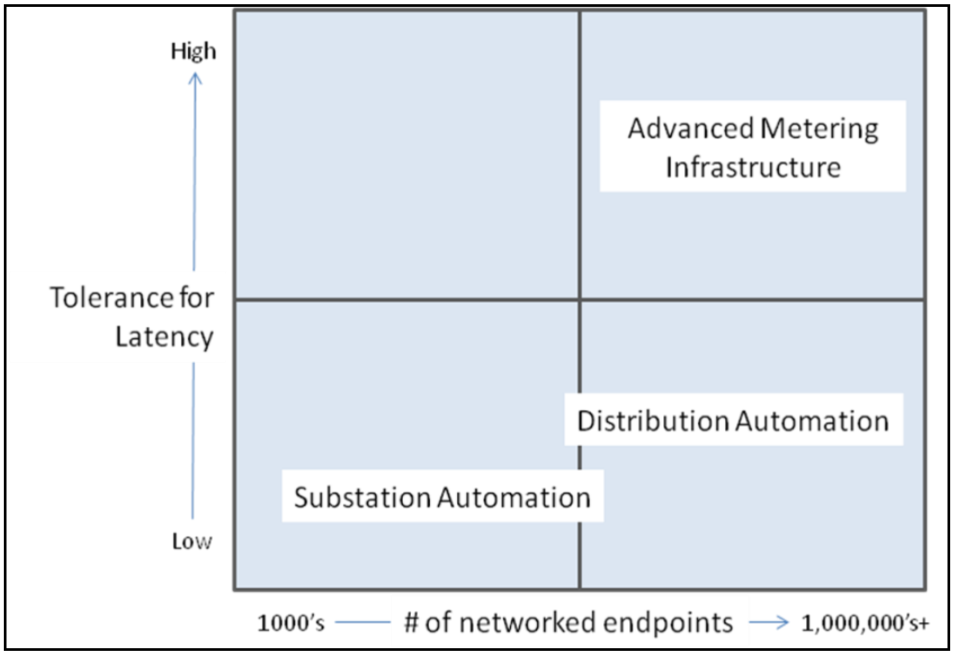
Source: Cleantech Group Analysis

Company	**Headquarters**	**Employees**	**Revenue**
ABB	Zurich, Switzerland	10,000+	$1B-$10B+
GE	Fairfield, CT	10,000+	$1B-$10B+
Cooper	Waukesha,WI	10,000+	$1B-$10B+
Siemens	Munich, Germany	10,000+	$1B-$10B+
S&C Electric	Chicago, IL	1,501-3,000	$100M-$500M
SEL	Pullman, WA	1,501-3,000	$100M-$500M
Schneider Electric	Rueil Malmaison, France	10,000+	$1B-$10B+
Chance/Hubbell	Centralia, MO	10,000+	$1B-$10B+
Thomas & Betts	Memphis, TN	3,000-10,000	$1B-$10B+
G&W Electric	Blue Island, IL	501-1,500	$100M-$500M
ACS/EFACEC	Norcross, GA	3,000-10,000	$1B-$10B+

Source: Cleantech Group Analysis

Distribution automation relies on new communication channels to relay data and commands to a growing number of intelligent devices deployed in the distribution network. Unlike substation automation, which has a limited number of endpoints (bounded by the number of substations), distribution automation has a rapidly growing number of endpoints. Network latency is also a significant challenge given the operational nature of distribution automation commands, and rapid, secure communication is critical.

Smart Grid Communication Requirements



Source: Cleantech Group Analysis

Historically, utilities have relied on a tapestry of networking technologies to communicate to field devices. Recent studies indicate fiber and RF (both licensed and unlicensed) have been the primary means for facilitating distribution automation.[57] Increasingly, utilities are attempting to leverage investments in AMI communications platforms as a backbone for distribution automation. There is healthy debate in the industry if these networks will be capable of serving dual purposes.

Nonetheless, the landscape of communication vendors for distribution automation increasingly mirrors the competition taking place in the AMI world with Silver Spring Networks, Trilliant, and other communication-centric players in the market along with legacy vendors such as GE, Landis+Gyr, Itron, Elster, and Sensus. Just as communication vendors are eager to demonstrate integration in the meter market by pursuing partnerships with a wide variety of vendors, these same communication players are moving to secure partnerships with legacy power systems manufacturers such as ABB and Cooper Power Systems.

The overlap with AMI deployments makes it difficult to parse out communication spending specific to DA, but we concur with earlier Newton-Evans estimates of $50-$100M in DA-related communication equipment purchases in 2010.

[57] Newton-Evans Research

Substation Automation
As the data earlier in this chapter highlighted, basic substation automation has achieved a significant rate of penetration – upwards of 50% of distribution substations have some form of connectivity. The majority of these networked substations remain at a fairly simple state of integration with an RTU communicating back to a central control system facilitating some forms of simple equipment control. Fewer substations are taking full advantage of networking all of the IEDs on the substation premise back through a substation platform (and/or RTU) to feed operational data back to the control center. However, this is changing and consequently the market for substation automation is continuing to grow. In addition, the growth in distribution automation is resulting in an increasing amount of data from the feeder system that needs to be concentrated and backhauled to the control center. Therefore, the substation is becoming a central network point and a focus for data aggregation.

Much as we saw in the market for distribution automation equipment, there is a large installed base of substation equipment - transformers, circuit breakers, and switches - not typically counted as part of market sizing exercises that try to focus on only the "intelligent" substation automation market. The automation market is more typically associated with a variety of instruments, controls, and monitoring equipment that collectively work to ensure the stable flow of electricity into and out of the distribution substation.

In our assessment of the substation market, we see three distinct layers of vendors:

Equipment Categories	**Specific Equipment Categories**	**Major Vendors**
Substation Communications	• Routers • Switches	• RuggedCom • GarrettCom • GE • Cisco
Substation Platforms	• RTUs • Gateways • Hardened Computers	• GE • Telvent • EFACEC/ACS • Siemens • DAQ • Cooper Power Systems • Novatech • Subnet Solutions • SEL
Substation IEDs	• PLCs (Programmable Logic Controllers) • Multi-function meters/recorders • Digital Fault Recorders • Sequence of Event Recorders • Power Quality Recorders	• Rockwell • Eaton • Schneider Electric • GE • ABB • Siemens Qualitrol

Source: Newton-Evans, Cleantech Group Analysis

The first layer of vendors are manufacturers of various IEDs that monitor and control specific pieces of substation equipment. In a well-integrated substation, these IEDs network into a second layer of vendor equipment that provides central processing and integration. A third layer of equipment is responsible for the communications layer of the converged datastream. Depending on how sophisticated the implementation is, this second and third layer can sometimes both be performed by a single piece of equipment.

We believe that the 2010 U.S. market for substation automation and communication equipment should near $400M. To reiterate, this does not account for underlying substation power equipment, nor does it include standard protective relays that are in widespread use in substations. The relay market itself is likely to be on a similar order of magnitude. This is relatively consistent with previous projections made by Newton-Evans research:

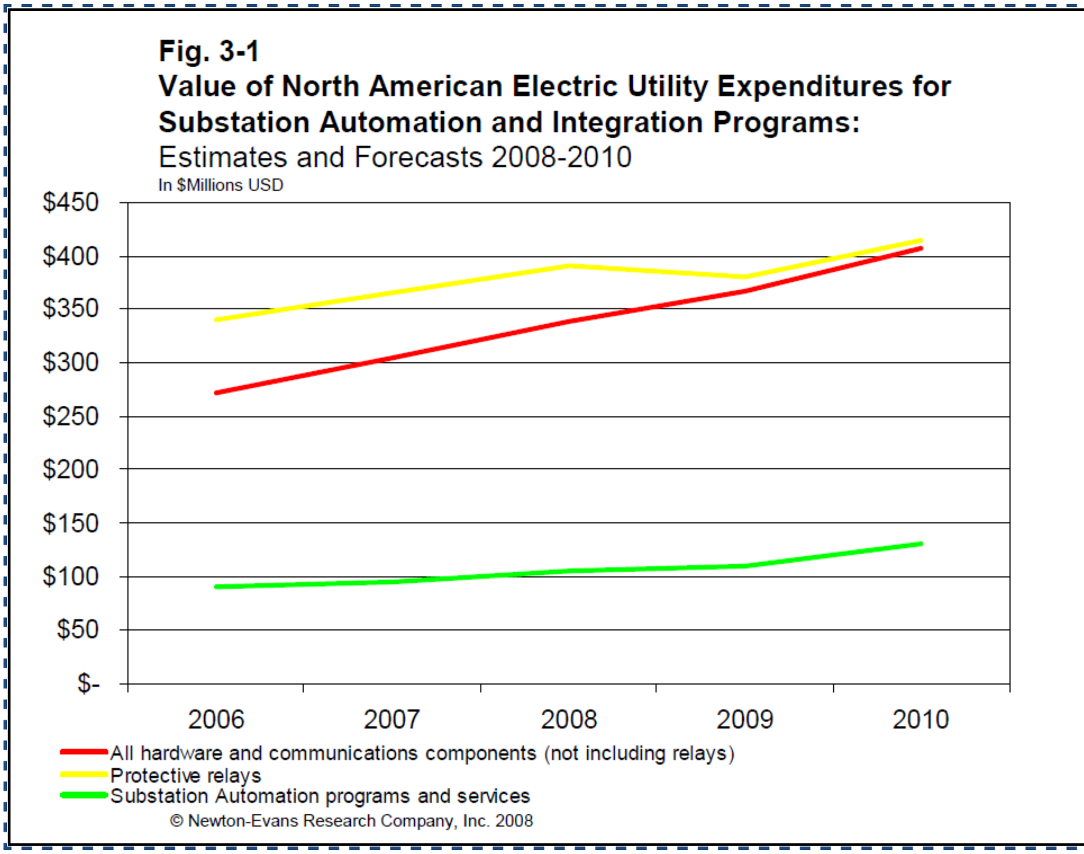
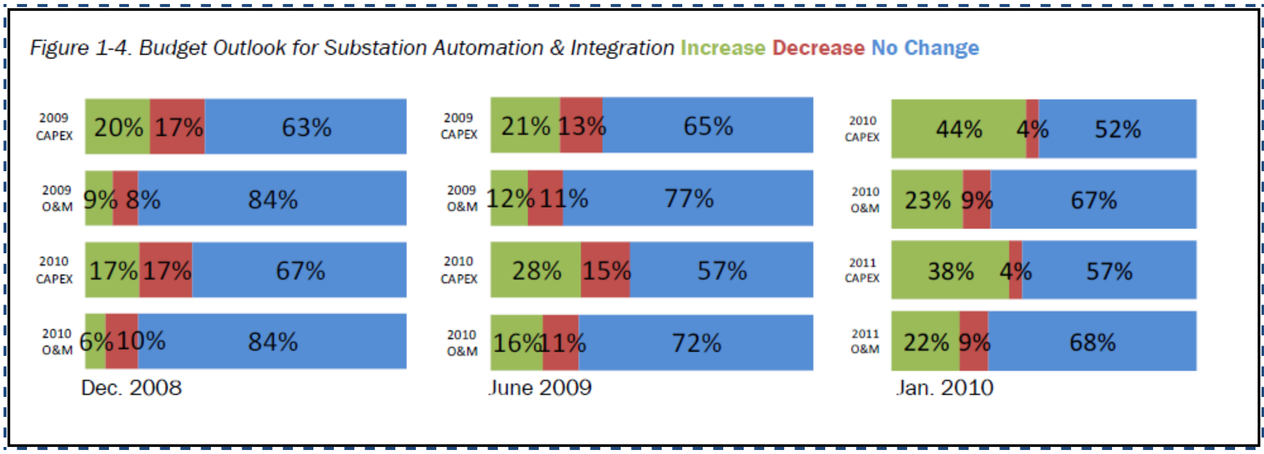


Fig. 3-1
Value of North American Electric Utility Expenditures for Substation Automation and Integration Programs:
Estimates and Forecasts 2008-2010

Newton-Evans further confirmed the directional correctness of these estimates in a January 2010 utility industry survey which indicated that over half of respondents indicated no change to substation automation budget plans in 2010, with 44% indicating a potential increase. Given this proclivity to increase budgets and the impact of the government stimulus funding, we expect to see substation automation budgets tick upward for the full year 2010. We also expect an increase in spending for substation communications gear which we have layered into our estimate.

Utility Capex Survey



Source: Newton-Evans Research, Utility Capex Study, January 2010

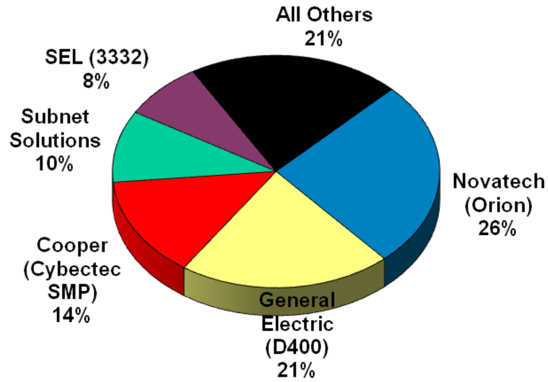
In order to assess the vendor landscape, we will first segment vendors by estimated revenue and then look closely at market share in some of the larger market sub-segments:

Substation Automation: Vendor Breakdown	
Multi-Product Vendors *(likely $10-$50M+ in U.S. SA revenue)*	• ABB • GE • Cooper Power Systems • Siemens • SEL • Novatech • Ametek • Qualitrol • RuggedCom
Equipment Specific Vendors *(likely $1-$10M in U.S. SA revenue)*	• Subnet Solutions • Telvent • SATEC • Utility Systems Inc. • Schneider Electric • Mehta Tech • ACS • Rockwell • DAQ • Eaton • Survalent • Garrettcom

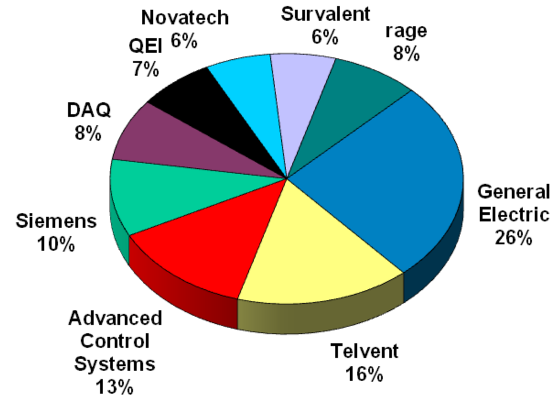
Source: Cleantech Group Analysis

In sub-sector specific markets such as platform and RTU, the following market share data demonstrate that the gear is the convergence point in the substation and, as such, is a critical point of intelligence. Large, integrated solution vendors such as GE, Siemens, and Cooper all have strong positions in these markets. The RTU market is also populated by a number of SCADA/DMS vendors such as Telvent, ACS, and Survalent; the hardware business is not the primary business of these vendors, but without RTUs, control center software would lack visibility and functionality at the substation level.

Substation Platforms



Substation RTUs



Source: Newton-Evans Research, January 2010 North American Substation Market Assessment

Market share for the myriad other substation equipment markets vary, but vendors in all of these markets tend to be consistent producers. The majority of vendors providing products in the substation sector are established vendors that have adapted over time to the growing demands of utilities.

Company	**Headquarters**	**Employees**	**Revenue**
Novatech	Lenexa, KS	501-1,500	\$100M-\$500M
Ametek	Paoli, PA	3,001-10,000	\$1B-\$10B+
Subnet Solutions	Calgary, Canada	1-100	\$1M-\$20M
Survalent	Mississuaga, Canada	1-100	\$1M-\$20M
DAQ	Piscataway, NJ	1-100	\$20M-\$100M
Eaton	Cleveland, OH	10,000+	\$1B-\$10B+
Mehta Tech	Eldridge, IA	1-100	\$1M-\$20M
Rockwell	Milwaukee, WI	10,000+	\$1B-\$10B+
SATEC	Union, NJ	1-100	\$1M-\$20M

Source: Cleantech Group Analysis

Given the live, operational nature of substation automation, utilities have long favored private, dedicated communications channels from the substation to the control center. This path has primarily been over fiber, leased lines, and licensed radio using the DNP3.0 protocol. Deploying this communication link required either a privately constructed network or a leased line service provider. It also required networking equipment which varied by the chosen physical medium. The legacy leaders in this market include GE MDS and many of the traditional telecom equipment vendors such as Motorola, Nortel, and Alcatel.

We will not go into great length about this data backhaul connection. While it is a mission critical link in the smart grid network topology and requires careful consideration on the part of utilities, it leverages the vast amount of innovation that has taken place in the data communications world over the past two decades and consequently is not a technology category that is unique to the development of the smart grid. Nonetheless, it will continue to be an area of capital expenditure for utilities as they increase the amount of data being extracted from substations that requires transport to a central control center.

One exception to this generalization about the substation communication market is the development of the substation routing and switching category. While most communication in the substation remains over DNP3.0 serial or LAN links, DNP3.0 can be transported using TCP/IP over Ethernet and there appears to be growing interest, primarily on the part of larger utilities, in using IP more generally for faster, more secure substation communication. Cisco recently unveiled a line of substation routers and switches and has made a significant push into the smart grid space building a substantial network of partner relationships.[58] Cisco does not enter a greenfield market however as there is incumbent competition for substation switching and routing gear commanding a U.S. market of between $20-$30M according to a recent study by GlobalData[59]. RuggedCom has built a leadership position in the space followed distantly by GarrettCom and GE.

2010 Market Share for Substation Ethernet Switching/Routing

Substation Routers/Switches	
RuggedCom	54%
GarrettCom	12%
Moxa	8%
GE	8%
Hirschmann	5%
Kyland	3%
Others	10%

Source: GlobalData, February 2010

We expect substation automation to continue to borrow best of breed solutions being developed in the broader data communications market to ensure that utilities can keep pace with growing data transport challenges.

[58] http://www.eetimes.com/electronics-news/4199585/Cisco-tunes-router-switch-for-smart-grid
[59] http://www.pressreleasepoint.com/globaldata-iec-61850-routers-and-switches-smart-grids-reportsresearchcom

Distribution Management Systems

So far this chapter has covered the market for hardware equipment deployed in the distribution portion of the grid, both in substations and the feeder network. This equipment is the eyes, ears, and hands of the emerging smart distribution system. The final critical element of this intelligent ecosystem is the "brains" of the operation – the software control systems that are responsible for coordinating actions across the grid and optimizing the performance of these increasingly smart field assets.

Historically, activity in the distribution system has been coordinated through a SCADA (Supervisory Control and Data Acquisition) system that was primarily oriented toward command and control at the substation level. As the sophistication of substation and distribution automation has increased, and as an exponentially more complex distribution system lies ahead, specific Distribution Management Systems (DMS) are being developed to address new required functionality.

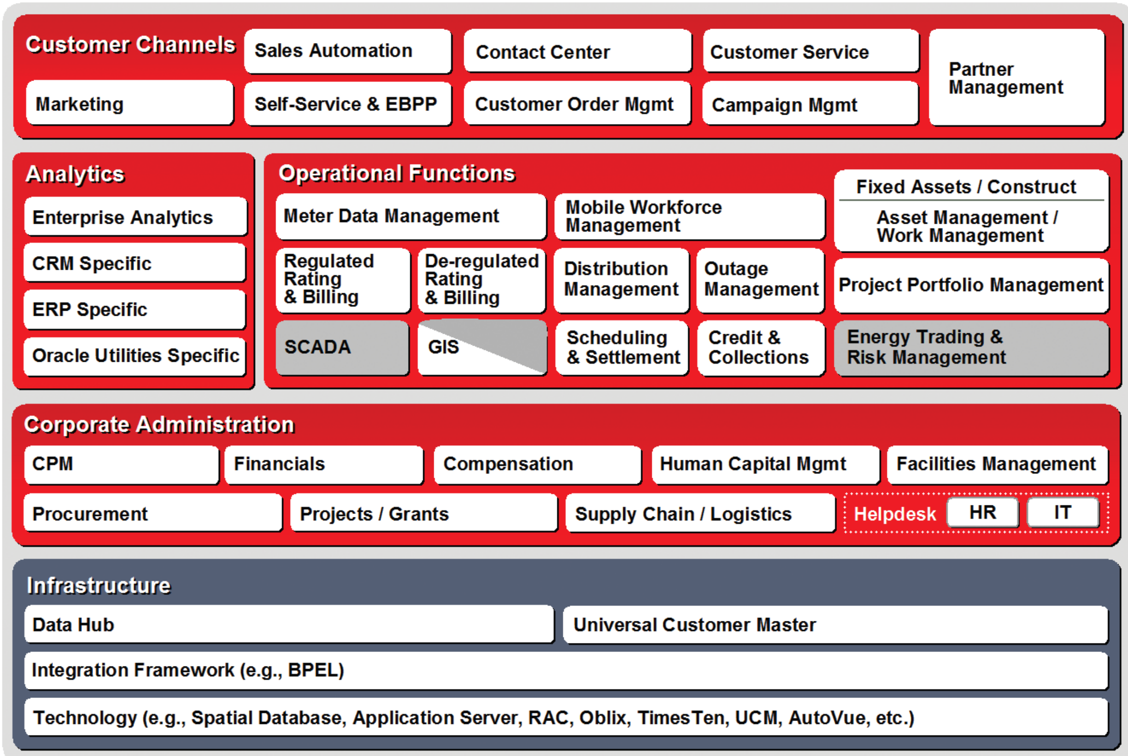
The DMS market is still in the development stages and there are multiple converging systems, each interacting with equipment and data from the distribution network. The market is composed of enhanced SCADA systems that have grown to encompass DMS features, or stand-alone DMS systems that are capable of managing fault detection and restoration or Volt/VAR control, as well as providing overall monitoring and load balancing of the distribution system. There are also stand-alone products that are configured to just manage voltage control or fault isolation and recovery processes.

In sophisticated deployments, DMS systems are integrating with MDMS systems and leveraging data generated by smart meters. In addition, the DMS can be called upon to integrate with the Outage Management System (OMS), a suite that utilities have traditionally relied on to coordinate response to a network outage, as well as GIS (Geographic Information Systems), which is responsible for mapping and analyzing utility assets in the field. There is significant overlap in this space with MDMS vendors building OMS functionality and some basic DMS functionality; and DMS vendors encroaching into some of the features offered by vendors of OMS or MDMS systems.

The interplay of these systems takes place against the backdrop of a broader utility control center and back office that is a complicated web of IT systems working collectively to do everything from balancing the load on an overtaxed portion of the grid, to dispatching a field employee to an outage location, or to allowing a call center representative to correct a customer's bill. There are a web of systems that have been deployed with widely varying levels of integration. Data often resides in silos defined by specific information sets that employees need to execute on their individual function.

This data complexity is often managed by systems integrators such as IBM, Cap Gemini, and Accenture, who have assisted utilities in configuring custom deployments. Consequently, when we look at software revenues in the market, it is important to note that systems integration and services revenue often can dwarf the cost of software licenses.

Utility IT Systems Complexity: Oracle Map of Utility IT Systems



Source: Oracle

We believe that the 2010 U.S. market for DMS-related software (both stand alone DMS systems and SCADA systems configured to handle some aspect of advanced distribution management) will be between \$100M-\$150M. While the market has a relatively limited set of vendors developing software, it is a competitive landscape with a healthy list of vendors maintaining meaningful market share:

U.S. DMS and Distribution SCADA systems

	% Market Share
Telvent	16%
ABB	14%
OSI	14%
ACS	12%
Siemens	10%
Survalent	5%

Source: Cleantech Group estimate; adapted from Newton-Evans Research

DMS Specific Vendors

Company	Headquarters	Employees	Revenue
Telvent	Madrid, Spain	3,001-10,000	\$500M-\$1B
OSI (Open Systems Int'l)	Minneapolis, MN	101-250	\$20M-\$100M

Source: Cleantech Group Analysis

Distribution Grid Management: Conclusions

Distribution and substation automation holds tremendous promise for improving grid efficiency and performance. Achieving these gains will require continued capital investment. These investments must be supported by regulatory frameworks that encourage and reward utilities for pursuing these projects. In the case of distribution and substation automation, technology is not the gating factor to achieving more widespread deployment. As we have seen in this chapter, there is a large equipment market supported by established vendors who are providing the necessary elements to upgrade many aspects of the distribution system. While it is not a market that has attracted the same type of public attention and venture investment as smart metering, it is a market of similar magnitude with perhaps even greater potential for efficiency improvements if the right incentives are provided for the utility industry.

V. Home Energy Management

Key Takeaways
• The Home Energy Management (HEM) market is still quite nascent, but has attracted substantial venture investment into new entrants, as well as significant interest and development efforts by technology stalwarts such as Microsoft, Google, Cisco, Intel, and others. • A robust HEM will have new hardware such as wireless sensors, smart appliances, and smart plugs which should provide two-communication and intelligence. Due to the high costs associated with the HEM, many HEM vendors are offering non-energy related functionality with their energy management services, including security and entertainment. • Unlike some other aspects of the smart grid, the HEM currently does not have an obvious "killer application" that can provide an attractive economic payback for the utility and the consumer although it is generally agreed that in aggregate, the HEM is valuable to both the utility and consumer. As such, there will be multiple pathways to mass adoption. • The emerging HEM leaders will emphasize interoperability and broad product offerings to "future-proof" its network, particularly when future applications like distributed generation, electric vehicles, and storage reaches critical mass.

Key Vendors		
• Tendril	• Control4	• OpenPeak
• Gridpoint	• 4Home	• Cisco
• EnergyHub	• AlertMe	• Google
• OPower	• EcoFactor	• Microsoft
• iControl	• Intamac	
• PeoplePower	• Sequentric	

Home energy management is a relatively new entrant to applications associated with the Smart Home and Home Area Network (HAN). "Smart Home" has been more traditionally associated with the integration of entertainment devices, security, and perhaps some appliances, but energy management is an increasingly critical component of the smart home dialogue. In the past, home energy management was limited to the thermostat. In the future, a robust Home Energy Management system will have new hardware such as wireless sensors, smart appliances, and smart plugs which should provide two-way communication and intelligence.

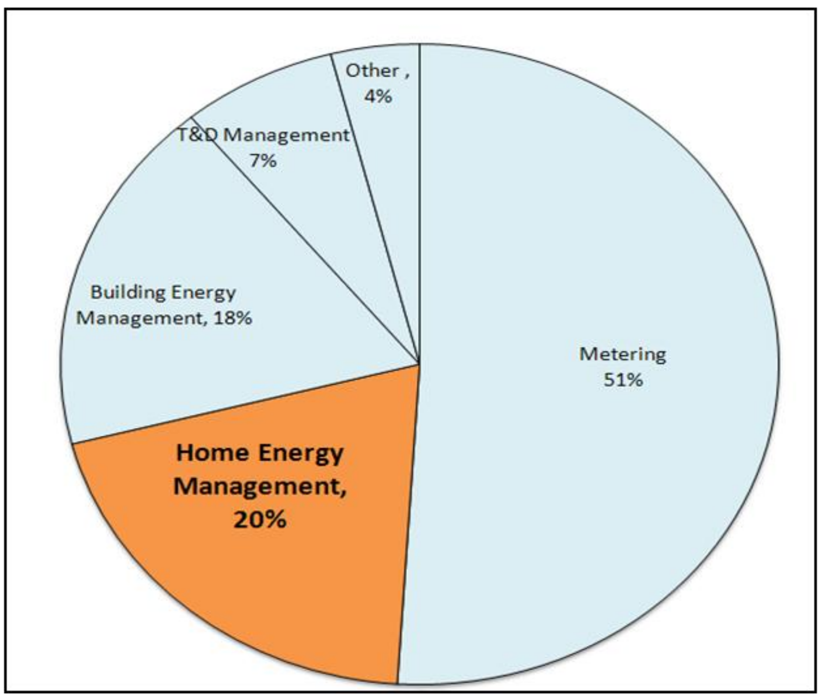
Home Energy Management Still Nascent Compared to Other Aspects of the Smart Grid But Growing

Just as we observed a Version 1.0 in the markets for smart metering and distribution grid management, so too home energy management has a precursor: the smart, programmable thermostat. As we observed in our demand response chapter, tens of thousands of smart thermostats have been deployed to residences by utilities, supplied by traditional vendors such as Carrier and Emerson, as well as upstarts such as EcoFactor. These thermostats represent a first wave of home energy management that is poised for growth as a more full featured ecosystem develops for the home.

Beyond the market for thermostats, the HEM space is still quite nascent compared to other aspects of the Smart Grid. While smart meter deployments may number close to 20 million homes by the end of 2010, most HEM utility deployments are in the hundreds or thousands at most. For example, Duke has a 100-home pilot for Cisco's Home Energy Controller[60] , GE is working with Louisville Gas and Electric Company on a smart appliance and dynamic rate pilot of approximately 150 homes,[61] and the Xcel SmartGridCity project, which now faces financial and implementation setbacks, had limited its first deployment of In-Home Devices to between 500-1000.[62]

Nevertheless, we see HEM beginning to progress from "Power Points to Pilots"[63] (to borrow a phrase from Grid Net's Ray Bell describing market evolution). From 2007 to 2010 year to date, HEM constituted 20% of all venture financing in the Smart Grid space. Moreover, the trend of investments is increasing. HEM received only $8 million in venture dollars in 2006 but has already raised over $115 million in 2010 thus far.[64]

Venture Capital By Category; 2007-2010



Source: Cleantech Group Analysis

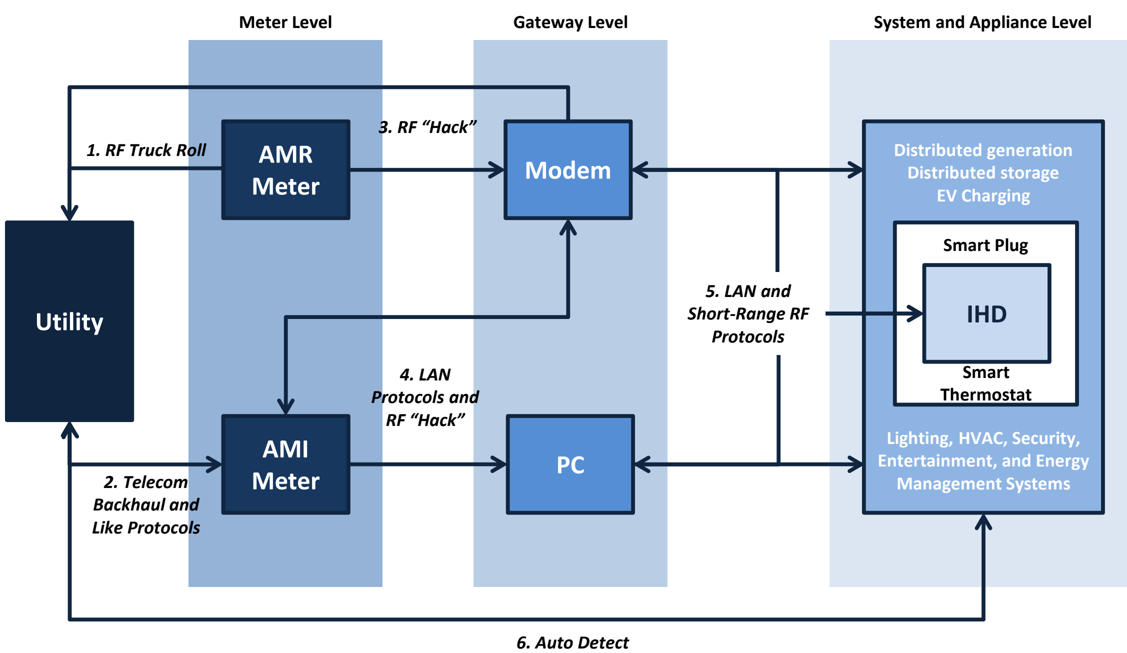
[60] http://www.smartgridnews.com/artman/publish/Technologies_Home_Area_Networks_News/Smart-Grid-into-the-Home-The-Battle-Begins-2720.html
[61] http://www.eon-us.com/newsroom/archive2008/news_092408.asp
[62] http://www.xcelenergy.com/SiteCollectionDocuments/docs/In-Home-Smart-Device-Pilot-Program-description.pdf
[63] http://www.smartgridnews.com/artman/publish/Technologies_Home_Area_Networks_News/The-Smart-Home-in-2010-From-PowerPoints-to-Pilots-1874.html
[64] The Cleantech Group

HEM Communication Landscape

With a dizzying array of new offerings being proposed by vendors, it can become difficult to decode precisely how different providers are approaching the market. In our evaluation of the market, we believe that the key to understanding today's landscape of products is to understand how each derives its data. As our communications map explains, there are a variety of paths to showing a customer usage data and allowing that customer to take control of energy choices. Some paths rely on data from the meter. This path can either be directly from the meter itself or can be established through a device that clips-on to the meter. For example, Google PowerMeter is capable of receiving data from an AlertMe device that clips-on to a meter; in addition Google is working with Itron on receiving data directly.

Second, customers can receive data over an internet connection from the utility. This data may have been derived from a smart meter and then processed via a utility's MDMS for customer viewing or can be new data analytics on traditional billing. OPower is an example of a company providing novel billing analytics accessed via an internet browser or a paper bill. In addition, companies such as Tendril allow a utility to communicate demand response events over an internet connection directly to the customer's display device.

Finally, there is a class of vendors working solely from data derived directly from appliances and smart plugs. These applications do not need to interact at all with the utility or the meter to promote efficiency. They can analyze usage data on-premise and can help consumers make real-time adjustments or turn off unnecessary loads. They are limited, so long as they do not integrate with the utility in some fashion, in making use of real-time pricing data or being used to facilitate demand response.

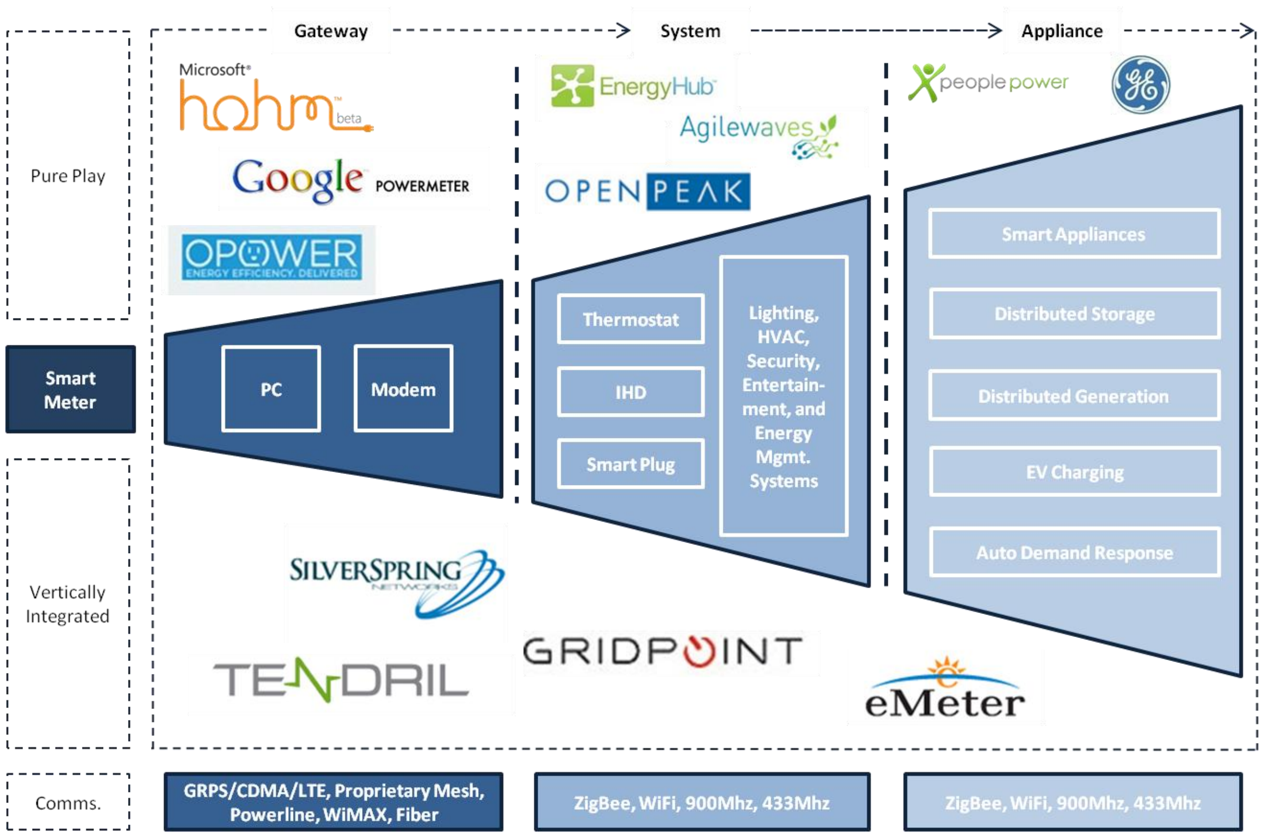


Source: Cleantech Group Analysis

The Emerging Home Energy Management Product Landscape

A robust and comprehensive HEM system from Tendril or Control4 can be priced from anywhere between $150 for a simple installation to upwards to over $1,000, although some vendors can provide limited functionality for free (as in Google Powermeter) or for under $100, as with some of OpenPeak's In-Home Display (IHD) offerings. Utilities and CSPs have begun to recognize the value of a Home Energy Management system for demand response and other smart grid applications, but the acquisition cost for each residential kilowatt has stymied mass adoption so far. Nevertheless, as we discussed earlier, residential demand response is still very attractive as residential load represents at least one-third of all demand.[65]

The Home Energy Management Ecosystem



Source: Cleantech Group Analysis

Due to the high costs associated with the HEM, many HEM vendors are offering non-energy related functionality with their energy management services, including security and entertainment. For example, companies like Control4 and 4Home provide security and entertainment functionality in their systems and these companies often lead with these adjacent, more established applications as an entry

[65] EIA, 2008.

into the home. Because these applications also utilize some of the key components of a HEM system, such as wireless sensors and a customer engagement platform, adding non-energy functionality does not add much in incremental cost. Many HEM vendors are entering the home through these different verticals and thus, no preferred distribution channel or partnership has emerged. Some, like Tendril, are working through utilities while others, like AlertMe, are selling directly to customers.

Components of HEM Systems:

Gateway: The Gateway can be a physical hub that enables two-way connectivity to the utility, meter, and other “smart” devices in the home or a cloud-based customer engagement platform. Vendors like OPower, Google PowerMeter, and Microsoft Hohm do not develop any physical appliances but rather provide a web-based customer engagement platform with detailed energy management information, suggestions for energy conservation, and/or protocols to speak to the various smart-enabled devices.

System: At the System level, vendors such as OpenPeak and EnergyHub provide smart hardware such as IHDs, thermostats, and plugs to create a managed network for lighting, HVAC, security, entertainment, and home energy management systems. Many of these System-level vendors have their own customer engagement platform, although some provide interoperability with leading gateway players. For example, Blue Line Innovations recently released an IHD that is compatible with Microsoft Hohm.

Appliance: Few pure-play vendors have focused on the appliance level, as it is believed that “white good” appliance makers like GE and Whirlpool will develop natively smart appliances. Still, some start-ups see opportunity here. PeoplePower, for example, sells a development kit for developers to create appliances that speak to its HEM software. “Future” applications like distributed generation, distributed storage, and EV charging each have distinct vendors. We are also seeing companies that enable these future apps, like Enphase Energy, looking to expand beyond microinverters towards building out a HEM system.

Vertically Integrated: Many HEM vendors are pursuing vertical product offerings. Companies like Silver Spring and Gridpoint have a broad suite of products/services, sometimes from acquisition. Silver Spring recently acquired Greenbox for their customer engagement software, a product suite now known as Customer IQ. Gridpoint has also been active in the M&A space, most recently with its acquisition of Standard Renewable Energy (SRE), a distributed generation integration company. In many instances, the aim of the fully vertical vendors is to future-proof their HEM system for when future applications like distributed generation, distributed storage, and EV charging reach critical mass.

VI. Building Energy Management

Key Takeaways
• Key stakeholders (e.g., major equipment providers, utilities, building owners/operators, CSPs) are beginning to recognize the importance of increased intelligence around energy use and the value of increased granularity and precision in identifying sources of curtailable and inefficient loads. • The Building Energy Management market increasingly features a dynamic vendor field. Global building automation leaders such as Johnson Controls, Honeywell, Siemens, and Schneider Electric continue to lead the market, but are increasingly looking to incorporate innovation from a variety of upstart vendors. Major CSPs such as EnerNoc, Comverge, CPower, and Gridpoint are also moving toward managing energy at the building premise. • State of the art building energy management systems will incorporate data streams from all enterprise-level systems including HVAC, lighting, security, and IT and may additionally incorporate a layer of GHG accounting and analytics on top of energy management. • Enabling these data streams will be a new category of sensors and monitors that provides more granularity and precision in the sources of load. These sensors will measure, control, be networked, and even utilize new energy harvesting technologies.

Key Vendors		
• Johnson Controls	• Hara Software	• Adura Technologies
• Honeywell	• ENXSuite	• PowerIT Solutions
• GE	• SAP	• Verdiem
• Schneider Electric	• Oracle	• Redwood Systems
• Siemens	• EnOcean	• Agilewaves
• IBM	• SynapseSense	• BuildingIQ

The Building Energy Management market is undergoing a transformation as all the key stakeholders (e.g. major equipment vendors, utilities, building operators, and CSPs) are beginning to recognize the importance of increasing intelligence around energy usage in the built environment. Vendors are increasingly developing technologies and services to unlock the value that can be created with granular and precise identification of curtailable and inefficient building energy loads. As the commercial and industrial markets represent at least two-thirds of all energy use in the United States, the market opportunity to reduce this load is significant.[66]

Building automation systems (BAS) have existed in basic forms for decades, but are gaining increased attention and innovation as building owners and enterprises begin to recognize the opportunity to more proactively control building environments for energy efficiency, cost savings, and occupant comfort. In the past, many equipment vendors have focused on “silo-ed” building systems like HVAC, lighting, and

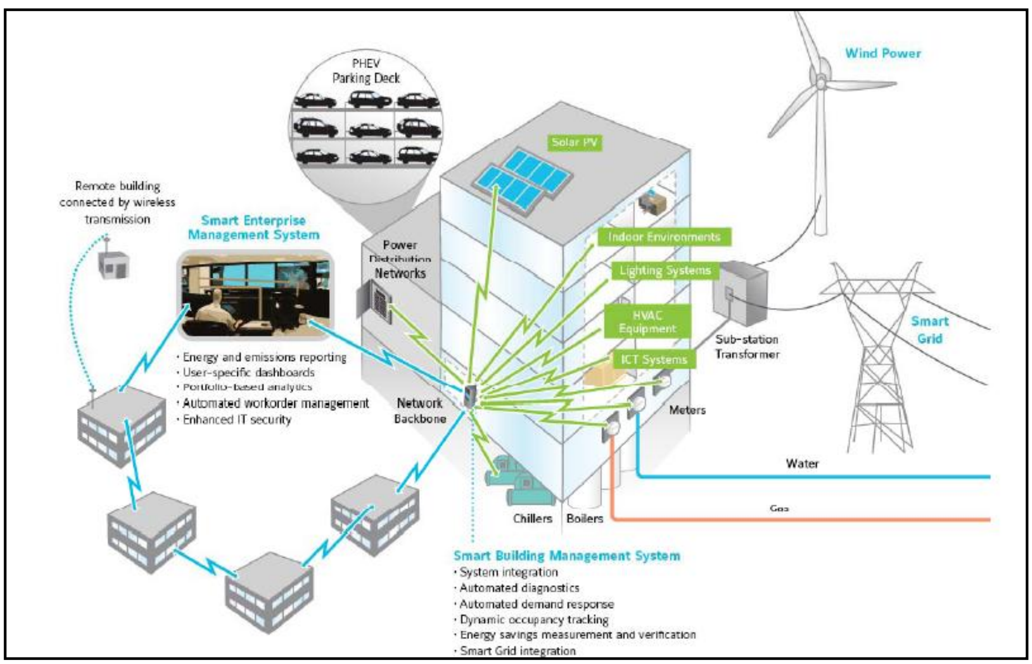
[66] EIA, 2008.

security systems. This has changed rapidly as major equipment vendors such as Johnson Controls, Siemens, Schneider Electric, and Honeywell have all begun to introduce products and services that help manage energy more holistically.

Increasingly, systems can tie together monitors and sensors throughout a building, as well as HVAC, lighting, and information technology equipment. In sophisticated deployments, these systems allow for centralized monitoring and control of all of these building elements - creating a smart building energy Local Area Network (LAN).   In an ideal, optimized network topology, this centralized LAN would be integrated to a wider smart grid, making use of demand response interactions with utilities and energy suppliers.

This LAN layer is a particularly interesting arena with some movement toward converged standards. Widely deployed protocols for in-building communication consist of BACNet, a standard developed by an industry working group that included major vendors, and Lon Talk, developed by the Echelon Corporation.   There are competing wireless protocols developed by the ZigBee Alliance (led by Ember), the EnOcean Alliance (led by EnOcean), as well as vendors leveraging standard WiFi networks (such as GainSpan). Cisco, through its January 2009 acquisition of Richards-Zeta Building Intelligence, has moved aggressively to push a common IP standard and has introduced its Network Building Mediator product with the intention of integrating disparate building systems.   Johnson Controls, through its 2008 acquisition of GridLogix, and Honeywell, through its 2005 acquisition of Tridium, have also been leaders in pushing for convergence.

The Anatomy of a Smart Building



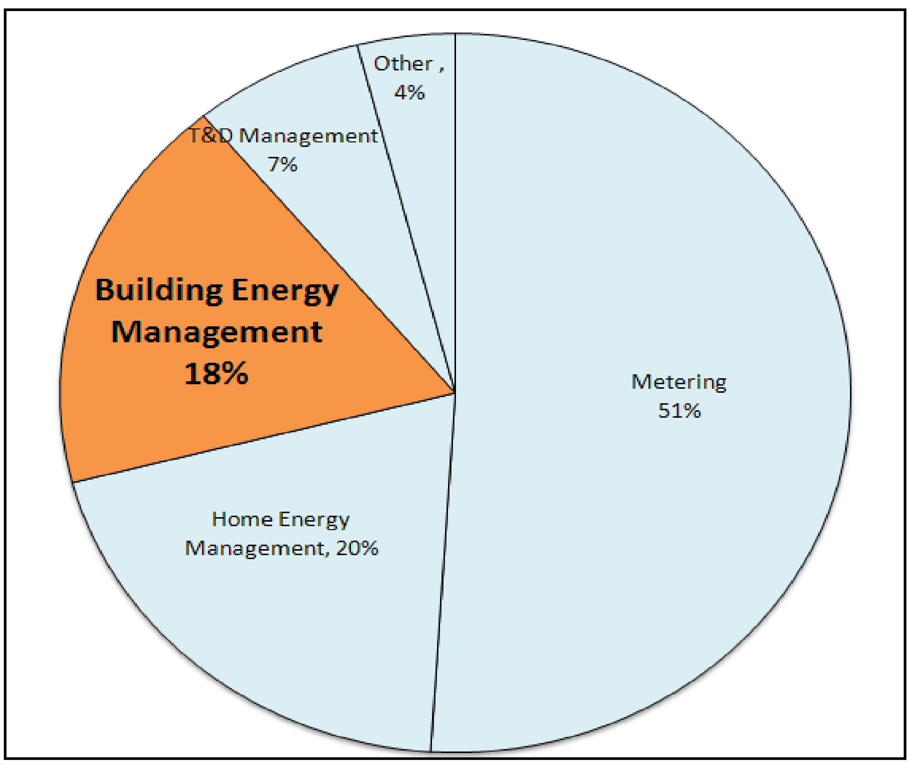
Source: Johnson Controls

When systems converge and when all of these elements work in concert, coordinated integrations are possible. For example, smart, networked buildings can take note of when employees depart, via integration with security cards, and can shutdown lights, cooling, and non-critical IT systems in unoccupied sections of the building. To the extent that the communication layer moves toward open standards, we would expect to see continued innovation at the management and control layer. Given the complexity of the building environment and the fact that most facilities decisions are made with a risk adverse orientation however, we expect – even with more open, innovation friendly standards – that incumbent solutions will remain very strong.

The Building Energy Management Ecosystem

The U.S. market for energy efficiency in buildings is approximately $236 billion annually, and it's expected to triple by 2030.[67] As such, venture financing dollars have chased the market opportunities in building energy management systems. Since 2007, more than $270 million has been raised in the space, accounting for approximately 18% of all smart grid investments. The largest recipient of venture financing has been GridPoint, who is active in both home and building energy management. We are also seeing recent investment activity in building sensor investments like EnOcean and SynapSense and in enterprise carbon accounting companies like Hara.

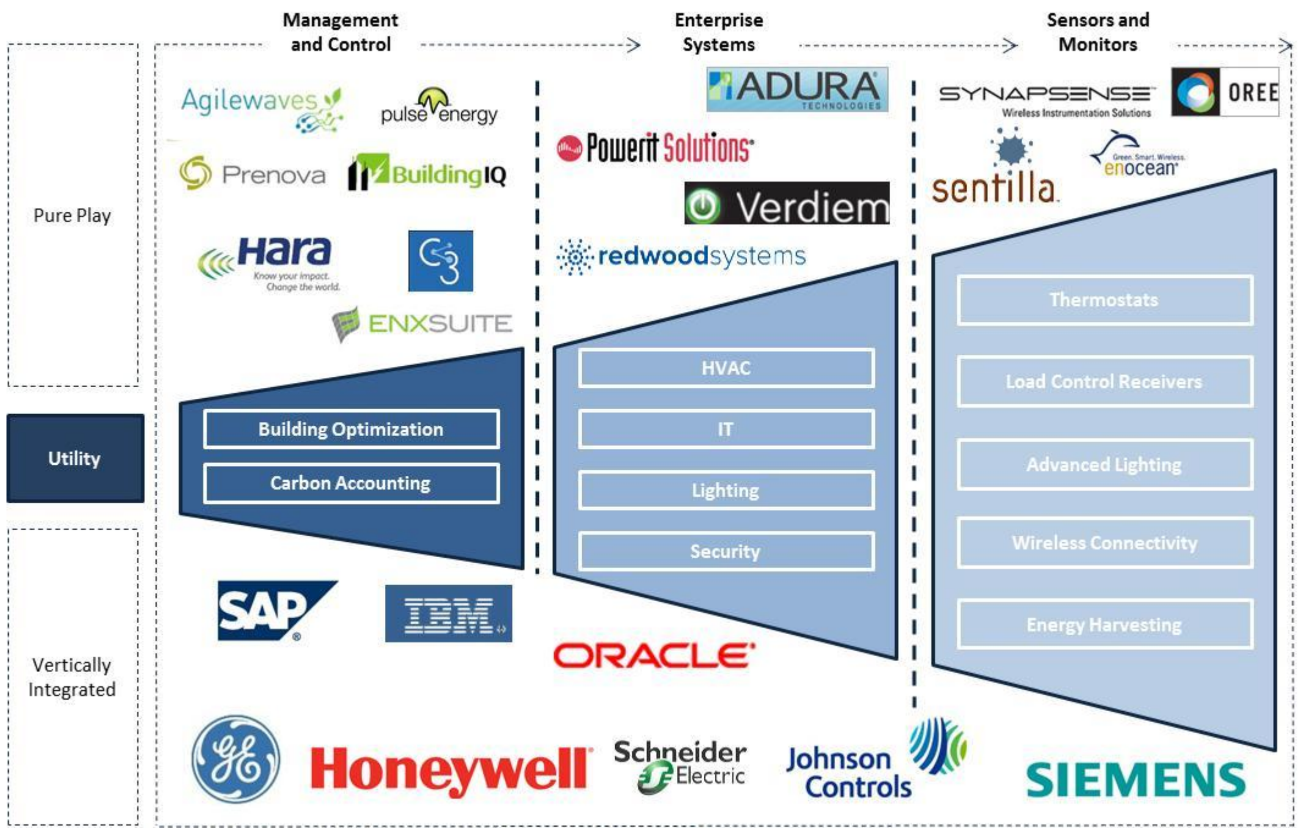
Venture Capital By Category; 2007-2010



Source: Cleantech Group Analysis

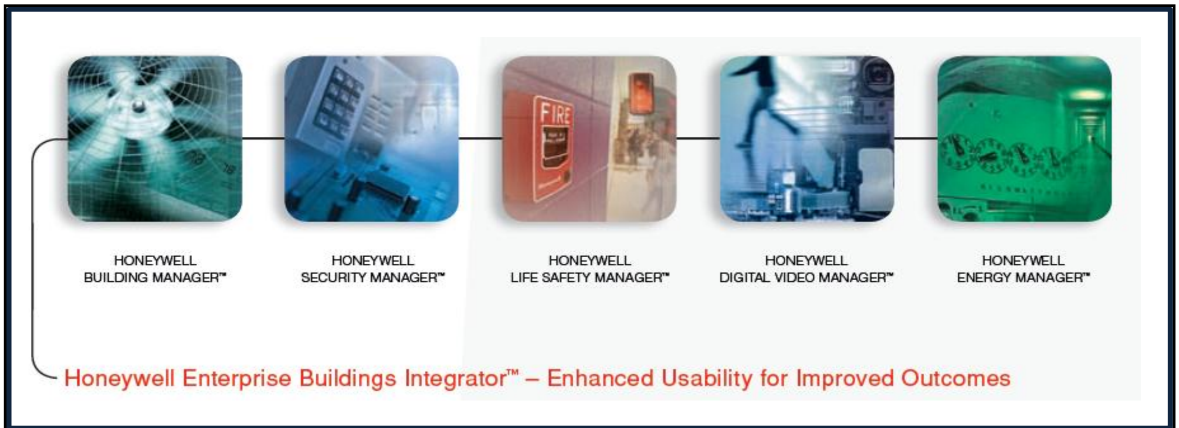
[67] McKinsey & Company

These startups enter a competitive landscape that is dominated by large, vertically integrated players, and that is being approached by both product and services companies. We have tried to summarize some of the key players in the market as follows:



Source: Cleantech Group Analysis

Vertically Integrated: As we have mentioned, vertically integrated firms such as Honeywell, Johnson Controls, and Siemens are unique in their ability to provide not only software and control solutions but also the underlying building systems, sensors, and monitoring hardware required for a comprehensive and robust building energy management system. Honeywell, for example, offers an "Enterprise Buildings Integrator" product that pulls data from a wide variety of Honeywell enterprise level building solutions, including security, energy management, and building operations.



Source: Honeywell

While many of the pure-play vendors can offer best-of-breed tools, there is value to building owners/operators to choose one vendor that can provide a full suite of services, especially if they can pull directly from enterprise systems reading off their own sensors or switches.

Another emerging category of vertically integrated vendors is demand response vendors such as EnerNoc, CPower, and Comverge that are moving, via acquisitions and their own development, to stake a larger claim on activity at the building premise. As detailed in our demand response chapter, EnerNoc has made several acquisitions to strengthen its portfolio of energy management solutions. Similarly, the traditional building vendors are eyeing opportunities outside the building premise. This will be a very interesting area of convergence and consolidation to watch in the coming years.

Management and Control: Management and Control acts as the software layer that analyzes the multiple data streams from other enterprise-level reporting and monitoring systems to provide intelligence on energy or carbon usage. This leg of the building energy management value chain has had a disproportionate amount of venture financing because of its familiarity to middleware providers. Venture-backed companies like Agilewaves, Scientific Conservation, and BuildingIQ pull building data into proprietary software solutions. This data may come directly from existing BMS systems or can be collected from sensor networks that vendors may deploy in buildings lacking legacy gear. The aggregated data is then parceled into useful and actionable recommendations for energy reduction, asset management, or utility-level applications like demand response. Enterprise carbon accounting (ECA) companies like Hara and ENXSuite also aggregate data but specifically account for GHG emissions (either directly or indirectly) from enterprise-level data streams.

Enterprise Systems: At the enterprise-level, multiple best-of-breed systems are being developed to optimize specific equipment such as HVAC, IT, Lighting, and Security systems. The opportunity for energy savings is ripe for industrial and commercial end users. In industrial environments, industrial processes like machine drive (59%) and process heating (19%) are the two largest end uses of energy. Venture-backed companies like PowerIT Solutions can provide software and hardware solutions to measure, monitor, and control industrial processes, including variable speed motors and HVAC systems. For commercial customers, lighting is the most significant identified source of energy use at 25% of total energy use. Adura Technologies and Redwood System (also venture-backed) tackle this problem by providing network connectivity and intelligence into lighting systems, which enable energy management, better lighting comfort, and even utility-level applications like demand response. Office equipment is also a large energy hog, at 16% of commercial buildings. Verdiem, another venture-backed company, provides power management through PC networks.

Not to be outdone by the smaller and niche-focused venture-backed companies, traditional enterprise software players like SAP, IBM, and Oracle are also quite active in building energy management. Because of their larger product offerings, most incumbent enterprise software vendors have a vertically integrated software solution. SAP, for example, has a building optimization and carbon accounting product, both of which take in reporting data from multiple SAP software data streams (see below) as well as third party reporting.

Source: SAP

As the market for building energy management increases due to regulatory concerns and rising electricity costs, we expect increased activity for the vertically integrated software vendors either through new product offerings, acquisitions, or strategic partnerships. For example, SAP acquired carbon accounting startup Clear Standards in 2009 to augment its existing suite of BMS products. Partnerships are also critical. IBM is working with a wide variety of BMS and sensor companies to integrate its Tivoli monitoring software to the energy use end points, including Schneider Electric, Siemens Building Technologies, and GE-backed SynapSense.[68]

Sensors and Monitors: In order to achieve the level of granularity and precision for a comprehensive building energy management system, start-ups are adding new functionality to end processes so they can be measured, controlled, networked, and even utilize new energy harvesting technologies. SynapSense, for example, has a wireless sensor solution comprised of sensor nodes, gateways, routers and server platforms for data centers and other enterprise built environments. While many sensor and monitor companies like SynapSense also provide a software solution that speaks to their sensor/monitor network, for the purposes of this study, we will highlight companies whose hardware is their competitive advantage in this section. Sentilla, another VC-backed company, is also a next-generation sensor company with a focus on its software solution.

In addition to adding networking functionality, we expect to see more next-generation sensors to incorporate an energy harvesting technology from vendors like Siemens-spinout EnOcean. Energy harvesting technology utilizes the energy generated by the device being measured (e.g., a pressed switch or latent heat) to transmit a wireless signal. This is particularly significant because energy harvesting technologies can now enable sensor installations in industrial processes and devices that, in the past, could not economically or logistically be monitored (such as in remote base stations). We predict as this technology matures, more devices will utilize energy harvesting.

[68] http://www.synapsense.com/go/index.cfm/about-us/press-media/ibm-adds-to-green-data-center/

VII. Grid Interconnection

Key Takeaways
• Grid interconnection products and technologies enable important future elements of the smart grid including distributed generation, energy storage, EV charging, and renewables integration. Grid interconnection will become increasingly important as these smart grid developments move forward. • Inverters are currently the key product amongst the diverse set of technologies that make up grid interconnection. This is due to their high cost relative to other equipment, and because they are required for the rapidly growing markets of solar arrays, and (most) wind farms and grid-connected storage. • Distributed small-scale sources of energy generation such as residential/commercial solar, community wind, and vehicle-to-grid charging (V2G) pose a different set of interconnection challenges than utility-scale renewable generation. However, it is an open question how quickly these technologies will penetrate their respective markets.

Key Vendors		
• ABB	• ECOtotality	• SATCON
• AeroVironment	• GE	• Schneider Electric
• Areva	• Leviton	• Siemens
• Better Place	• Mitsubishi	• SMA
• Coulomb	• Panasonic	• Square D

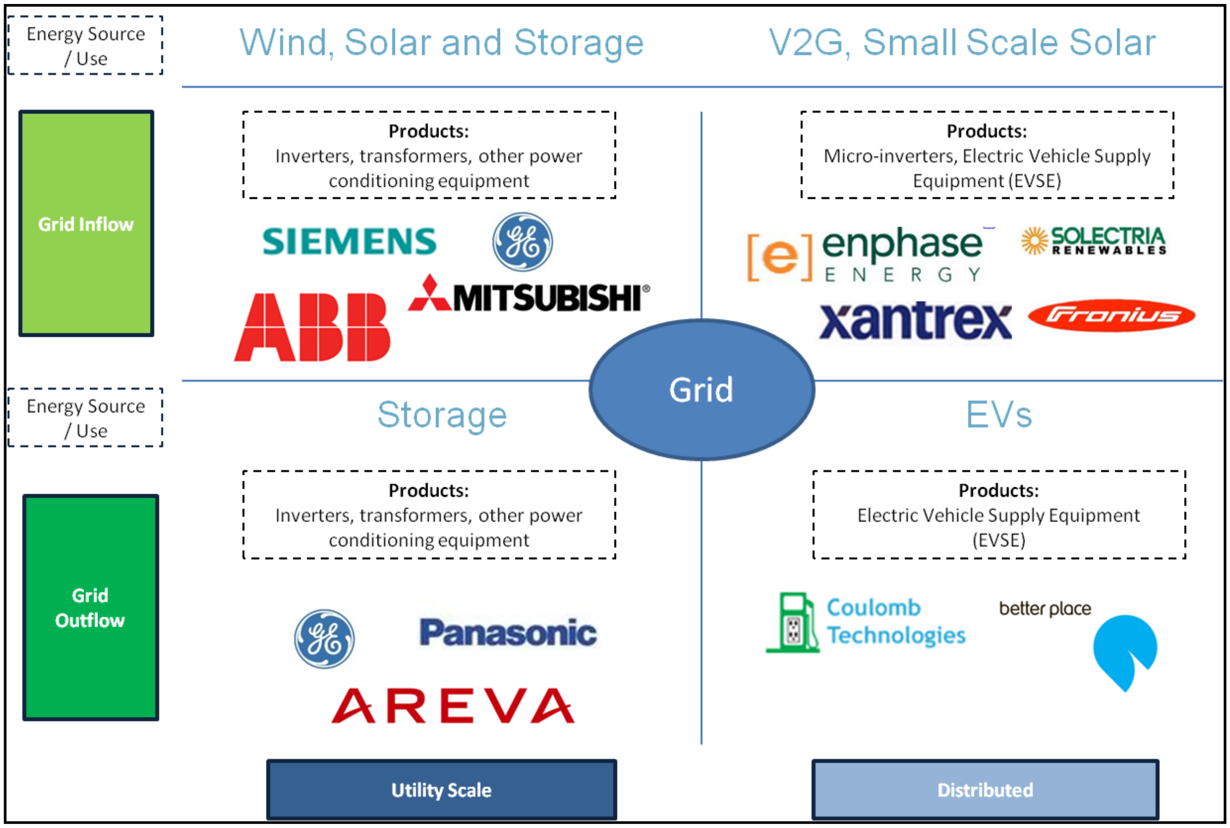
Grid interconnection involves the technologies and products necessary to connect energy to the grid. While there are well-established and standardized approaches to connecting traditional forms of energy (e.g., nuclear, hydro-electric, coal) to the grid, renewable sources of energy, energy storage, and electric vehicles pose unique interconnection challenges. These challenges include the variability, complexity and unpredictability of generation output, which require changes at both the transmission and distribution level to ensure grid stability.

While grid interconnection is challenging, the benefits from improved grid interconnection run into the billions of dollars and include the prevention of economic damage from blackouts, greater penetration of electric vehicles and renewable energy, reduced excess capacity on the grid, and diminished fossil-fuel consumption. [69] In short, grid interconnection can help save utilities and consumers billions of dollars, while also reducing carbon emissions.

Grid interconnection can be a difficult area to understand as it involves a wide variety of companies and products, and is often highly technical in nature. One way to understand the grid interconnection "ecosystem" is as follows:

[69] See United Nations, "Multi-Dimensional Issues in International Electric Power Grid Interconnections," 2006.

The Grid Interconnection Ecosystem



Source: Cleantech Group; illustrative in nature and is not inclusive of all relevant companies and products

As our chart illustrates, grid interconnection is required for various applications and technologies. Interconnect is necessary anytime that benefits are generated by putting power onto the grid ("grid inflow") or taking it off the grid ("grid outflow") for use at a later time. We segment the technologies in the market based on whether they are used to take power off or put power on the grid.

Utility-Scale Grid Inflow

In some important ways, connecting grid scale wind and solar energy is no different than connecting traditional energy sources. For example, both wind and solar require a "step-up" transformer at a substation near the generation site where voltage is increased, and a "step-down" transformer at another substation where voltage is decreased for distribution. The transmission to and from substation is enabled by switchgear, transformers, and other standard relay equipment. While there are a large variety of vendors for this equipment, major names include ABB, GE, Siemens, and S&C Electric. However, it is important to note that companies making transformer and switching products may not sell directly to utilities or project developers; many utilities seek out and buy "turnkey" solutions for interconnection. Large conglomerates and/or inverter manufacturers such as GE often play a dual role as product supplier and system integrator to provide a "turnkey" solution to utilities; they may manufacture the bulk of equipment and leverage their scope of product offerings and source remaining elements.

Utility-Scale Solar

While some equipment elements are indeed standard, grid scale renewable energy sources do pose unique grid interconnection challenges due to their variability and unpredictability. Solar energy in particular requires a specific set of grid interconnection products and technologies because solar panels produce direct current (DC). This DC power must be converted to alternating current (AC) for grid use. Therefore, every large scale solar or fuel cell system require inverters (which perform the DC-AC power conversion). At the solar utility scale, SMA has a commanding market share of between 40-50% of a global market estimated by many analysts to be more than \$2.5B[70]. Other key inverter vendors include large industrial conglomerates such as GE and Siemens, but also manufacturers such as Ingeteam, Fronius, Kaco, Satcon, Advanced Energy Industries, Inc.

Utility-Scale Wind

Wind energy also has unique interconnection features. For example, wind turbines themselves include various generator and interface types to connect wind energy to the grid. Therefore, wind turbine manufacturers play a much more important role in grid interconnection for wind. Companies like Vestas, Clipper, GE and Gamesa provide turbines with asynchronous induction generators that are connected directly to the grid or provide ac-dc-ac power converters for grid interconnection.[71]

However, depending on the age of the turbine and the site's characteristics, utility-scale wind sites may require a variety of auxiliary equipment including static switches, converters, injection transformers, and master control modules.[72] While there are a large variety of vendors for these devices, major names include ABB, Mitsubishi Electric and SquareD.

Energy Storage (inflow and outflow)

The newest developing energy source in utility environments – storage – typically involves some combination of the auxiliary equipment described above, the storage device itself, and (usually) two converters (also known as rectifier inverters). One of these converters is stationed between the generation site and storage, and the other is stationed between storage and the grid. The same vendors

[70] http://www.reuters.com/article/idUSTRE60B38M20100112
[71] Electric Power Research Institute (EPRI), "Renewable Energy Technology Guide: April 2009 Update."
[72] Ibid.

making utility scale solar inverters also sell into the storage market. Key names include industrial conglomerates such as Siemens, ABB and GE.

There are a very large number of vendors selling the storage devices themselves – including some (like Areva and Panasonic) who also sell inverters or related equipment. As to the final set of products in the utility environment –auxiliary equipment – the vendors in the storage market are the same as those described above in the utility-scale wind section.

Finally, it is important to note that one of storage's key advantages is that the energy flows in both directions – to and from the grid. The equipment in both instances in largely the same and includes converters (or rectifier inverters) in addition to the auxiliary equipment such as switches.

Distributed Grid Inflow: Small-Scale Solar

Small-scale, distributed solar from residential and commercial sites pose a unique set of grid interconnection requirements. First, there needs to be the metering capability to feed short-term excess power generated to the grid (i.e., run the meter backward). Second, there are an extensive list of regulations designed to prevent potential safety and power quality problems including unintentional islanding, loss of effective voltage regulation, and voltage fluctuation.[73] As the consumer typically does not want the trouble of learning how to comply with these regulations, residential solar installers select, install and commission the necessary interconnection equipment. There is a large, diffuse and diverse market of installers but major names include Sun Run, SolarCity and Sungevity.

One of the key pieces of interconnection equipment purchased and installed by residential solar companies is inverters. The smaller scale requirements of the residential and commercial solar markets have given rise to a new category of inverters called micro inverters. Micro inverters – like traditional inverters – transform DC to AC power so the panels can connect to the grid. However, micro inverters perform this conversion for every individual panel in contrast with inverters who do so for the entire set of panels. The advantage of micro inverters are that they can isolate damaged, shaded or weak panels, while allowing other panels to continue generating energy at the highest possible efficiency. Also, the device is "smart" and can alert array operators to problems.

Key micro inverter companies include DirectGrid Technologies, Enphase Energy, Enecsys, Petra Solar and Solar Bridge.   Some industry experts maintain that micro inverters may begin to chip away at the inverter market if they can address reliability and cost challenges.

[73] Ibid.

Distributed Grid Inflow: Vehicle to grid charging “V2G”

Vehicle to grid (“V2G”) technologies are an important future aspect of the smart grid that envisions plug-in vehicle batteries serving as nodes in a massively distributed energy storage network that can handle bi-directional power flow. Under V2G protocols, idle vehicles would be able to “return” electricity to the grid during periods of extreme demand, and for grid management services such as frequency regulation or peak shifting. The vehicle owner would stand to benefit from the energy arbitrage (purchasing electricity at a low price and selling at a high price) and could use such incentives to justify the initial capital hurdle of the vehicle. V2G initiatives are still very early and will require real-time information processing and advanced communication between grid, vehicle, and intermediate points such as the home. They also demand logic infrastructure that will dictate the onset, intensity, and duration of discharge and capture the associated economics. Notably, V2Green was an early developer of 2-way grid-to-vehicle connectivity software before its acquisition by GridPoint.

Distributed Grid Outflow: Electric Vehicles (EVs)

The next-generation smart grid will need to meet the charging needs imposed by hundreds of thousands of plug-in electric (EVs) and hybrid electric vehicles (PHEVs) coming online in the next few years. This poses a tremendous grid interconnection challenge because the charging will need to be safe, convenient, and – to the extent that it is “smart” – with as much grid intelligence and vehicle owner buy-in as possible.

Charging is most commonly achieved directly (conductive charging), through a physical electrical connection between the grid and the PEV. In this setup, the vehicle’s battery is connected to an inlet port. The inlet port is designed to accommodate a complementary connector plug, which is attached to a control device (the “heart” of the charging station) via a cord. The charging station serves as the interface to the grid. Charging can also be accomplished indirectly via magnetic induction (inductive charging is working on a wireless charger, for example), but this “charge from a distance” procedure is not as efficient in energy transfer.

Three standardized levels of direct charging have been defined by EPRI’s Infrastructure Working Council (IWC): Level 1, Level 2, and Level 3. Level 1 and 2 describe AC charging, at 120 V and 240 V and maximum power of 2 and 20 kW, respectively. Level 3 charging, also known as “DC fast charging”, uses a 480 V source and transfers a large amount of power: up to 100 kW or greater. A Level 3 charging approach can replenish a large vehicle battery in 20 minutes or less.

Level 1 and 2 charging will most commonly be handled with a 5-pin coupler sanctioned by the Society of Automotive Engineers (SAE), the J1772 standard. All new electrics and hybrids to be introduced in the US market, including the Nissan LEAF and GM/Chevy Volt, are expected to be J1772-compliant, and new residential and commercial charging stations will be J1772 connector-equipped. The link between the charging station and grid can be made via a standard 3-prong 120 V NEMA 5 plug and receptacle (Level

1) or via a dedicated hardwired high voltage connection (Level 2). While the SAE has not yet settled on a Level 3 standard, an important Level 3 protocol has been established by Tokyo Electric and Power (TEPCO's) consortium with industry partners Nissan, Toyota, Mitsubishi, and Fuji Heavy Industries. Known as CHAdeMO, this standard is being incorporated in charging stations from Aker Wade and SGTE Power, for example.

SAE J1772 Interface	Level 1 Charging	120 V, 16 A, 2 kW Typical
	Level 2 Charging	240 V, 30 A, 7 kW Typical
CHAdeMO JARI Interface	Level 3 Charging	480 V, 200 A, 100 kW Typical

It is estimated that fewer than a thousand charging stations have been installed nationwide to date. DOE's $100 M EV Project, being led by Ecotality's ETec subsidiary, is expected to add over 12,000 stations in 5 states. Additionally, in a project funded partially by ARRA, Coulomb Technologies is slated to deploy 4,600 ChargePoint networked stations in 9 major urban centers by 2011 (roughly 2,000 residential and the rest commercial). The installed price for most Level 2 residential charging systems is roughly $1,500 per home, while commercial points are expected to cost $3,000 and beyond. Much of the cost is represented by installation, not the actual hardware/software. It remains to be seen whether charge terminals will command a strong commercial footprint or whether most charging will take place at residential sites or fleet centers.

Due to the large power loads involved in PEV charging, utilities and industrial partners will need to strongly incentivize PEV owners to charge their vehicles during off-peak periods. To frame this in quantitative terms, the summer peak load of the average California home is approximately 5 kW. Typical Level 2 residential charging, by comparison, requires more than 7 kW of power. Apart from managing the significant electrical loads to be imposed on the grid, the industry faces challenges such as deploying new vehicle-specific metering techniques, instituting time-of-use protocols, and developing meaningful tariff structures and incorporating them into charging schedules.