U.S. Smart Grid

Finding new ways to cut carbon and create jobs

April 19, 2011

Marcy Lowe, Hua Fan
and Gary Gereffi

CENTER ON GLOBALIZATION Governance & Competitiveness

Contributing CGGC researcher: Ghada Ahmed

This research was prepared on behalf of Environmental Defense Fund:
http://www.edf.org/home.cfm

Picture on cover page is courtesy of the Department of Energy:
http://www.oe.energy.gov/smartgrid.htm

Acknowledgements – The authors would like to thank our anonymous interviewees, who gave generously of their time and expertise. Many thanks also to Jackie Roberts, Isabel Grantham, Miriam Horn, Mark Brownstein, Jesse Berst, Witold Bik, Nicholas Ashworth and John Ruiz for comments on early drafts.

None of the opinions or comments expressed in this study are endorsed by the companies mentioned or individuals interviewed. Errors of fact or interpretation remain exclusively with the authors. We welcome comments and suggestions.

The lead author can be contacted at marcy.lowe@duke.edu.

List of Abbreviations

AC	Alternating current
AMI	Advanced Metering Infrastructure
CGGC	Center on Globalization, Governance & Competitiveness
DC	Direct current
DOE	Department of Energy
EIA	Energy Information Administration
EPRI	Electric Power Research Institute
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission
HAN	Home Area Networks
IEA	International Energy Agency
IT	Information technology
NREL	National Renewable Energy Laboratory
OECD	Organization for Economic Co-operation and Development
PHEV	Plug-in Hybrid Electric Vehicle
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RED	Recycled Energy Development
T&D	Transmission and Distribution
V2G	Vehicle to Grid

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Executive summary

The smart grid is often referred to as an "energy internet"—a decentralized system that turns the electric power infrastructure into a two-way network. This smart system allows utilities and customers to share information in real time so they can more effectively manage electricity use. The Pacific Northwest National Laboratory (PNNL) estimates that a fully deployed smart grid could reduce the U.S. electricity sector's energy and emissions by 12% in 2030.[1] Even greater savings would accrue from tapping the smart grid as an enabler of clean energy sources. If accompanied by substantial support for decentralized power, renewable power, and electric vehicles, smart grid could reduce energy and emissions by an estimated 525 million metric tons, or 18% of the total from the electric sector (PNNL, 2010).

The United States is among the global leaders in smart grid development, which is expected to create tens of thousands of jobs annually in coming years. Previous research suggests that for each $1 million in investment, a range of 4.3 to 8.9 direct and indirect jobs will be created.[2] For example, global energy consulting firm KEMA, using the low end of this range, estimated that 278, 600 U.S. smart grid jobs will be created by 2012, including jobs with utilities, contractors, and suppliers (KEMA, 2009).

In this report, we focus on the subset of these jobs represented by the broad array of supplier firms involved, including those that have traditionally provided electric equipment and those that provide information technology (IT), core communications, smart hardware, energy services, energy management, telecom service, and system integration. We examine 125 leading smart grid firms in order to help assess their potential role in creating jobs. These lead firms provide hardware, software and services, which we divide into nine broad categories of smart grid technologies. Where possible, we identify what hardware, software and services each firm provides, and in which U.S. locations the relevant manufacturing and product development occurs.

Key findings:

1) **Our sample identifies 334 U.S. relevant employee locations in 39 states**. These include 70 sites for hardware manufacturing, 76 for hardware development, 63 for software development and services, and 125 company headquarters. The region with the highest number of total sites is the Southeast (83). The next notable concentration is California—constituting its own region—with 75 total locations. The Midwest is next (74), and then the Northeast (70). Based on levels of investment to date, we estimate that the U.S.

[1] Baseline 2030 emissions as forecast by the U.S. Energy Information Agency (EIA).

[2] 4.3 multiplier is calculated from (KEMA, 2009); 8.9 multiplier is from (Robert Pollin, 2009).

supplier segment alone—which does not include utility jobs—has so far created roughly 17,000 U.S. jobs.[3]

2) **Smart grid provides a way for well-established firms to transition from traditional products into new areas, including new manufacturing opportunities**. For decades, a number of U.S. firms provided equipment for the power industry, but performed the manufacturing increasingly outside the United States. Many of these firms are now transforming from a device-only focus to new products including software, smart controls, and communications. These new activities are largely performed domestically.

3) **The fast-growing global market for smart grid technologies presents valuable export opportunities to be tapped by U.S. firms, large and small.** Smart grid, renewable energy, and electric vehicles are counted among the most promising sectors for increasing exports in the National Export Initiative—the federal government's goal, announced in 2010, of doubling the nation's exports in five years (U.S. DOC, 2010). Industry leaders such as Cisco, GE, Hewlett Packard, and IBM are moving quickly to establish a stake in China's smart grid market (Zpryme, 2010). Much smaller U.S. firms have also won large contracts in China and throughout Europe.

4) **Future U.S. job creation by product vendors will likely concentrate in high-value IT innovations, product development, and systems design and engineering.** Many of the world's leading smart grid vendor firms—including leaders in IT, core communications, energy management, telecom service, and system integration—are either headquartered in the United States or have an extensive U.S. presence. A number of large and small U.S. firms are also pursuing breakthrough innovations in hardware—especially those associated with renewable power, energy storage, or electric vehicles. These activities are often performed in domestic facilities to protect intellectual property.

5) **Others are catching up quickly, so the United States will need to continue emphasizing not just innovation but also supportive policies.** Chinese, Korean, Japanese, and Indian firms have reached U.S. levels or surpassed them in selected innovative technologies, such as high-voltage transmission (Berst, 2011b). Perhaps more important, several countries' smart grid goals reflect energy policies that are not currently emphasized in the United States, including aggressive targets for renewable energy. Similarly ambitious targets in the United States would increase demand for U.S. smart grid firms' products and encourage investment in related clean tech innovations.

6) **Regardless of where smart grid products are made, many additional U.S. smart grid jobs will be located in the service territories of participating utilities, which means they cannot be off-shored.** These will include jobs not covered in this study, such as

[3] Based on 2010 U.S. smart grid spending (public and private) estimated at $8.16 billion, and a CGGC multiplier of 2.14 jobs per $1 million of investment, based on (KEMA, 2009).

direct employment with utilities, contractors, and temporary field offices, engaged in performing construction, installation, maintenance and ongoing services. By definition, these will be local jobs.

To make the most of job opportunities, it will be important for the United States to continue to pursue the cutting edge of smart grid technologies, including those needed for integrating renewables, decentralized sources and electric vehicles into the grid. Collaborations between public and private organizations can play a key catalyzing role. Concentrated local and regional efforts can leverage important partnerships in which R&D is directly connected to new product development, commercialization, new business incubation, and workforce development. Such efforts are needed if the smart grid is to deliver on its considerable promise to reduce CO_2, stimulate technology innovation, and create jobs.

Introduction

The U.S. electric grid, designed more than a century ago, is badly in need of an overhaul. Relying on antiquated equipment put in place long before the benefits of 21st century networking and communication, the highly centralized, one-way system wastes energy and increasingly struggles to keep up with demand. Since 1982, growth in peak power demand—such as on summer days when countless air conditioners are running—has outpaced growth in transmission by nearly 25% per year. Too often, the result is power outages and even blackouts. The U.S. Department of Energy (DOE) reports that such interruptions cost the nation at least $150 billion annually (U.S. DOE, 2008).[4]

A smarter grid offers a cleaner, more efficient way to address the problem of peak demand. Providing peak-hour electricity requires grid operators to use expensive "peaker" plants that sit idle most of the year and require fuel bought on the volatile "spot" market. A truly smart grid would use digital technology to help utilities and customers manage existing resources more efficiently, thus reducing reliance on peaker plants and costly capacity expansions.

Perhaps even more important over the long term is the smart grid's crucial role as "enabler," facilitating the economy's much-needed transition to clean energy. Analysts have noted that the smart grid holds the key to bringing renewable energy options to scale, making them more reliable and affordable (Leeds, 2009a). In addition, as the automotive industry makes its expected shift to electric vehicles in the coming decades, a smart grid will be needed to meet the challenge of charging millions of plug-in hybrid and all-electric vehicles.

The smart grid encompasses many technical, economic and social goals, including making the grid more reliable and enhancing safety and national security. In this report, however, we will limit our focus to aspects of the smart grid that can potentially reduce energy use and carbon emissions. We ask the question, "What will these developments mean for U.S. jobs?"

Our analysis is structured as follows: First we will give an overview of the most important carbon-reducing functions of the smart grid. Next we will briefly describe the state of global smart grid development, placing the United States' trajectory in the context of other leading countries. Then we will map out the U.S. value chain for smart grid hardware, software and services, drawing upon the extensive contribution made in recent studies by the Cleantech Group (Neichin & Cheng, 2010) and Greentech Media Research (Leeds, 2009a). Finally, we will discuss the types of U.S. jobs involved, where they will likely be located, and what workforce development will be needed in order to fully tap the carbon-reducing benefits of the smart grid.

[4] The DOE reports that the demand problem is compounded by "an economy relentlessly grown digital." In the 1980s, electrical load from sensitive electronic equipment such as computerized systems, appliances and automated manufacturing was very small. Today this "chip" share is 40%, and it is expected to exceed 60% by 2015 (U.S. DOE, 2008).

How can a smarter grid reduce CO_2 emissions?

The smart grid is often referred to as an "energy internet"—or a decentralized system that turns the electric power infrastructure into a two-way network. This smart system would enable utilities and customers to share information in real time so they can more actively and effectively manage electricity use. The smart grid has potential to reduce carbon emissions in at least four ways: by improving energy efficiency, by encouraging renewable and distributed energy, by communicating between utility and consumers about deferrable loads, and by facilitating the adoption of plug-in hybrid and all-electric vehicles.

In 2008, the Electric Power Research Institute (EPRI) estimated that smart grid mechanisms could reduce greenhouse gas emissions by 60 to 211 million metric tons annually in 2030 (EPRI, 2008). In 2010, the Pacific Northwest National Laboratory (PNNL) made follow-on estimates. Assuming full deployment (100% penetration), PNNL estimated that direct smart grid mechanisms could reduce the U.S. electricity sector's energy and emissions by 12%, and the indirect mechanisms by another 6%, for a total direct and indirect reduction of 18%, or 525 million metric tons of carbon.[5] The researchers concluded that while the smart grid is not the main tool for meeting aggressive national goals for carbon savings, it can make a very substantial contribution. They further noted that a smart grid could help remove barriers to high penetration of distributed renewable energy (PNNL, 2010).

Five carbon-reducing "buckets"

For this report, we have divided the smart grid into five energy-saving and emissions-reducing "buckets," shown in Figure 1:

Smart power will harness new devices and accompanying communications networks to save energy in at least two important ways. First, utilities can optimize voltage and avoid overkill. Since voltage gradually decreases on a feeder line, utilities often transmit excessive voltage to ensure that the end of the line receives the minimum standard during peak load, thus "overjuicing" residents with more power than they need. Smart power delivery would save energy by continuously monitoring and correcting voltage as needed (Leeds, 2009a).

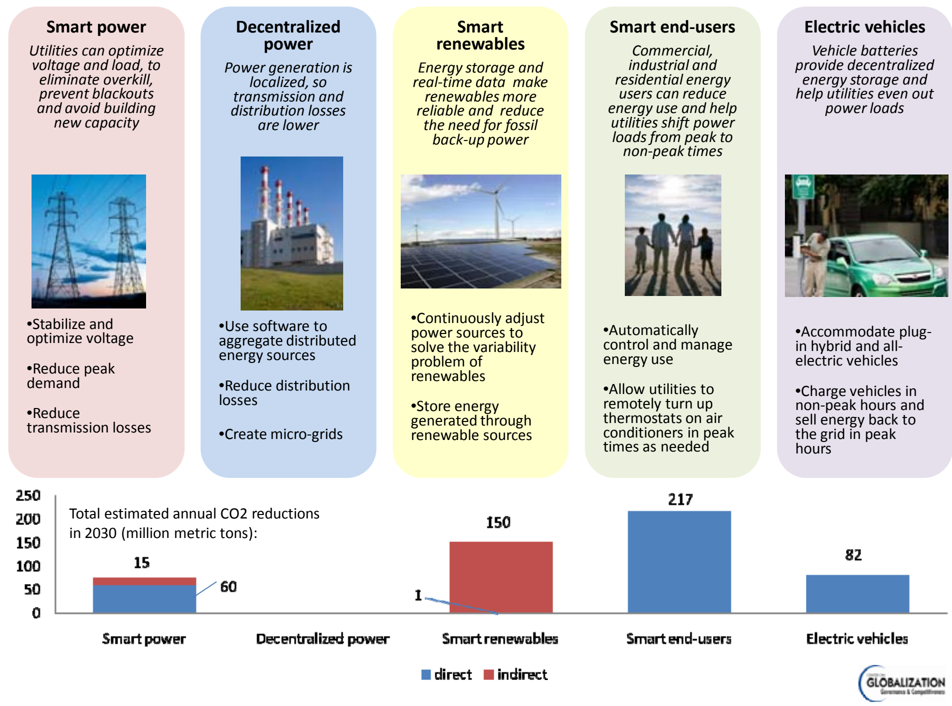
Second, smart technologies enable utilities to reduce peak demand. Whereas the old grid focuses only on supply, a smarter system can communicate with customers to control and reduce demand, and to steer it away from peak hours. For example, customers can allow the utility to turn up the air conditioner thermostat remotely for brief periods as needed. By reducing peak demand, utilities can avoid capacity expansions and reduce the use of inefficient peaker plants.

An additional option is building superconductive transmission lines. Although building new transmission lines is not typically considered a smart grid effort, new superconducting direct

[5] Baseline 2030 emissions as forecast by the U.S. Energy Information Agency (EIA).

current (DC) cable is estimated to reduce transmission losses at full load by 50 percent or more. The technology shows promise for efficiently transporting power to cities from large, remote wind farms. EPRI reports that if the technology continues to improve in performance and cost, within a decade such lines could be built with commercially available technology and construction methods like those used in building gas pipelines (EPRI, 2009).

Figure 1. Five carbon-reducing "buckets" of smart grid technology



Notes:

1. *PNNL authors estimated the total direct and indirect reductions at 525 million metric tons (18% of U.S. total), which assumes a policy decision to reinvest capital savings into further efficiency and renewables.*
2. *Separate data on decentralized power are not included in the PNNL study.*

Source: CGGC, based on (PNNL, 2010).

Decentralized power such as small wind farms, roof-top solar panels or combined heat and power facilities,[6] can benefit from the smart grid's two-way power flow to generate clean electricity virtually anywhere and sell it to the grid. Also called "distributed generation," such alternatives to the centralized grid are closer to the end user and so create much lower distribution losses. They can help utilities increase feeder capacity limits and, if adopted widely, mitigate peak problems (Wildeman, 2009).

[6] Combined heat and power captures the waste heat from on-site electric generators and uses it to heat nearby buildings. Or, in a related process called energy recycling, waste heat and gases from industrial processes can be captured and used to generate electricity. See Recycled Energy Development (RED) website, http://www.recycled-energy.com/

An area with further potential is the concept of microgrids. Hospitals, data centers, and other institutions that cannot afford even the briefest power outage often provide their own backup power. In a stand-alone microgrid, several decentralized power sources in a region, neighborhood or campus could link together and operate their own autonomous grid. Modern inverter technology (devices that convert direct current to alternating current) would remove a present obstacle to microgrids by allowing them to quickly and safely disconnect and reconnect to the wider grid as needed. Microgrids would also serve the grid by providing crucial backup and helping stabilize loads (St. John, 2010). Clean tech research firm Pike Research reports that the United States is well positioned to be a global leader in microgrids, projecting that institutional and campus microgrids alone will add 940 MW of new capacity by 2015, valued at $2.76 billion (Pike Research, 2009).

Smart renewables. A daunting obstacle to renewable energy sources is their intermittent nature. Power generated from the wind or sun can nosedive when the wind dies or the sun is covered by clouds. Using these energy sources at grid scale therefore requires utilities to supplement them, often with gas-fired peaker plants. At the same time, excess wind and solar power can also go to waste when demand is low.

A smart grid could address both problems by continuously monitoring and adjusting all its energy resources to ensure that a steady supply reaches the customer. More important, advances in energy storage would make wind and solar power reliably available when most needed, reducing the role of non-renewable peakers. The leading grid-level energy storage options are pumped hydro and compressed air. Utilities can use the hydro option by pumping water uphill into reservoirs during non-peak hours and releasing it later to generate power during peak times. Similarly, air can be compressed and later released to spin a turbine. Several utilities have received DOE stimulus grants for compressed-air projects, including one project in Iowa that would use wind power to compress the air (Achenbach, 2010).

Smart end-users can get direct feedback on their energy use and actively control it, automatically exchanging information with the utility in real time. A wide variety of "demand response" programs encourage end-users to reduce electricity demand in response to price signals. Although few U.S. utilities today offer "time of use" pricing, a change to variable pricing combined with the necessary metering infrastructure would allow customers to see the cost differences between peak and non-peak power, and shift some electricity use to non-peak times. Smart appliances, which could be programmed to run at non-peak times, would help users automatically shift their electricity use to when power is cheaper to produce. If utilities were to pass this price differential on to customers, this would tap tremendous potential to reduce peak demand.

Many large commercial and industrial power customers already pay different rates according to time of use, so they have incentive to shift demand way from expensive peak periods. If applied to residential customers, similar "load control" programs would allow a utility to sign a customer contract allowing the utility to remotely turn down a home's air conditioning and certain appliances as needed (for brief periods, in agreed-upon ways), saving the customer money with little or no inconvenience. To date, such programs have not typically been extended to residential power customers, who in most cases pay fixed, single rates.[7]

Federal Energy Regulatory Commission (FERC) Chairman Jon Wellinghoff has called demand response the “killer app” of the smart grid (FERC, 2008). If combined with variable pricing, demand response programs could be extended to millions of households. A study prepared for FERC estimated that demand response programs, if fully deployed, could cut U.S. peak electricity demand in 2019 by 20 percent, eliminating the need for roughly 2,000 peaker plants (The Brattle Group et al., 2009).

Electric vehicles (EVs), including plug-in hybrids and all-electrics, will reduce vehicle-related emissions and use fuel more efficiently than gasoline-powered transportation. DOE researchers estimate that with the current mix of power plants and vehicles, a shift to EVs could reduce foreign oil imports by 52%, and, for every vehicle-mile of travel, reduce CO_2 emissions by 27% and energy consumption by 30% (PNNL, 2010).

Accommodating millions of EVs will require a smarter grid, so that vehicle charging times are spaced evenly enough to avoid worsening peak loads. A smart connection can be added to allow the electricity to flow two ways, enabling users to charge their vehicles at night, drive to work, then send power back to the grid while vehicles are parked at the workplace all day. This vehicle-to-grid (V2G) arrangement could provide utilities with much-needed energy storage to help meet peak day-time demand. In September 2010, FERC’s Jon Wellinghoff stated that electric vehicle drivers should be able to make money in V2G arrangements, which would help reduce the costs of vehicle ownership while helping utilities continuously balance energy supply and demand. Wellinghoff noted that this could earn vehicle owners up to $3,000 per year (LaMonica, 2010).

Estimated energy and CO_2 reductions

How much difference can the smart grid make in reducing energy use and carbon emissions? The DOE’s Pacific Northwest National Library (PNNL) analyzed the energy- and carbon-reducing potential of several smart-grid mechanisms, drawing on three major studies and using emissions in 2030 forecast by the U.S. Energy Information Agency (EIA).[8] PNNL found that the largest direct category is “smart end-users,” potentially yielding an annual CO_2 reduction of 217 million metric tons. The remaining categories yielded reductions in the following order: “electric

[7] Fully tapping “smart end-user” potential will require eliminating the single fixed retail rate for electricity, so customers are motivated to shift consumption to off-peak hours. As Greentech Media analyst David Leeds wrote, “A smart meter without a smart rate schedule is not smart at all.” (Leeds, 2009b)

[8] The PNNL report used a framework of nine smart grid mechanisms, which roughly corresponded to our 5-bucket scheme. We used our own judgment to assign each mechanism to what we deemed the most relevant bucket.

vehicles," including plug-in and all-electric vehicles, at 82 million metric tons, "smart power providers," at 60 million metric tons, and "smart renewables," at 1 million metric tons.

The study further calculated *indirect* reductions, or those made possible if the capital saved from these direct energy and CO_2 savings were reinvested in further energy efficiency. Such indirect reductions would depend, of course, on a policy decision to reinvest capital savings accordingly. Indirect reductions were highest for smart renewables, at 150 million metric tons. If support for additional EVs and plug-in hybrid electric vehicles (PHEVs) is included (82 million metric tons), the total estimated energy and CO_2 reductions climb to 525 million metric tons, or 18% of the total U.S. electricity sector (PNNL, 2010).

Smart grid's role as enabler

Many analysts have rightly emphasized that the smart grid's clean energy benefits are not automatic. There is a risk that smart grid efforts could actually take away from clean energy, if investments do not specifically support energy efficiency, distributed generation, renewable energy and electric vehicles. Smart grid has significant potential to enable such resources, but only if accompanied by policies that give utilities and consumers adequate incentives to embrace them.

Analysts have also stressed the need for regulatory reforms, a daunting challenge for a system in which each state has its own public utility commission. Many have noted that making the power sector more energy efficient will require regulatory reforms to remove utilities' inherent profit motive to sell more energy. Energy consulting executive Peter Fox-Penner makes the case for transforming utilities so that they act more as energy service providers who find it in their best interest to actively pursue energy efficiency and accommodate renewable and decentralized power sources. This change will require creating not just a smart grid, but an entirely new business model for power providers. Fully tapping the clean energy potential of the smart grid, according to Fox-Penner, will depend on "the intelligence of the institutions we create, not that of the hardware and software we deploy" (Fox-Penner, 2010).

U.S. smart grid in the global context

In a recent analysis, the International Energy Agency (IEA) concluded that "the development of smart grids is essential if the global community is to achieve shared goals for energy security, economic development and climate change mitigation" (IEA, 2011). The report emphasizes that to realize these benefits, greater investment is needed in large-scale, system-wide demonstrations. To date, most pilot projects have been dominated by advanced metering infrastructure, which consists of the hardware, software, and communications that provide the foundation for the smart grid. By contrast, important smart grid applications that will be built upon the network infrastructure—including those needed to accommodate grid-scale renewable energy, distributed power, and electric vehicles—are still in their infancy. Networking giant Cisco expects the communications network underlying the smart grid to be 100 or 1,000 times larger than the internet (The Economist, 2009). Its vast potential will lend itself not only to the electric power grid, but also to gas and water utilities and waste management (Lux Research Inc., 2008).

Analysts consider global smart grid development quite immature to date, although it is growing quickly. Estimates of total market size differ, depending on what analysts include in their definition of the smart grid. According to market research firm SBI Energy, the global market value of products to enable the smart grid has grown from an estimated $26 billion in 2005 to more than $69 billion in 2009, a compounded annual growth rate of 22%. Total market value is expected to exceed $186 billion by 2015 (SBI Energy, 2010).

Lead countries in smart grid stimulus investments

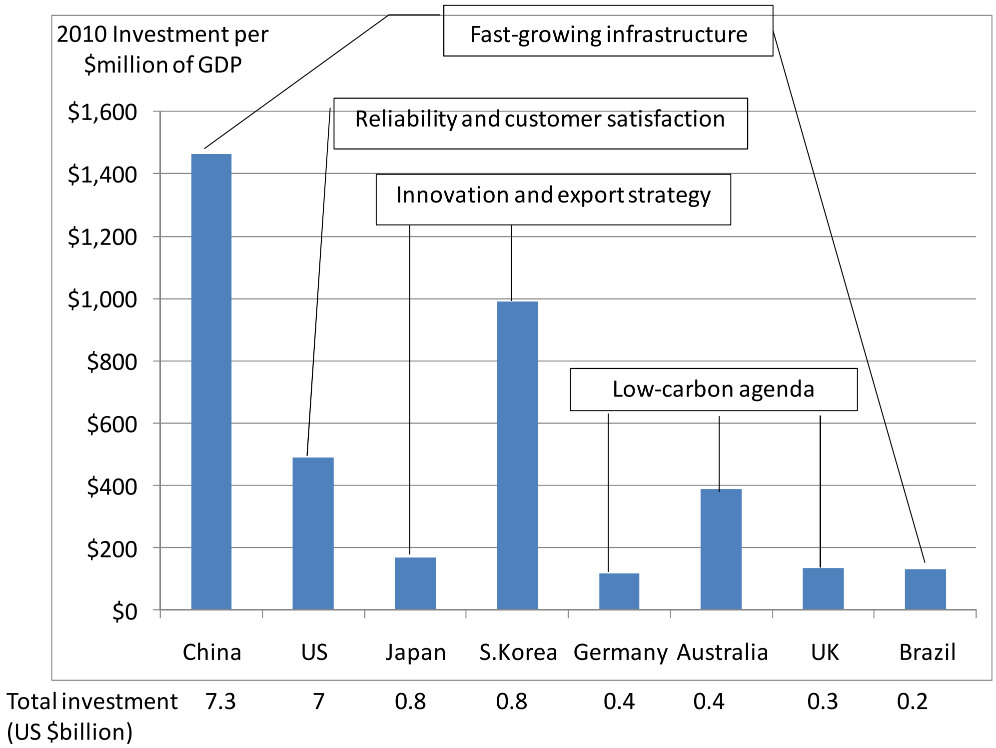
Figure 2 shows eight of the top ten governments investing in smart grid in 2010, expressed in total investment and investment per million dollars of GDP. China is the leader in both categories, with $7.3 billion total investment, or $1,400 per $US million of GDP. As China builds out its modern grid to accommodate extraordinarily rapid growth, it is adopting smart grid technologies from the beginning.[9] Each country has its own emphasis in smart grid development.[10] For example, the U.S. smart grid effort to date has emphasized updating the outmoded "legacy" power system to improve customers' experience. Japan and South Korea appear to be pursuing intellectual property development and economic growth. Meanwhile, in Germany, Australia, and the United Kingdom, smart grid efforts are a specific part of a low-carbon agenda (World Economic Forum & Accenture, 2010). In addition to these countries, Sweden and Denmark stand out for integrating the smart grid into a holistic low-carbon vision.

[9] According to a Bloomberg report, building its modern grid will cost China up to $10 billion per year through 2020 (Zpryme Research & Consulting, 2010)

[10] The analysis of various countries' primary drivers of smart grid investments is taken from (World Economic Forum & Accenture, 2010).

Sweden is the first country in the world to hit 100-percent penetration for smart meters (Berg Insight, 2010).

Figure 2. Leading countries' focus for stimulus investment in smart grid, 2010



Source: CGGC, based on (World Economic Forum & Accenture, 2010; Zpryme Research & Consulting, 2010)

U.S. smart grid development

By some measures, the United States' smart grid efforts seem to be lagging those of other countries. Adoption of smart meters is an example. While U.S. coverage is growing quickly, with 50% of all households expected to have smart meters by 2020, the European Union has mandated 80% penetration by 2020—the same year in which the largest Asian-Pacific economies are expected to approach 100% penetration (Enbysk, 2010). Another weak area is commitment to renewable energy, a prominent feature of smart grid strategies in Europe and China. The United States has no national renewable energy target, and renewables' share of domestic electricity generation is only 7% (U.S. EIA, 2010). Approximately 20% of electricity in OECD Europe is from renewable sources (IEA, 2010). Northern Ireland has a renewables goal of 40% by 2020, and Portugal expected to reach 45% renewables in 2010 (Enbysk, 2010).

U.S. investment in smart grid is growing quickly, however. The federal government has helped spur this momentum with $3.4 billion in federal stimulus grants. Nearly every major U.S. utility is undertaking smart grid efforts, most of them, to date, focusing on smart metering. Of the $200 billion of expected global investment in smart grid from 2008 to 2015, more than $50 billion is expected to be in the United States. (Bogoslaw, 2010).

Leading U.S. smart grid firms

The smart grid value chain brings together a wide range of vendors, power providers, investors, regulators, government agencies, research institutions, and standard-setting organizations. In this study we focus in detail on the vendors—a category that, in itself, comprises hundreds of firms[11] from a broad array of industries. Most of these can be described as follows, with a few examples of firms:

- **"Legacy" power firms** that have traditionally provided electric equipment and are now involved in smart grid-related hardware, software and services (ABB, GE, Cooper Power Systems, S&C Electric Company)
- **IT firms** that provide communications, networking, and data management (Cisco, IBM)
- **Communications firms** that provide products for advanced metering infrastructure (Motorola, Silver Spring Networks, SmartSynch, Trilliant)
- **Meter hardware firms** that provide smart meters (Itron, Landis+Gyr, Sensus)
- **Energy services firms** that provide curtailment services to reduce peak demand (Comverge, Constellation Energy, EnerNOC)
- **Energy management firms** that provide automation, monitoring, and control systems for buildings (Honeywell, Johnson Controls, Schneider Electric)
- **Telecom service firms** that provide cellular network access (AT&T, Sprint, Verizon)
- **System integration firms** that help manage data from millions of smart devices (Accenture, Capgemini, SAP)

For this report, we focus on 125 leading smart grid vendors, most of which were identified by two recent, comprehensive reports, by Cleantech Group (Neichin & Cheng, 2010) and by GTM Research (Leeds, 2009a).[12] To construct our U.S. value chain of specific hardware, software and service products, we used the above two resources, additional industry reports, and company websites. To improve and confirm our product break-out and identify relevant U.S. employee locations, we then completed phone and email contacts with approximately half of the 125 identified firms.

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[11] In its recent report, *2010 U.S. Smart Grid Vendor Ecosystem*, the Cleantech Group drew on a total database of 600 relevant firms. Our simplified list of vendor types is based on the Cleantech Group's much more in-depth analysis.

[12] To further understand the complex dynamics of the industry, we followed updates in the informative online publication "Smart Grid News," at http://www.smartgridnews.com/index.html.

U.S. vendor value chain

Our depiction of the U.S. value chain for smart grid vendors is found in Figure 3. The left-to-right structure begins with power generation, moves through transmission and distribution, and ends with consumption. This roughly parallels the process in which electric power is delivered to the customer: first electricity is generated, then it is stepped up by transformers to a high voltage so it can be transmitted over long distances (similar to the way high water pressure is needed to transport water), then it arrives at a substation, where it is stepped back down to a lower voltage that is safer for local distribution. Most smart grid activity is focused not on transmission but on the distribution side of the chain—the part that stretches from the substation to the customer.[13]

As for the hardware, software and services that make up the smart grid market, they can be thought of as two market segments. In the first market (utility side), products for generation, transmission and distribution are largely sold by vendors to utilities. In the second market (consumer side), products tend to be sold directly to consumers, often with utilities' close cooperation (Kanellos, 2010).

In Figure 3, the main functional categories we chose to break out (eight colored boxes with headings in bold) are divided into major product types (white boxes). Selected leading U.S. vendors are listed for each product (hardware in black font, software and/or services in red). The eight functional categories in the vendor value chain can be summarized as follows:[14]

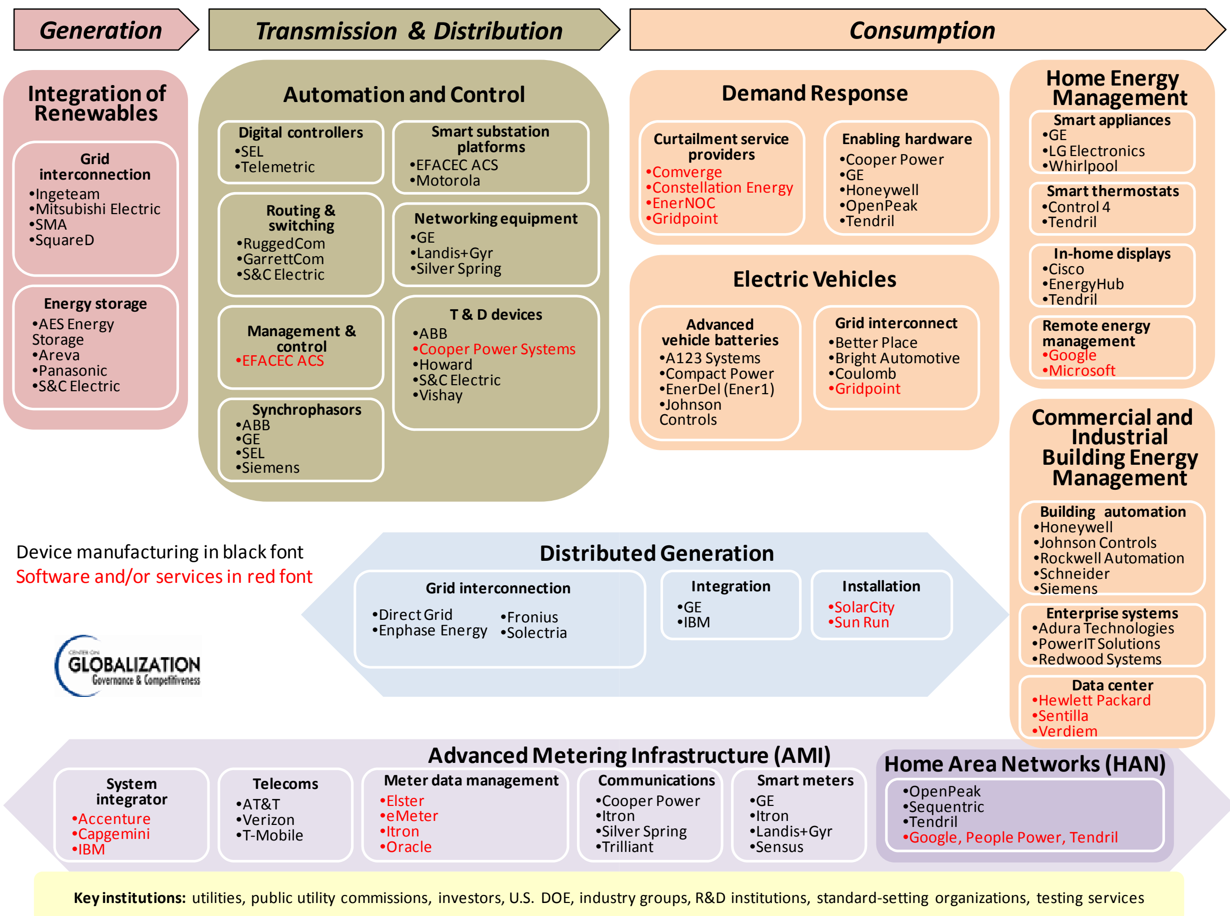
Integration of Renewables. Successfully connecting solar arrays, wind farms and energy storage to power grids requires not only standard technologies traditionally used to connect traditional sources such as coal and nuclear, but also important additional products. For instance, because solar panels produce direct current (DC), they require inverters to convert DC to AC power. To connect the grid to energy storage (necessary to accommodate the variable nature of renewable energy), the storage device itself is required, along with converters (called rectifier inverters), and traditional field equipment associated with conventional power.

Automation and Control. Adding intelligence to the distribution system requires devices that allow better monitoring and control of voltage, improved communication, and the use of real-time information. These improvements to the distribution network do not get as much attention in the media as smart metering, but they have vast potential for improving system efficiency, making the grid more reliable, and saving energy. Lead firms in this space are the legacy power equipment firms such as ABB, Cooper Power Systems, GE, and S&C Electric Company.

[13] GTM Research analyst David Leeds writes, "The challenges at the transmission level are less about adding intelligence, and more about ensuring that there are adequate amounts of transmission to move bulk power to where it is most needed" (Leeds, 2009a).

[14] To divide the value chain into these categories, we drew heavily on Neichin & Cheng, 2010. Our framework is a much-simplified variation. We encourage readers to refer to Neichin & Cheng for their more in-depth analysis.

Figure 3. U.S. smart grid vendor value chain



Source: CGGC, based on company websites, industry interviews, and industry sources.

Demand Response. To create a large pool of capacity to reduce peak power loads through demand response, utilities turn to curtailment service providers. These are firms that aggregate demand response customers and serve as the sole point of contact to the utility. The two main firms of this kind are Comverge and EnerNOC. Although demand response is primarily a service model, specific hardware is required to achieve the necessary communication, monitoring, control and automation. Lead firms include Cooper Power Systems, GE, and OpenPeak.

Electric Vehicles. Electric vehicles rely on energy storage in the form of advanced vehicle batteries.[15] Connecting electric vehicles to the grid requires recharging stations. If the stations are designed to allow power to flow both ways, electric vehicles can serve as a source of distributed energy storage—discharging electricity back to the grid during hours when the vehicle is parked

[15] For a U.S. value chain analysis of lithium-ion batteries for vehicles, see the recent CGGC report, "Lithium-ion Batteries for Electric Vehicles: The U.S. Value Chain" (Lowe et al., 2010).

and peak power is needed. Leading storage and interconnection firms include power giants (ABB), advanced lithium-ion battery manufacturers (A123 Systems), global diversified technology and industrial leaders (Johnson Controls), IT firms (Cisco) and specialty firms (Better Place, Coulomb Technologies).

Home Energy Management. Expanding on the original concept of programmable thermostats, HEM systems include many more options: smart appliances, displays that allow customers to monitor and manage their energy use, and remote control capability from any location outside the home. Leaders include IT firms (Google), in-home display providers (EnergyHub) and new specialty firms providing software platforms and systems (Tendril).

Commercial and Industrial Building Energy Management. Large firms such as Johnson Controls and Honeywell have provided building automation systems for years, but now they are making them more integrated, using networked sensors and monitors and incorporating data from individual systems such as lighting and heating, ventilation and air conditioning (HVAC). In addition to the longstanding, vertically integrated firms (Schneider Electric), emerging leaders include demand response firms (Constellation Energy), and venture-backed firms (PowerIT Solutions).

Distributed Generation. Accommodating small-scale, distributed power sources (such as rooftop solar) requires different capabilities from those for grid-scale renewable sources (concentrating solar array). A key technology for small-scale solar is micro inverters (DirectGrid Technologies). Because of extensive, complex safety regulations, installers play a crucial role in selecting equipment on behalf of customers and making sure it conforms to requirements (Sun Run).

Advanced Metering Infrastructure (AMI). The foundation of the smart grid's two-way flow of data, and the key to most smart grid efforts to date, is the underlying infrastructure that combines smart meters, communications and data management. Leading firms include smart meter vendors (Landis+Gyr), those that provide the network infrastructure to transmit data from smart meters to the utility (Silver Spring Networks), those that provide access to cellular networks (AT&T), and those that provide software to compile and manage the massive quantities of data produced (eMeter).

Hardware, software and services

We collected data on 125 leading firms to get a sense of how the activity is distributed between hardware, software and services. We divided the major smart grid technologies into four categories on the utility side (AMI; energy storage; grid interconnection for renewables or EVs; and transmission and distribution) and five categories on the consumer side (commercial and industrial building management; demand response; EV charging; home energy management; and smart appliances, thermostats or plugs). A summary of the data from all 125 firms appears in

Table 1. To view the full 10-page table listing each company's footprint, please see Appendix A on page 33.

Table 1. 125 lead smart grid vendors: footprint in hardware, software and services

	Utility side				Consumer side				
	AMI	Energy storage	Grid interconnect of renewables or EVs	T&D	CI building energy mgt [a]	Demand response	EV charging	Home energy mgt	Smart appliances, thermostats or plugs
Firms involved in hardware total: 128 [b]	32	11	7	32	8	5	11	10	12
Firms involved in software and/or services total: 140[c]	44	7	8	8	23	21	9	20	0

a: Commercial and industrial building energy management
b: Each firm may be involved in multiple categories. Number of unique firms involved in hardware is 88.
c: Number of unique firms involved in software and services is 81.

Sources listed in full table in Appendix A.

Our analysis is far from exhaustive; it provides only a snapshot, based on a sample of leading firms drawn from a much larger and rapidly evolving industry marked by many new entrants, new technologies, and mergers and acquisitions. Despite this limitation, the data do yield a few useful conclusions about the participation of leading U.S.-based vendors to date:

- Measured by number of firms involved, overall vendor activity is split almost evenly between hardware (88 unique firms involved) and software/services (81 unique firms involved).
- More firms have been involved on the utility side (94 unique firms) than on the consumer side (61 unique firms). It is not surprising that the utility side is larger, since most activity to date has focused on advanced metering infrastructure, the foundation of much consumer-side activity.
- Most technology categories involve a fairly even mix of hardware, software and services firms. Notable exceptions include transmission and distribution, in which more firms are involved in hardware (32) than in software/services (8). Similarly, demand response involves only a few hardware firms (5) and many more in software/services (21). Smart appliances, thermostats and plugs involve hardware only (12 firms).

- Over 70% of firms in our sample appear in one of the nine technology categories only. The remaining 30% appear in two or more categories. For instance, selected global, vertically integrated Fortune 100 companies (GE, Honeywell, Siemens) develop and manufacture hardware across three or more categories. Several newer firms provide software and services across at least five categories (BPL Global, Gridpoint, Sequentric).

U.S. jobs

The United States is among the global leaders in smart grid development, which is expected to create tens of thousands of domestic jobs annually in coming years. Previous research suggests that for each $1 million in investment, a range of 4.3 to 8.9 direct and indirect jobs will be created.[16] For example, global energy consulting firm KEMA, using the low end of this range, estimated that 278, 600 U.S. smart grid jobs will be created by 2012, including jobs with utilities, contractors, and suppliers (KEMA, 2009).

Many smart grid jobs are associated with vendors that supply the utilities and sell products and services directly to electricity consumers. For this report, we focus on what the leading vendor activities mean for U.S. employment, especially jobs in manufacturing. Our analysis is based on industry research and our contacts with roughly half the firms in our sample of 125 leading smart grid vendors with a major presence in the United States. Based on levels of investment to date, we estimate that the U.S. supplier segment alone—which does not include utility jobs—has so far created roughly 17,000 U.S. jobs.[17]

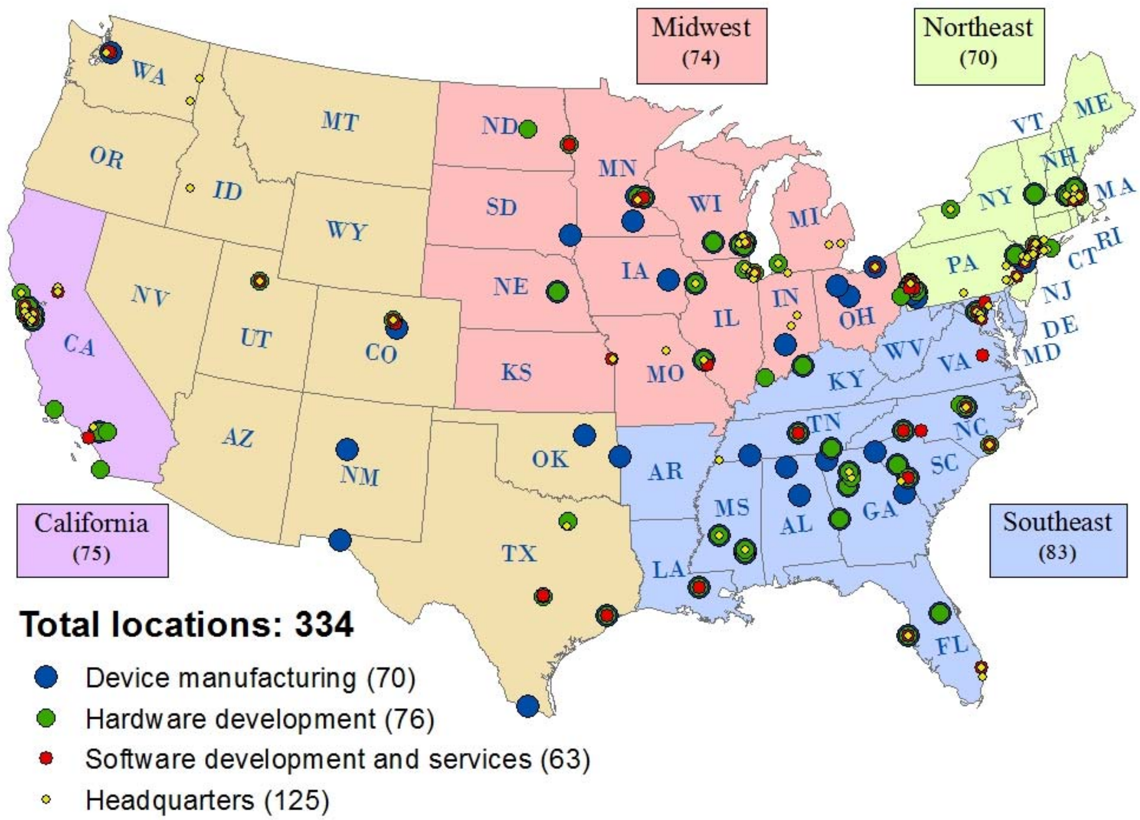
Relevant locations

For our sample of 125 leading firms, we identified relevant U.S. locations for four categories of activity: hardware development, hardware manufacturing, software development/services, and company headquarters. Our purpose is to help provide a basis for comprehensive job estimates in future research, by first delineating the main relevant activities (see Appendix A on page 33) and identifying their U.S. locations. Please note that these data are not exhaustive—covering only the locations for leading firms, where available—and our analysis is only a snapshot of a landscape that is changing rapidly. Our map of relevant U.S. locations is found in Figure 4.

[16] 4.3 multiplier is calculated from (KEMA, 2009); 8.9 multiplier is from (Robert Pollin, 2009).

[17] Based on 2010 U.S. smart grid spending (public and private) estimated at $8.16 billion, and a CGGC multiplier of 2.14 jobs per $1 million of investment, based on (KEMA, 2009).

Figure 4. Relevant employee locations of leading U.S. smart grid vendors



Note: Software development and services (63 sites) is an undercount, since these activities often are also performed at company headquarter sites.

Source: CGGC, based on industry interviews and company websites.

We identified a total of 334 U.S. locations spread across 39 states, including headquarters, device manufacturing, hardware development, and software development/services. The three states with the most locations are California, Pennsylvania and North Carolina. The data showed the following characteristics:

- **Headquarters**. The firms represent 125 headquarters distributed over 27 states. Top regions for headquarters include the state of California (35), the Northeast (33) and the Southeast (25). Other top states for company headquarters are New York (10) and North Carolina, Massachusetts and Pennsylvania, each with 8 headquarters. Cities with the most headquarter locations are San Francisco (6), Redwood City, CA (5) and Raleigh, NC (5).
- **Device manufacturing**. The sample yielded 70 device manufacturing locations distributed over 31 states. The top three states are California, Georgia and Texas (5 each). Unlike headquarters, which clustered in several “favorite” cities, manufacturing locations were much more dispersed.

- **Hardware development**. A total of 76 hardware development locations are distributed over 27 states. The top three states are California (17), Wisconsin (6) and Pennsylvania (5). The top cities for identified hardware development sites are San Jose, CA (3), Milwaukee, WI (3), Petaluma, CA (2), San Francisco, CA (2), and Germantown, MD (2).
- **Software development**. A total of 63 software development and/or services locations are distributed over 23 states. The top three states are California (18), North Carolina (4) and Pennsylvania (4). The cities with most software development and/or services locations are Palo Alto, CA (3), San Francisco, CA (2), San Mateo, CA (2), Raleigh, NC (2), and Austin, TX (2).

The above data on company locations are summarized in Table 2. For a complete table listing each company in our 125-firm sample—including data (where available) on year of founding, employee size range, sales range, and identified locations, please see the full 14-page table in Appendix B on page 43.

Table 2. Relevant U.S. job locations of leading U.S. smart grid vendors: summary data

	U.S. headquarters	Device manufacturing	Hardware development	Software development and/or services
Total number of locations	125	70	76	63
Total number of distributed states	27	31	27	23
Top regions	California - 35 Northeast - 33 Southeast - 25 Midwest - 23	Southeast - 26 Midwest - 18 Northeast - 12 California - 5	Midwest - 20 Southeast - 20 California - 17 Northeast - 14	California - 18 Midwest - 13 Southeast - 12 Northeast - 11
Top states	CA - 35 NY - 10 MA - 8 NC - 8 PA - 8	CA - 5 GA - 5 TX - 5	CA - 17 WI - 6 PA - 5	CA - 18 NC - 4 PA - 4
Top cities	San Francisco, CA - 6 Redwood City, CA - 5 Raleigh, NC - 5	Fremont, CA - 2	San Jose, CA - 3 Milwaukee, WI - 3 Petaluma, CA - 2 San Francisco, CA - 2 Germantown, MD - 2	Palo Alto, CA - 3 San Francisco, CA - 2 San Mateo, CA - 2 Raleigh, NC - 2 Austin, TX - 2

Source: CGGC, based on industry interviews, company websites, D&B Selectory database and Hoover's database.

Workforce development

The smart grid's infusion of IT with the traditional power sector will require new efforts in workforce development. The utility industry itself will undergo extensive changes; managers will need training on the many new options available, existing computing systems will require users to have new IT skills, and electrical engineers and workers will need training on building and connecting new networks (Fehrenbacher, 2009). Installing and maintaining advanced devices will also necessitate new skill sets. To prepare the workforce, new approaches will be needed in universities, community colleges and technical schools, as well as on-the-job training for electrical equipment manufacturers.

A useful example of a concerted local effort to attract smart grid jobs and prepare the workforce is the City of Austin, Texas. Austin has a unique setting, with a state-owned grid and a city-owned utility, Austin Energy, which operates the nation's largest green power program.[18] The city has undertaken a smart grid initiative by collaborating with 15-20 public and private organizations, including leading smart grid firms and the University of Texas. UT-Austin is playing a central role in researching, developing and commercializing new smart grid technologies and providing an incubator to help new clean tech companies in the area succeed. The Austin collaboration aims to train or retrain workers for jobs ranging from electricians, installers, repair workers and technicians, to higher-paying jobs such as project managers and civil, electrical, and mechanical engineers. The goal is to prepare 25,000 people in Central Texas over ten years (Austin Chamber of Commerce, 2009).

Recognizing workforce needs, the U.S. Department of Energy in April, 2010 announced awards of nearly $100 million for 54 smart grid workforce training programs nationwide. Roughly $42 million is devoted to developing curriculum and training programs, with $58 million for carrying out the training. Grantees estimate that the programs will train approximately 30,000 people (U.S. DOE, 2010). An additional $44 million was awarded to state public utility commissions to provide the training needed to improve the application review process for utilities' smart grid project proposals (U.S. DOE, 2009). The training will dramatically increase the number of personnel qualified to review project proposals, which should speed up the application process. This is welcome news for clean power and energy efficiency projects. In past years, some efforts, including solar thermal plants and transmission lines, have taken a year or more to gain approval (Fehrenbacher, 2009).

[18] In 2009, Austin Energy sold the largest amount of renewable energy in the nation, according to an annual assessment by the U.S. DOE's National Renewable Energy Laboratory (NREL)

U.S. opportunities

For basic field equipment, many power sector firms for years have done their manufacturing outside North America, an arrangement that is unlikely to change. Indeed, fast-emerging markets in developing countries, especially in Asia, will contribute further to this dynamic. However, for newer smart grid devices involving electronics, higher-value portions of the manufacturing—such as the addition of customized communication features—often take place in the United States. Since most basic electronics consist of off-the-shelf components made in Asia, it is common for U.S. firms to perform their own product design and engineering to turn these low-value components into innovative communication modules. These are then integrated into final smart products such as smart thermostats, displays, or control units used for demand response services.

Smart grid provides an opportunity for well-established firms to transition from traditional products into new areas. A number of U.S. firms that for decades manufactured equipment for the power industry (performed increasingly outside the United States) are making the switch from device-only products to new applications including software, smart controls, and communications. For instance, Waukesha, Wisconsin-based Cooper Power, founded in 1952, now has 250 engineers working on new smart grid solutions (Cooper Power Systems, 2011). Another example is Chicago-based S&C Electric Company, founded in 1911 (see case study on page 27).

The fast-growing global market for smart grid technologies presents extensive export opportunities to be tapped by U.S. firms. Smart grid, renewable energy, and electric vehicles are counted among the most promising sectors for increasing exports in the National Export Initiative—the federal government's goal, announced in 2010, of doubling the nation's exports in five years (U.S. DOC, 2010). Industry leaders such as GE, Cisco, and Hewlett Packard are moving quickly to establish a stake in China's smart grid market. IBM was noted in 2010 as the only corporation that provided hardware, software and consulting for smart grid infrastructure in China (Zpryme, 2010).

Smart grid software platforms hold particular potential for U.S. firms, including much smaller firms, to sell internationally. An example is San Jose, California-based Echelon, a metering and control technology firm with 350 employees and a 20-plus history of developing intelligent control networking technology to save energy in buildings and homes. The company's LonWorks platform has been incorporated into standards for many industries worldwide. Italy's 30 million installed smart meters all use Echelon technology. Echelon has recently won large contracts in China, Russia, and Denmark (Echelon, 2011; Modern Markets Intelligence, 2011).

Smart grid clearly presents U.S. job potential in a large and growing market marked by rapid innovation. Based on industry research and our interviews with firms, we offer the following observations:

- **Future U.S. job creation by product vendors will likely concentrate in high-value IT innovations, product development, and systems design and engineering.** Many of the world's leading smart grid vendor firms—including leaders in IT, core communications, energy management, telecom service, and system integration—are headquartered in the United States or have an extensive U.S. presence. A number of large and small U.S. firms are also pursuing breakthrough innovations in hardware—especially those associated with renewable power, energy storage, or electric vehicles. These activities are often performed in domestic facilities to protect intellectual property.
- **Others are catching up quickly, so the United States will need to continue emphasizing not just innovation but also supportive policies.** Chinese, Korean, Japanese, and Indian firms have reached U.S. levels or surpassed them in selected innovative technologies, such as high-voltage transmission (China) and software (India) (Berst, 2011b). Perhaps more important, several countries' smart grid goals reflect energy policies that are not currently emphasized in the United States, such as long-distance transmission and aggressive targets for renewable energy. China, for instance, has set two such policy goals for 2020: to meet 15% of national energy demand with renewable energy, and to reduce the carbon intensity of the national economy by 40 to 45 percent from a 2005 baseline (Zpryme, 2011). Similarly ambitious targets in the United States would increase demand for U.S. smart grid firms' products and encourage investment in related clean tech innovations.
- **Regardless of where smart grid products are made, many additional U.S. smart grid jobs will be located in the service territories of participating utilities, which means they cannot be off-shored.** These will include direct employment with utilities, contractors, and temporary field offices, engaged in performing construction, installation, maintenance and ongoing services. By definition, these will be local jobs.

Case study: S&C Electric Company

Chicago-based S&C Electric Company is an example of a long-established power equipment firm that has found new U.S. manufacturing opportunities in smart grid. Established in 1911 and employee-owned since 2007, the company holds thousands of patents in switchgear, interrupters and other transmission-voltage devices. In the 1980s, long before "smart grid" became a buzz word, S&C began to focus on adding intelligence to its products (Bik, 2011). The company is well-positioned to provide innovations for the growing smart grid market. In the past four years, its business has expanded approximately 50% (S&C Electric Company, 2011).

In 1999 S&C acquired two other firms and technology that enabled it to make the transition from providing only hardware to including products for advanced distribution automation and power quality. It then further expanded to include intelligent power solutions via its new Power Systems Services Division. A primary focus is distributed intelligence—the placement of intelligent capabilities out in the field instead of just linking devices to large control centers. Analysts consider this new approach a vital complement to the traditional centralized method (Berst, 2011a).

Most of S&C's products are made in the United States and Canada, while only a small portion are made elsewhere. For instance, commoditized products such as simple power fuses are manufactured in Mexico or at the company's wholly-owned subsidiary in China. Most of the more advanced products, however, are made at the company's 1.2-million-square-foot facility in Chicago, as well as additional plants in Florida and Wisconsin. At a facility in Alameda, California, the company focuses on software and electronics, working with Silicon Valley firms. In all, the U.S. workforce totals about 1,900 employees, including more than 1,100 machinist, manufacturing, assembly, and support positions; 300 engineers and technicians, a global sales force, and finance and accounting offices. At subsidiaries in Canada, Brazil, China, Mexico, and UK, employees total roughly 500 (Bik, 2011; S&C Electric Company, 2011).

S&C Electric is specifically leveraging its expertise in renewable energy and emerging technologies. It played a lead role in designing and building what in 2008 was Canada's largest wind farm, which produces enough power for 40,000 homes (S&C Electric Company, 2008). The company makes a truck-sized device that connects such wind farms to the grid. Currently providing engineering and equipment to solar plants in California, Texas, and Arizona, the company is also the leading U.S. integrator of battery storage into utility systems (S&C Electric Company, 2010a). Another substantial new business line is in large-scale Uninterruptible Power Supplies (UPS), the high-quality power required for critical applications such as data centers and microchip manufacturers. All of these products are manufactured in the United States.

In 2010, S&C added a new Advanced Technology Center (ATC) to its complex in Chicago. The $37-million ATC includes the largest high-power testing laboratory in North America, so that the firm no longer has to test its smart grid products in labs outside the United States—an advantage that will help speed development of future innovations. Use of the ATC is available to other power product manufacturers in North America through the National Electric Energy Testing Research and Application Center (NEETRAC). The ATC is LEED Gold-certified, with an 8,000-square-foot green roof (S&C Electric Company, 2010b).[19]

Conclusion

Smart grid efforts are well underway in the United States and abroad, with leading countries spending billions of dollars annually in public and private investment. Much of this activity is focused on reducing peak power demand and making an outdated electric system more reliable. Yet even greater energy- and carbon-saving potential lies in harnessing the smart grid to deploy distributed generation, renewable energy and electric vehicles. Fully tapping these resources will not happen automatically with smart grid development, but will require targeted policy support. It will also require regulatory reform and, more important, fundamental changes in the electricity sector's prevailing business model, which incentivizes utilities to sell more, not less energy.

The smart grid promises a considerable role for U.S. jobs. Many of the positions necessary to install, maintain, and repair the new technologies are tied to utilities' local service territories and so cannot be outsourced. In addition, many of the world's leading smart grid vendor firms—including global leaders in IT, core communications, energy management and services, telecom service, and system integration—are headquartered in the United States or have a large U.S. presence. Their U.S. job locations will likely emphasize product development, software and services. New manufacturing opportunities may be largest in assembly and integration of smart devices, and in production by new firms that specialize in emerging clean technologies for renewables, energy storage and electric vehicles.

To make the most of job opportunities, it will be important to actively pursue the cutting edge of smart grid technology. Collaborations between public and private organizations can play a key catalyzing role. Concentrated local and regional efforts such as those in Austin, TX can leverage important partnerships in which R&D is directly connected to new product development, commercialization, new business incubation and workforce development. Such efforts are needed if the smart grid is to deliver on its considerable promise to reduce CO_2, stimulate technology innovation and create jobs.

[19] S&C's sustainability efforts include meeting the EPA's mandate of zero hazardous pollutants at its facilities, and membership in the Green Suppliers Network. Having achieved a nearly 76% recycling goal, the company recently received an award from the Chicago Waste to Profit network, which "facilitates the transformation of one company's waste, or by-product, into an industrial input for another company" (Chicago Waste to Profit Network, no date).

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Appendix A. 125 lead firms in U.S. smart grid and their technology footprints

• = hardware; Δ = software and/or services

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
1	4Home	• Δ							Δ	
2	A123 Systems		• Δ							
3	ABB	•	•	•	• Δ			•		
4	Accenture	Δ			Δ	Δ	Δ			
5	Aclara	• Δ								
6	Adura Technologies	• Δ				•	Δ			
7	AeroVironment							•		
8	AES Energy Storage		Δ							
9	Agilewaves					• Δ				
10	Alcatel-Lucent	• Δ								
11	American Superconductor			•						

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
12	Ametek				•					
13	Arcadian Networks	• Δ								
14	Areva		•							
15	AT&T	Δ								
16	Beckwith Electric				•					
17	Better Place							• Δ		
18	BPL Global	•			Δ	Δ	Δ		Δ	
19	Bright Automotive		• Δ	• Δ						
20	Capgemini	Δ								
21	Cisco	• Δ				Δ		• Δ	• Δ	
22	Compact Power		•							
23	Comverge						• Δ	Δ	• Δ	•
24	Consert	• Δ						Δ	Δ	•
25	Constellation						Δ			

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
	Energy									
26	Control4								• Δ	
27	Cooper Power Systems	• Δ			• Δ		•		•	•
28	Coulomb Technologies							•		
29	CPower						Δ			
30	Current Group	•								
31	Direct Grid Technologies			• Δ						
32	Eaton				•	Δ		•		
33	Echelon	•								
34	EcoFactor								Δ	
35	Ecologic Analytics	Δ								
36	ECOtality		•					• Δ		
37	EFACEC ACS				•					
38	Eka Systems	• Δ								

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
39	Electrolux									•
40	Elster	Δ								
41	eMeter	Δ								
42	EnerDel (Ener1)		•							
43	EnergyAxis	•					Δ	Δ	Δ	
44	EnergyConnect						Δ			
45	EnergyHub								•	
46	EnerNOC						Δ			
47	EnOcean	• Δ								
48	Enphase Energy							•		
49	ENXSuite					Δ				
50	Fronius			• Δ						
51	G&W Electric				•					
52	GainSpan	• Δ								

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
53	GarretCom	• Δ								
54	GE	•	•		•				• Δ	•
55	Google								Δ	
56	Grid Net	Δ	Δ					Δ	Δ	
57	Gridpoint		Δ	Δ		Δ	Δ	Δ	Δ	
58	Hara Software					Δ				
59	Hewlett Packard	Δ				Δ				
60	Hirschmann				•					
61	Honeywell	•				• Δ	• Δ			•
62	Howard Industries				•					
63	Hubbell Power Systems				•					
64	IBM	Δ				Δ				
65	iControl	• Δ					• Δ		• Δ	
66	ICx DAQ Electronics				•					

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
67	Ingeteam			•						
68	Intel	Δ							Δ	
69	Itron	• Δ								
70	Johnson Controls	Δ				• Δ				
71	KEMA	Δ	Δ	Δ	Δ	Δ	Δ	Δ		
72	Landis+Gyr	•								
73	Leviton							•		
74	LG Electronics									•
75	Mehta Tech				•					
76	Microsoft								Δ	
77	Mitsubishi Electric				•					
78	Motorola				•					
79	Novar Controls	Δ				Δ	Δ			
80	NovaTech				•					

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
81	OpenPeak								• Δ	
82	Opower	Δ					Δ		Δ	
83	Oracle	Δ								
84	OutSmart Power System					Δ				
85	Panasonic		•							
86	People Power					Δ			Δ	
87	PowerIT Solutions					• Δ	Δ			
88	Qualitrol				• Δ					
89	Redwood Systems					• Δ				
90	Rockwell Automation				•					
91	RuggedCom	• Δ								
92	S&C Electric		•	• Δ	•					
93	Samsung Electronics									•

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
94	SAP	Δ				Δ				
95	SAS	Δ				Δ				
96	SATCON				•					
97	SATEC Powerful Solutions	•								
98	Schneider Electric	Δ			•	•				
99	SEL	•			•					
100	Sensus	• Δ			•					
101	Sentilla					Δ				
102	Sequentric	• Δ					Δ	•	• Δ	•
103	Siemens	Δ	•		• Δ	• Δ	Δ			
104	Silver Spring	•			•		Δ			
105	SMA Solar Technology				•					
106	SmartSynch	• Δ								
107	SolarCity			Δ						

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
108	Solectria Renewables							•		
109	Sprint	Δ								
110	Square D				•					
111	Sun Run			Δ						
112	SynapseSense	Δ								
113	Tantalus Systems	• Δ			Δ		• Δ			•
114	Telemetric				•					
115	Telvent	•								
116	Tendril	Δ					Δ		• Δ	•
117	Thomas & Betts				•					
118	Tibco	Δ								
119	Trilliant	• Δ								
120	Verdiem					Δ				
121	Verizon	Δ								

	Company	Utility side				Consumer side				
		AMI	Energy storage	Grid interconnection of renewable s or EVs	T&D devices	Commercial building energy management	Demand response	EV charging	Home energy management	Smart appliances, thermostats or plugs
122	Vishay				•					
123	Whirlpool									•
124	Xantrex				•					
125	Zenergy Power				•					

Note: Sector is highly dynamic. Matrix reflects status of firms based on data collected as of March 2011.
Sources: CGGC based on (Neichin & Cheng, 2010 and Leeds, 2009), company websites and industry interviews.

Appendix B. Firm-level data: U.S. locations

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
1	4Home (2005)	Sunnyvale, CA			Sunnyvale, CA	1~100	n/a
2	A123 Systems (2001)	Watertown, MA				1001~5000	20~100M
3	ABB (1999) (Switzerland)	Cary, NC	Hazelwood, MO			10,000+	10B+
4	Accenture (1989) (Ireland)	New York, NY				10,000+	10B+
5	Aclara (1978)	Hazelwood, MO	Cleveland, OH		Wellsley, MA Cleveland, OH St. Louis, MO	501~1,000	20~100M
6	Adura Technologies (2004)	San Francisco, CA		San Francisco, CA		1~100	0~20M
7	Aero Vironment (1971)	Monrovia, CA				501~1,000	100~500M
8	AES Energy Storage (2007)	Arlington, VA				1~100	0~20M
9	Agilewaves (2006)	Menlo Park, CA			Menlo Park, CA	1~100	0~20M

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
10	Alcatel-Lucent (2006) (France)	Murray Hill, NJ	Plano, TX Longview, TX Murray Hill, NJ Raleigh, NC	Calabasas, CA Naperville, IL		10,000+	10B+
11	American Super conductor (1987)	Devens, MA	Devens, MA New Berlin, WI Middleton, WI West Mifflin, PA	Devens, MA New Berlin, WI Middleton, WI West Mifflin, PA		501~1,000	100~500M
12	Ametek (1930)	Paoli, PA		San Diego, CA		10,000+	1~10B
13	Arcadian Networks (2006)	Valhalla, NY		Valhalla, NY	Valhalla, NY	1~100	0~20M
14	Areva (2001) (France)	Philadelphia, PA	Redmond, WA Charleroi, PA Waynesboro, GA		Redmond, WA	10,000+	1~10B
15	AT&T (1983)	Dallas, TX				10,000+	10B+
16	Beckwith Electric (1967)	Largo, FL	Largo, FL	Largo, FL	Largo, FL	101~500	0~20M
17	Better Place (2007)	Palo Alto, CA		Palo Alto, CA		1~100	n/a
18	BPL Global (2004)	Cranberry Twp, PA		Cranberry Twp, PA	Cranberry Twp, PA	1~100	0~20M
19	Bright Automotive (2008)	Anderson, IN				1~100	0~20M

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
20	Capgemini (1975) (France)	Rosemont, IL				10,000+	10B+
21	Cisco (1984)	San Jose, CA		San Jose, CA Petaluma, CA Goleta, CA Austin, TX Richardson, TX RTP, NC Atlanta, GA Boxborough, MA		10,000+	10B+
22	*Compact Power (a subsidiary of LG Chem) (2000)	Troy, MI				5001~10,000	10B+
23	Comverge (1997)	Norcross, GA	Atlanta, GA	Norcross, GA	Broomfield, CO	101~500	20~100M
24	Consert (2008)	Raleigh, NC			Raleigh, NC Austin, TX	1~100	0~1M
25	Constellation Energy (1999)	Baltimore, MD				5001~10,000	10B+
26	Control4 (2003)	Salt Lake City, UT		Salt Lake City, UT	Sunnyvale, CA Salt Lake City, UT Chicago, IL Charlotte, NV	101~500	0~20M
27	Cooper Power Systems (1952)	Waukesha, WI		Carrington, ND Milwaukee, WI Germantown, MD Minneapolis, MN		5001~10,000	1~10B

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
28	Coulomb Technologies (2007)	Campbell, CA	San Jose, CA			1~100	0~20M
29	*CPower (acquired by Constellation Energy in 2010)	New York, NY				5001~10,000	10B+
30	Current Group (2000)	Germantown, MD	Germantown, MD	Germantown, MD		1~100	0~20M
31	Direct Grid Technologies (2009)	Edgewood, NY				1~100	0~20M
32	Eaton (1916)	Cleveland, OH	Milwaukee, WI Cleveland, TN Greenwood, SC Raleigh, NC Alpharetta, GA	Milwaukee, WI Cleveland, TN Greenwood, SC Raleigh, NC Alpharetta, GA Pittsburgh, PA	Pittsburgh, PA Milwaukee, WI Raleigh, NC	10,000+	10B+
33	Echelon (1988)	San Jose, CA		San Jose, CA Fargo, ND	San Jose, CA Fargo, ND	101~500	100~500M
34	EcoFactor (2006)	Redwood City, CA				1~100	0~1M
35	Ecologic Analytics (2000)	Bloomington, MN			Bloomington, MN	1~100	0~20M
36	ECOtality (1999)	San Francisco, CA				n/a	n/a

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
37	EFACEC ACS (1975)	Norcross, GA				1001~5000	100~500M
38	Eka Systems (acquired by Cooper Power Systems in 2010)	Germantown, MD			Germantown, MD	1~100	0~1M
39	Electrolux (1901) (Sweden)	Martinez, GA				10,000+	10B+
40	Elster (2004) (Germany)	Raleigh, NC				5001~10,000	1~10B
41	eMeter (1999)	San Mateo, CA			San Mateo, CA	101~500	20~100M
42	EnerDel (Ener1) (2004)	Indianapolis, IN				101~500	20~100M
43	*EnergyAxis (a subsidiary of Elster)	Raleigh, NC				5001~10,000	1~10B
44	Energy Connect	Campbell, CA				1~100	n/a
45	EnergyHub (2007)	Brooklyn, NY				1~100	0~1M
46	EnerNOC (2003)	Boston, MA				101~500	100~500M

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
47	EnOcean (2001) (Germany)	Boston, MA				1~100	0~20M
48	Enphase Energy (2006)	Petaluma, CA		Petaluma, CA		101~500	0~20M
49	ENXSuite (2005)	San Francisco, CA				1~100	0~20M
50	Fronius (1945) (Austria)	Brighton, MI				1001~5000	500M~1B
51	G&W Electric (1905)	Blue Island, IL	Blue Island, IL			101~500	100~500M
52	GainSpan (2006)	San Jose, CA				1~100	0~20M
53	GarretCom (1989)	Fremont, CA	Fremont, CA North Andover, MA			n/a	n/a
54	GE (1892)	Fairfield, CT	Louisville, KY Selmer, TN Bloomington, IN Decatur, AL Lafayette, GA	Louisville, KY		10,000+	10B+
55	Google (1998)	Mountain View, CA			Mountain View, CA San Francisco, CA Menlo Park, CA Kirkland, WA Boston, MA New York, NY	10,000+	10B+

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
56	Grid Net (2006)	San Francisco, CA				1~100	n/a
57	Gridpoint (2003)	Arlington, VA				101~500	n/a
58	Hara Software (2008) (British)	San Mateo, CA			San Mateo, CA	1~100	0~20M
59	Hewlett Packard (1939)	Palo Alto, CA				10,000+	10B+
60	Hirschmann (1978)	Chambersburg, PA				1~100	0~20M
61	Honeywell (1899)	Morristown, NJ	Murfreesboro, TN Golden Valley, MN	Golden Valley, MN	Golden Valley, MN Richmond, VA	10,000+	10B+
62	Howard Industries (1969)	Laurel, MS	Laurel, MS Ellisville, MS	Laurel, MS Ellisville, MS		1001~5000	100~500M
63	Hubbell Power Systems (1968)	Centralia, MO	Leeds, AL			10,000+	100~500M
64	IBM (1911)	Armonk, NY				10,000+	10B+
65	iControl (2003)	Palo Alto, CA			Austin, TX Palo Alto, CA	1~100	0~20M
66	ICx DAQ Electronics (1975)	Piscataway, NJ	Piscataway, NJ		Piscataway, NJ	1~100	20~100M

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
67	Ingeteam (1990) (Spain)	Mequon, WI				101~500	500M~1B
68	Intel (1968)	Santa Clara, CA				10,000+	10B+
69	Itron (1977)	Liberty Lake, WA	Waseca, MN West Union, SC			5001~10,000	1~10B
70	Johnson Controls (1885)	Milwaukee, WI	McAllen, TX El Paso, TX	Milwaukee, WI	Philadelphia, PA St. Lewis, MO Milwaukee, WI	10,000+	10B+
71	KEMA (1927) (The Netherlands)	Burlington, MA				1001~5000	100~500M
72	Landis+Gyr (1897) (Switzerland)	Alpharetta, GA				5001~10,000	1~10B
73	Leviton (1906)	Melville, NY				5001~10000	100~500M
74	LG Electronics (2002)	Englewood Cliffs, NJ			Englewood Cliffs, NJ	10,000+	1~10B
75	Mehta Tech (1983)	Eldridge, IA	Eldridge, IA	Eldridge, IA		1~100	0~20M
76	Microsoft (1975)	Redmond, WA				10,000+	10B+

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
77	Mitsubishi Electric (1921) (Japan)	Warrendale, PA		Warrendale, PA		10,000+	10B+
78	Motorola (1928)	Schaumburg, IL		Schaumburg, IL Holtsville, NY		10,000+	10B+
79	*Novar Controls (a subsidiary of Honeywell) (1963)	Cleveland, OH				10,000+	10B+
80	NovaTech (1984)	Bethlehem, PA	Coraopolis, PA Woodbury, MN Aiken, SC Baton Rouge, LA Shelby, NC League City, TX	Coraopolis, PA Woodbury, MN Aiken, SC Baton Rouge, LA Shelby, NC League City, TX	Coraopolis, PA Woodbury, MN Aiken, SC Baton Rouge, LA Shelby, NC League City, TX Owings Mills, MD Lenexa, KS	101~500	20~100M
81	OpenPeak (2002)	Boca Raton, FL		San Francisco, CA	Boca Raton, FL	1~100	0~20M
82	Opower (2007)	Arlington, VA			Arlington, VA San Francisco, CA	1~100	0~20M
83	Oracle (1977)	Redwood City, CA				10,000+	10B+
84	OutSmart Power System (2008)	Natick, MA			Natick, MA	n/a	n/a

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
85	Panasonic (1935) (Japan)	Secaucus, NJ	Columbus, GA	Columbus, GA		10,000+	10B+
86	People Power (2009)	Palo Alto, CA			Palo Alto, CA	1~100	n/a
87	PowerIT Solutions (2001)	Seattle, WA				1~100	0~20M
88	Qualitrol (1945)	Fairport, NY	Fairport, NY	Fairport, NY		10,000+	10B+
89	Redwood Systems (2008)	Fremont, CA	Fremont, CA	Fremont, CA		1~100	0~20M
90	Rockwell Automation (1928)	Milwaukee, WI				10,000+	1~10B
91	Rugged Com (2001) (Canada)	Hollywood, FL				101~500	20~100M
92	S&C Electric (1911)	Chicago, IL	Chicago, IL Franklin, WI Orlando, FL Alameda, CA	Chicago, IL Franklin, WI Orlando, FL Alameda, CA	Chicago, IL Franklin, WI Alameda, CA	1001~5000	500M~1B
93	Samsung Electronics (1969) (South Korea)	San Jose, CA		Chicago, IL San Jose, CA		10,000+	10B+
94	SAP (1972) (Germany)	Newtown Square, PA			Palo Alto, CA	10,000+	10B+

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
95	SAS (1976)	Cary, NC				10,000+	1~10B
96	SATCON (1985)	Boston, MA		Boston, MA	Fremont, CA	101~500	20~100M
97	SATEC Powerful Solutions (1997)	Union, NJ				1~100	0~20M
98	Schneider Electric (1846) (France)	Palatine, IL				10,000+	10B+
99	SEL (1982)	Pullman,WA				1001~5000	100~500M
100	Sensus (2009)	Raleigh, NC				101~500	500M~1B
101	Sentilla (2003)	Redwood City, CA			Redwood City, CA	1~100	0~20M
102	Sequentric (2004)	Wilmington, NC		Willmington, NC	Willmington, NC	1~100	
103	Siemens (1847) (Germany)	New York, NY				10,000+	10B+
104	Silver Spring (2002)	Redwood City, CA		Redwood City, CA		101~500	20~100M

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
105	SMA Solar Technology (1981) (Germany)	Rocklin, CA	Denver, CO			1001~5000	1~10B
106	SmartSynch (2000)	Jackson, MS	Jackson, MS	Jackson, MS		101~500	0~20M
107	SolarCity (2006)	Foster City, CA				501~1000	100~500M
108	Solectria Renewables (2005)	Lawrence, MA	Lawrence, MA	Lawrence, MA	Huntington Beach, CA	n/a	0~20M
109	Sprint (1938)	Overland Park, KS				10,000+	10B+
110	*Square D (acquired in 1991 by Schneider Electric)	Palatine, IL				10,000+	10B+
111	Sun Run (2007)	San Francisco, CA				1~100	0~20M
112	Synapse Sense (2006)	Folsom, CA			Folsom, CA	n/a	n/a
113	Tantalus Systems (1989)	Raleigh, NC				1~100	0~20M
114	Telemetric (1999)	Boise, ID				1001~5000	500M~1B

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
115	Telvent (1941) (Spain)	Rockville, MD				5001~10,000	1~10B
116	Tendril (2004)	Boulder, CO		Boulder, CO	Boulder, CO	1~100	0~1M
117	Thomas & Betts (1898)	Memphis, TN	Albuquerque, NM Hackettstown, NJ	Hackettstown, NJ		5001~10,000	1~10B
118	Tibco (1997)	Palo Alto, CA				1001~5000	500M~1B
119	Trilliant (1985)	Redwood City, CA				101~500	0~20M
120	Verdiem (2001)	Seattle, WA				1~100	0~20M
121	Verizon (1983)	New York, NY				10,000+	10B+
122	Vishay (1962)	Malvern, PA	Columbus, NE Bennington, VT Ontario, CA	Columbus, NE Bennington, VT Ontario, CA		10,000+	1~10B
123	Whirlpool (1898)	Benton Charter Twp, MI	Fort Smith, AR Amana, IA Findlay, OH Cleveland, TN Tulsa, OK Marion, OH	Benton Harbor, MI Evansville, IN		10,000+	10B+

	Company (Year founded) (Country)	U.S. Headquarters	Device manufacturing	Hardware development	Software development and/or services	Employee size range	Sales size range ($)
124	*Xantrex (acquired in 2008 by Schneider Electric)	Elkhart, IN				10,000+	10B+
125	Zenergy Power (2004)	Burlingame, CA	Sioux Falls, SD Canonsburg, PA	Burlingame, CA San Bernardino, CA Brilliant, OH		1~100	0~20M

*Note: *For subsidiaries, employee size and sales size ranges refer to the parent companies.*
Source: CGGC, based on Neichin & Cheng, 2010; Leeds, 2010; industry interviews, company websites, D&B Selectory database and Hoover's database.