2010

Retrofitting the Workforce: Report #4

Energy Storage

TEXAS FOUNDATION FOR INNOVATIVE COMMUNITIES

Good Company Associates

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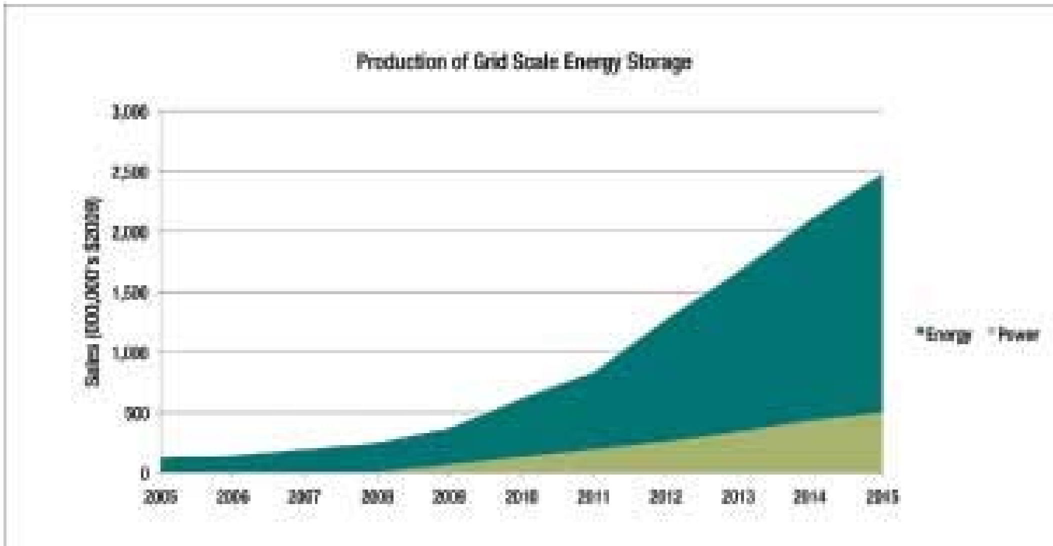
This report is designed to offer useful information to Texas' workforce investment boards and community colleges about the availability and potential of green jobs in the Energy Storage industry in Texas as well as to provide details on the workforce training needs of employees in the industry.

Thanks to all members of the Green Jobs Business Council and the Green Corridor Consortium for their participation and interest in this topic. Particular thanks to all those who gave time and expertise to contribute to the report.

EXECUTIVE SUMMARY

Energy storage today represents a very small part of the clean energy economy, but it is growing rapidly. GTM Research estimates that less than 1% of the total market size for energy storage has been reached. It expects 9x growth from 2009-2015[1] (see chart below). Similarly, Pike Research projects a 12x growth to 2018[2], while NanoMarkets expects the storage market to grow by over 5x from 2012-2016[3].



Credit: GTM Research

The market is currently between $300 and $400 million and is expected to grow to $2.5-$8.3 billion in the 2015-2018 timeframe[4]. The market for rechargeable lithium-ion batteries is expected to grow even larger to $25 billion (3 trillion yen) by 2014[5], with over two-thirds of that

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[1]GTM Research, "*Grid Scale Energy Storage: Technologies and Forecasts Through 2015*", August 2009. See
GTM Research, "*Grid Scale Energy Storage: Technologies and Forecasts Through 2015",* August 2009. See http://www.gtmresearch.com/report/grid-scale-energy-storage-technologies-and-forecasts-through-2015 Accessed in August 2010.

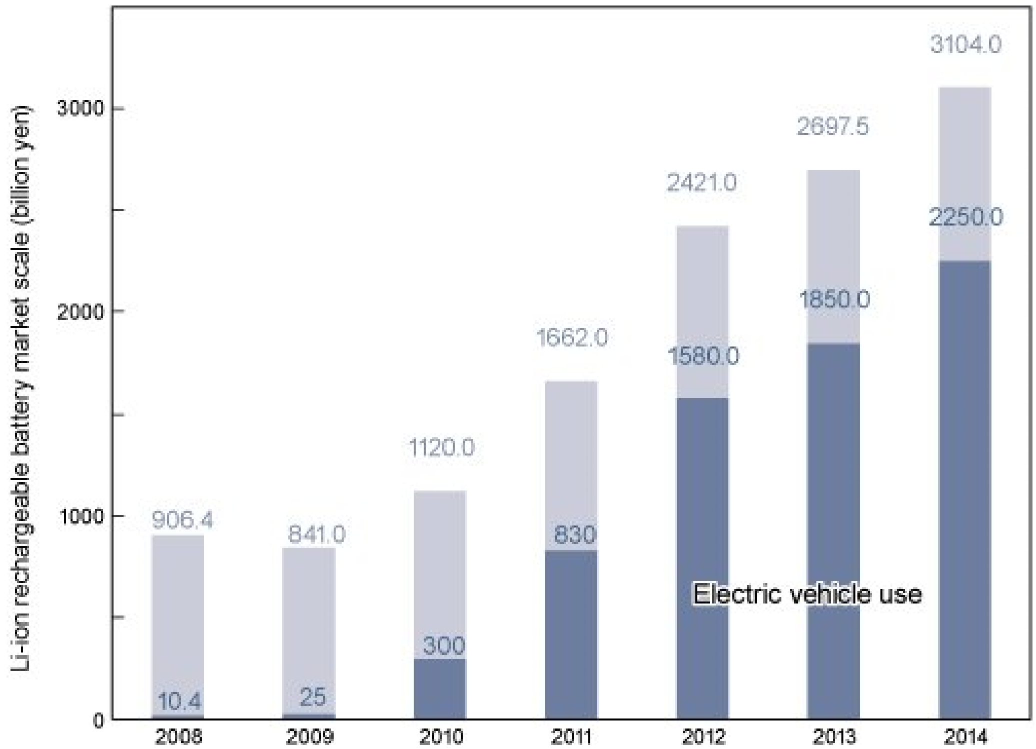
[2] PikeResearch, "*Energy Storage market to Reach $4.1 Billion in 10 Years",* May 2009. See http://www.pikeresearch.com/newsroom/energy-storage-market-to-reach-41-billion-in-10-years Accessed in August 2010

[3] NanoMarkets "*Batteries and Ultra-Capacitors for the Smart Power Grid: Market Opportunities 2009-2016*" . See http://nanomarkets.net/market_reports/report/batteries_and_ultra-capacitors_for_the_smart_power_grid_market_opportunitie/ Accessed in August 2010

[4] This is the range of size projected in the three reports referenced above.

[5]Kariatsumari, Kouji; Kume, Hideyoshi; Yomogita, Hiroki; Keys, Phil. Nikkei Electronics Asia, "*A new Era for Li-Ion Batteries*". February 2010, See http://techon.nikkeibp.co.jp/article/HONSHI/20100127/179667/?P=3 Accessed in August 2010

total for EV use (see chart below). This kind of rapid growth will have significant impacts on workforce readiness.



Source: Nekkei Electronics Asia

This growth will produce hundreds of new jobs for engineers, electricians, technicians, and renewable energy/smart grid system integrators who install and maintain energy storage resources. Many thousands more in related occupations will need to upgrade their knowledge and skills to understand and work with various types of energy storage. The main occupations affected will be electrical and mechanical engineers, electricians, utility linemen, solar installers, automotive technicians, HVAC technicians, and facility managers.

There is not currently an occupation specifically focused on energy storage as there is for wind and solar energy, although there are companies that specialize in power control systems that connect storage to the grid and end-uses.

Learning to install, maintain, and repair energy storage systems are "enhanced skills" for existing occupations, but will not likely be designated as a distinct "New and Emerging Occupation."[6]

There are companies emerging which specialize in energy storage system integration and installation, or which plan to build-own-operate storage systems to support the grid or individual utilities. **Specific trainings for various applications at this point are primarily**

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[6] O*NET Resource Center, The Green Economy, http://www.onetcenter.org/green.html?p=2 Accessed in August of 2010.

provided by the existing and emerging manufacturers who are developing their own networks of qualified design, installation and maintenance.

These companies can provide a variety of different functions. According to the Department of Energy[7]:

> Developing technology to store electrical energy so it can be available to meet demand whenever needed would represent a major breakthrough in electricity distribution. Helping to try and meet this goal, electricity storage devices can manage the amount of power required to supply customers at times when need is greatest, which is during peak load. These devices can also help make renewable energy, whose power output cannot be controlled by grid operators, smooth and dispatchable. They can also balance microgrids to achieve a good match between generation and load. Storage devices can provide frequency regulation to maintain the balance between the network's load and power generated, and they can achieve a more reliable power supply for high tech industrial facilities. Thus, energy storage and power electronics hold substantial promise for transforming the electric power industry.

Each of these applications has value, and many storage technologies are capable of delivering multiple benefits at the same time. Market barriers still exist in some potential markets where storage can provide benefits, but regulators are moving to reduce or eliminate impediments to storage implementation. The challenge to storage manufacturers, project developers, system operators, utility staff, and facilities managers is to develop projects with attractive economics.

Energy storage technologies, both familiar technologies like lead-acid batteries and thermal storage systems, as well as evolving new technologies, appear on the verge of taking on new and expanded roles both on the customer site and throughout the electric grid. This report will focus primarily on these emerging applications for both old and new energy storage systems in stationary applications associated with the electric power industry or grid connected electric power use. We will also discuss energy storage technologies associated with hybrid, plug-in hybrid, and fully electric cars, and the electrification of the transportation system.

In the near term, community colleges should create a short course covering the different types of energy storage, and the applications for which each is appropriate. Introduction to the various companies emerging in this space would give students an idea of the size and complexity of the industry, as well as some ideas about how to pursue a career in this fast growing business. The course should include fundamental information about system installation, power control systems, and safety.

Finally, the short course should include instruction with respect to the impact of evolving policy with respect to energy storage and the economics of energy storage systems, two intertwined

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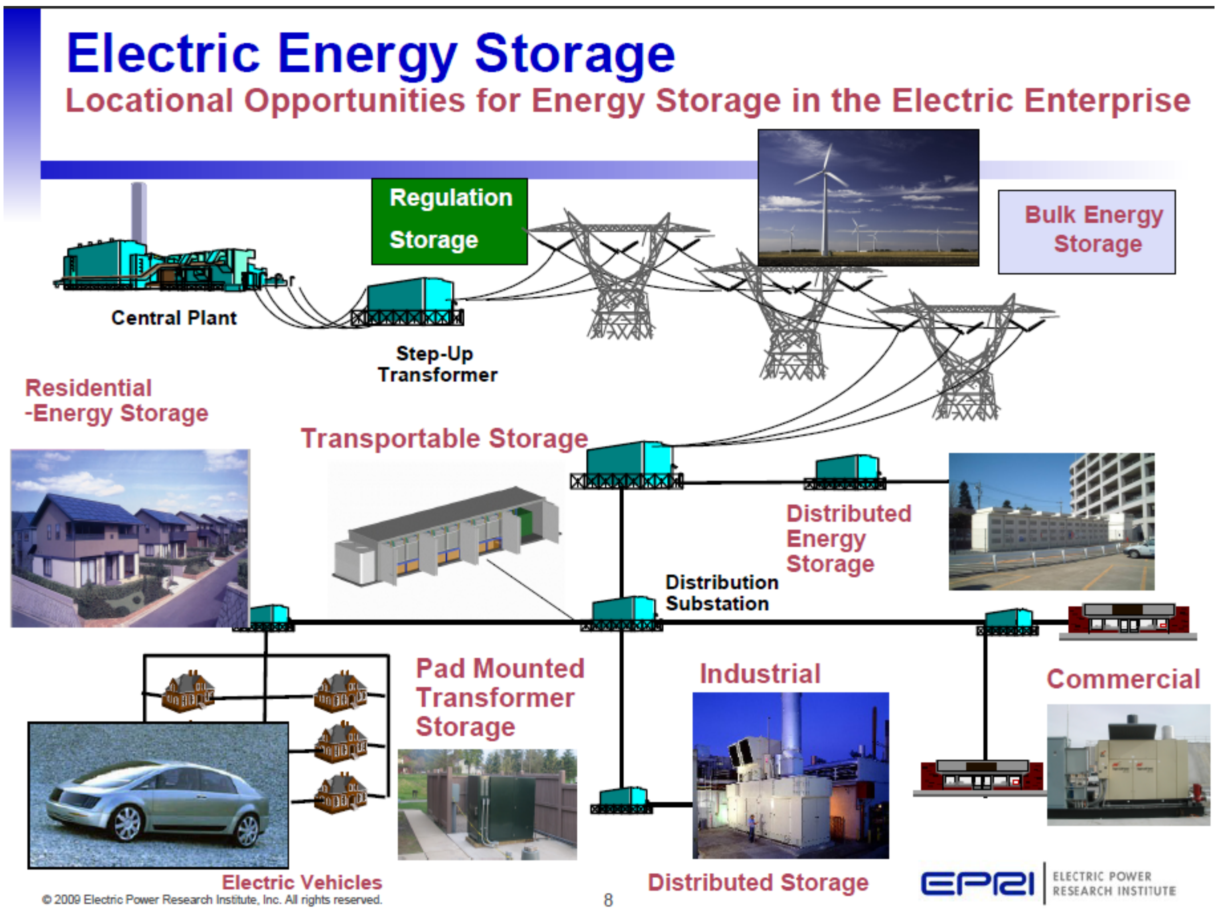
[7]DOE, Energy Storage. http://www.oe.energy.gov/storage.htm Accessed in August of 2010

sets of issues. This would also help students make judgments about career goals or choices, and make them more valuable to potential employers who might also be exploring the potential for business development in this space.

ENERGY STORAGE MARKET OVERVIEW

INDUSTRY OVERVIEW

The term "energy storage" encompasses a wide range of technologies and applications, from utility-scale storage at a power plant or substation to storage for electric vehicles, from industrial to residential energy storage applications. The following slide from EPRI depicts the range of opportunities for electricity storage on the grid.



Of the currently installed 22 gigawatts (GW) of stationary electricity storage applications in the US[8], almost all is at the bulk energy storage level (the top of the figure above), with only a small quantity at the distributed level (middle and bottom of figure above). The vast majority (>95%) of US energy storage is pumped hydroelectric storage, most of it installed between 1930-1980. While some pumped hydro may continue to be installed, there is limited growth opportunity because of the physical requirements (suitable geography and available water) required and significant permitting hurdles.

[8]Pew Center on Global Climate Change, "Electric Energy Storage". May 2009. See http://www.pewclimate.org/docUploads/Energy-Storage-Fact-Sheet.pdf. Accessed in August of 2010.

An alternative form of bulk storage is Compressed Air Energy Storage (CAES). There is one CAES facility in the US, in Alabama, of about 110 megawatts, which has been operated by an electric cooperative for almost 20 years. More recently a Texas project developer sold the development rights of a 2000 MW CAES project in Norton, Ohio, to First Energy.[9] There is significant potential for CAES in Texas. A 1,000 MW facility in West Texas which could store wind energy produced off-peak for delivery during peak periods has been contemplated for years by Luminant and Shell[10] but has yet to break ground. CAES, like pumped hydroelectric storage, is limited by the availability of suitable geological formations. Most proposed CAES facilities employ salt formations, creating caverns for compressed air in a similar fashion to that currently used by the natural gas industry for storage facilities.

Uninterruptible power systems (UPS) from manufacturers already constitute a multi-billion dollar market and are projected to grow to more than $10 billion by 2012, with much of its growth driven by the demand for new datacenters.[11] The majority of existing storage systems are based on lead-acid battery technology, but this hegemony is being challenged by younger companies with new technologies. Austin's Active Power is making serious inroads into this market with its flywheel technology because of its greater life expectancy and reliability.

The market for electric vehicle batteries, currently dominated by lithium-ion technologies, is expected to grow rapidly over the next six years to more than $20 billion by 2015.[12] Electric vehicle batteries become grid-connected resources when plugged in, and electric vehicles are likely to be the largest deployment of distributed energy storage resources in the next few years.

Battery technology investments for this market will likely have spill-over benefits for stationary grid applications as well. American Electric Power company predicts grid storage applications will get a boost as auto batteries are switched out of automobiles and repurposed for grid storage.[13] Batteries that have lost too much storage capacity after repeated cycling to be effective in a mobile environment would still be acceptable in a stationary application where power density was not so critical a concern.

New markets are emerging now for grid applications of energy storage. A recent study completed for the US Department of Energy and Sandia National Laboratories, describes 26 different benefits that can be derived by use of storage on the grid, including on the customer

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[9] Haddington Ventures, L.L.C. press release, 23 Nov., 2009. See http://www.hvllc.com/en/rel/93/, accessed August, 2010.
[10]Testa, Bridget Mintz, 2008. *Wind In A Bottle.* Power & Energy. See http://www.memagazine.org/contents/current/features/windina/windina.html . Accessed August 2010.
[11] United States Securities and Exchange Commission, Form 10-K, Active Power, Inc. 2008. See http://www.activepower.com/fileadmin/documents/financial_reports/2008_Form_10K.pdf . Accessed August 2010
[12]Kariatsumari, Kouji; Kume, Hideyoshi; Yomogita, Hiroki; Keys, Phil. Nikkei Electronics Asia, February 2010, "*A new Era for Li-Ion Batteries*". See http://techon.nikkeibp.co.jp/article/HONSHI/20100127/179667/?P=3; http://files.shareholder.com/downloads/ABEA-3DGNI7/745432919x0xS1047469-09-8512/1167178/filing.pdf . Accessed August 2010
[13]Bjelovuk, George, 18 July 2010. "*American Electric Power's Utility-Scale Energy Storage*". gridSmart See http://www.narucmeetings.org/Presentations/Bjelovuk,%20Energy%20Storage%20and%20Renewables,%20NARUC,%207-18-10.pdf . Accessed August, 2010

site, which offer a mid-range economic benefit of $228 billion for the US (see pages 20-21 for the list of benefits).[14]

The challenge to the market will be finding value propositions which manage to capture or monetize multiple benefits for select applications. Electric storage technologies, at least as applied to grid applications, tend to fall into one of two categories based on their physical and performance characteristics. There are electric storage technologies that provide services utilized to enhance grid reliability; these are generally called ancillary services, such as regulation and frequency support. Some ancillary services are required by grid operators, others are offered into markets (for a full description of ancillary services see pages 10-14). Energy storage can also provide other services like peak shifting, which are not required for reliability but provide significant economic benefits. In other words, some storage applications can store power produced off peak (e.g., energy produced in the middle of the night when demand is low) and deliver it on peak (e.g., in the late afternoon when power is in high demand). These areas of growth will be discussed further later in this report.

The relatively young market for stationary grid-connected storage, though smaller than the mature market for UPS systems and the rapidly growing EV battery market, is nonetheless expected to grow to almost $2.5 billion in sales over the next six years, with storage capacity expanding from approximately 190 megawatts to 2500 megawatts over the same period[15]. Three reports released over the last two years share a common conclusion: an order of magnitude growth over the next 5-8 years:

- GTM Research estimates that the grid storage market is set to grow from roughly $365 million in 2009 to nearly $2.5 billion by 2015.[16]
- Pike Research estimates that the global energy storage market is poised to grow from $329 million in 2008 to $4.1 billion by 2018.[17]
- NanoMarkets predicts the market for grid storage will grow from $1.5 billion in 2012 to $8.3 billion by 2016, which will mostly be batteries, though ultracapacitors will have their niche applications.[18]

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[14] Eyer, Jim; Garth, Corey. *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide.* Sandia Report. February 2010. See http://prod.sandia.gov/techlib/access-control.cgi/2010/100815.pdf . Accessed August 2010.

[15] GTM Research, "*Grid Scale Energy Storage: Technologies and Forecasts Through 2015*", August 2009. See http://www.gtmresearch.com/report/grid-scale-energy-storage-technologies-and-forecasts-through-2015 . Accessed August 2010.

[16] GTM Research, "*Grid Scale Energy Storage: Technologies and Forecasts Through 2015*", August 2009. See http://www.gtmresearch.com/report/grid-scale-energy-storage-technologies-and-forecasts-through-2015 . Accessed August 2010.

[17] PikeResearch, "*Energy Storage Market to Reach $4.1 Billion in 10 Years*", May 2009. See http://www.pikeresearch.com/newsroom/energy-storage-market-to-reach-41-billion-in-10-years . Accessed August 2010.

[18] St. John, Jeff. Greentechgrid. July 2009. See http://www.greentechmedia.com/articles/read/grid-storage-batteries-and-ultracaps-an-8.3b-market-by-2016 . Accessed August 2010.

Another indication of growth in this market is that energy storage was a strong clean tech investment area in 2009, with at least $455M invested.[19] In addition to that, over $200 million in grants were made for grid energy storage from the federal stimulus funds. The DOE Energy Storage program funded 16 energy storage projects under FOA 36 totaling approximately $185M[20] and six programs totaling approximately $30M were funded under ARPA-E.[21] Future investments are expected, including a major Energy Regional Innovation Center (E-RIC) opportunity focused on electric storage early next year; total funding would equal $120 million over the next five years.

In addition to those electricity storage technologies or applications discussed thus far, it can also make sense to use thermal storage to shift the demand for electricity needed for thermal applications, particularly heating and cooling. Thermal storage systems can be paired with air conditioning systems, for example, to make ice at night, and then use the ice to cool building space during peak demand hours. A California study found that total net savings which could be realized using this technology ranged between 8 and 25% of energy used for cooling, because both power plants and air conditioners run more efficiently at night.[22]

This application provides the same kind of economic benefits to utilities as charging electric vehicles off peak. Thermal storage has been employed by large commercial building developers or owners to avoid high capacity charges, and capture utility incentives for shifting load off peak. A similar trend for smaller building owners has awaited advanced digital meters and new cooling technology that could be coupled with the split or DX space conditioning units serving 95% of all buildings. That new technology now exists. Heating can also be generated off peak and stored. The most common example of this is a traditional hot water heater.

Finally, a good deal of the training required for the design. installation, operation and maintenance of energy storage systems, except for the specialized internal research on different technologies, involves power control systems (PCS). Control systems are required for safety, and to regulate the power quality coming from storage units, convert the power from the grid to DC, and then invert the power back to AC for applications or interconnection to the grid. This same PCS equipment is needed for distributed renewable energy systems such as solar photovoltaic systems.

Given the growth of both these industries, we would also predict rapid growth for PCS products and services. For example, demand from the alternative energy market will help to

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[19] Kanellos, Michael. "*Green VC Total: Second Best Year Ever*" Greentechmedia. December 2009. See http://www.greentechmedia.com/articles/read/green-vc-total-second-best-year-ever . Accessed August 2010.
[20] Sandia Labs "*Energy Storage Demonstrations*" November 2009. See http://www.sandia.gov/ess/About/docs/FOA36_%20storagedemos_11-24-09.pdf . Accessed August 2010.
[21] Sandia Labs. "*ARPA-E Energy Storage Projects*" November 2009. See http://www.sandia.gov/ess/About/docs/six_projects_11-2009.pdf . Accessed August 2010.
[22] California Energy Commission. "*Source Energy and Environmental Impacts of Thermal Energy Storage*". February 1996. See http://www.energy.ca.gov/reports/500-95-005_TES-REPORT.PDF . Accessed August 2010

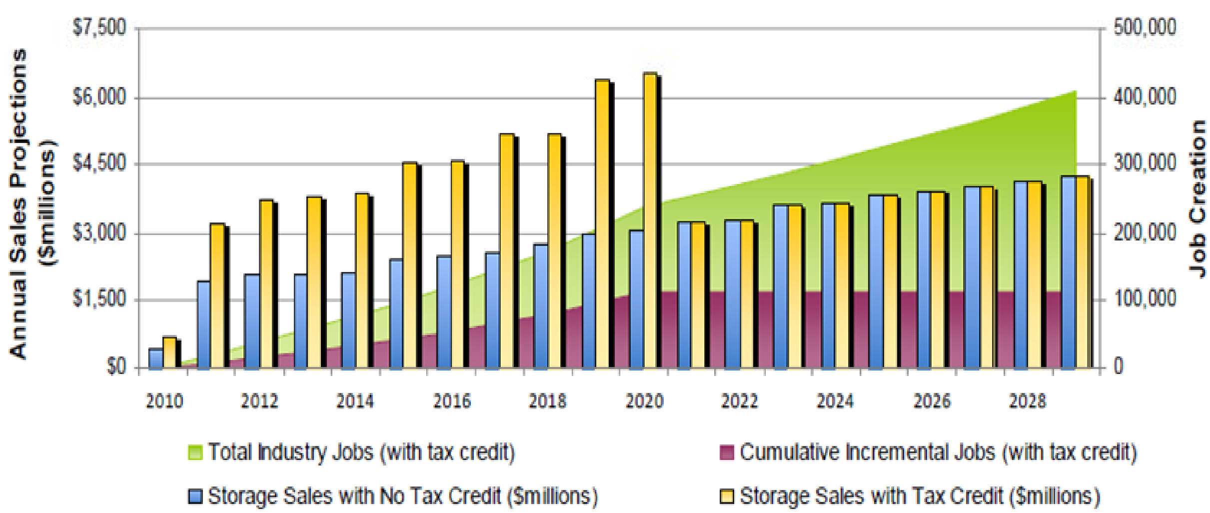
more than double the size of the inverter market from $2.9bn to $7.2bn in the next five years.[23] There are two companies in Austin today which are developing new inverter technologies using microelectronics which could be disruptive in this field in the next five years, which itself will force many existing electrical engineers, electricians, and technicians to upgrade their skills.

JOBS FORECAST

The Electric Storage Association (ESA) and KEMA, an electric industry consulting firm, did an analysis of potential jobs impacts of a piece of legislation introduced in 2009 to provide tax incentives for energy storage. The bill did not pass but the analysis gives a valuable insight into the number of jobs that could be created should investment in storage reach certain levels.

The figure shows a growth to $2 billion in sales (for stationary storage applications only, EV's not included) by 2015 and to $3 billion by 2020, even without a tax credit. The size of the market roughly doubles with a 30% investment tax credit. The jobs numbers are assuming passage of a tax credit and show over 100,000 direct jobs created by 2020 and an additional 150,000 indirect jobs.

Though they don't show it in their chart, if employment figures were roughly half (as sales figures are) without the tax credit, there would still be about 50,000 direct jobs and 125,000 total jobs created by the energy storage industry. Taking Texas' population proportionate share of those jobs would mean about 4,000 direct jobs and 10,000 total jobs.



[23] Manners, David. Electronics Weekly.com . "*Inverter market to double*" August 2010. See http://www.electronicsweekly.com/Articles/2010/08/17/49281/inverter-market-to-double.htm. Accessed August 2010.

EMERGING ENERGY STORAGE GRID APPLICATIONS

Energy storage can provide a variety of services at all levels of the grid, from power backup and reliability improvements at the level of individual electricity consumers to grid-scale energy balancing and stability services, renewable energy integration and peak shifting.

UNINTERRUPTIBLE POWER SUPPLIES

Uninterruptible power supply (UPS) and power control systems (PCS) provide reliable, high-quality power to commercial and industrial users with critical power needs such as hospitals and datacenters. Historically, such establishments have relied upon lead-acid battery banks and diesel engines for back-up in the event a power disruption lasts longer than 10 to 20 minutes. Still, new technologies like flywheels and advanced batteries are getting some traction in these markets, promising longer life-time, higher reliability and lower maintenance.

One of the lessons learned during the large blackout that affected a huge swath of the northeast in 2003 was that a number of UPS systems that had not been properly maintained didn't function as intended when they were actually needed. While lead-acid batteries are still the low-cost alternative, this experience helped open the market to a number of competitors.

Regulatory Issues and Market Barriers: This market is already a large, successful industry with no significant regulatory issues or market barriers.

Market Forecast: The UPS industry represented an almost $8 billion market worldwide in 2008 and is projected to grow to more than $10 billion by 2013, with the majority of UPS systems used for data center and IT applications.[24] With data centers accounting for over 1.2% of US utility power consumption[25] and new data centers being built at a rapid pace, the market for UPS systems is likely to experience continued strong growth for years to come. Competition by emerging technologies, however, will continue to drive diversity of the landscape here.

ANCILLARY SERVICES AND TRANSMISSION SYSTEM SUPPORT

A number of energy storage technologies are capable of competing with generation and loads to provide competitively offered ancillary services to electric markets. Years ago individual utilities were largely responsible for maintenance of their region of the grid, providing regional power to support native loads.

Now, however, most regions of the country have evolved larger more complex regional networks, responsible for maintaining reliability and the operation of competitive wholesale electricity markets. The Electric Reliability Council of Texas (ERCOT), one such example, is the independent system operator (ISO), overseeing the reliable operation of the electric power grid

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[24] "Global UPS market to dip more than 5% in 2009, says IMS" EE Times Europe, March 19, 2009. See http://www.powermanagement-europe.com/en/global_ups_market_to_dip_more_than_5-_in_2009-_says_ims?cmp_id=7&news_id=215901187, accessed August 2010.

[25] http://enterprise.amd.com/Downloads/svrpwrusecompletefinal.pdf

covering about 85% of the Texas population. Power generators and retail load serving entities still must schedule energy to meet forecast loads, but estimates are never exactly right, and the ISO must always maintain sufficient resources to deal with unexpected contingencies (such as forced outages of generators or a failure of a transmission line) so the system operator also acquires "ancillary" products or services to assure that the system continues to operate properly in real time.

After the fact, the system operator also hosts a "settlement" process, in which those supplying too much, for example, fairly compensate those who supplied too little in retrospect. Currently, this complex exchange takes place every 15 minutes all year long for four zones within ERCOT. In December, the system is switching over to a system based on such exchanges taking place every 5 minutes at over 1000 nodes scattered across the system.

Ancillary services for which energy storage systems are particularly useful include regulation, spinning reserves, and non spinning reserves. Energy storage can also provide voltage support and reactive power, but in general, these are usually assigned to generators as conditions of operation and not formally supplied through organized markets. Regulation service provides capacity that can respond to signals within three to five seconds to keep the frequency of power delivered within a narrow band around 60 megahertz. If it wanders outside a certain range (generally plus or minus .03 megahertz) it can affect the performance, and endurance of lights and motors and other appliances. A significant drop in the frequency can trigger under frequency relays, and even a cascading blackout.

Regulation service is the first ancillary product to emerge as a viable market for new storage technology. Traditionally, regulation service is provided by natural gas fired combustion turbines operating in the middle of their output range, allowing them to cycle up and down. However, because they are mechanical devices, they take time to change their power output, and more time to reverse that change. Frequency fluctuations occur in response to incessantly changing loads and generation, and even environmental conditions, and are often random in nature. Storage, which can respond almost instantaneously, is better suited to provide this support to the grid than generation.

Storage can quickly respond to an ISO's signals and charge or discharge in response to the system's need for decreasing (regulation down) or increasing (regulation up) frequency. In fact, a recent study for the California PUC by KEMA, indicated that a given storage capacity could provide twice the ancillary service value of an equivalent generator. [26] This is particularly true of frequency support in a market moving to five minute bids and settlement intervals, as modern gas turbines cannot respond that quickly. Lithium-ion batteries and flywheels are

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[26] KEMA, *Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid*, for the California Energy Commission, CEC-500-2010-010, June 2010.

currently the two leading storage technologies capable of supporting the thousands of rapid, shallow charge and discharge cycles required to provide regulation.

Regulatory Issues and Market Barriers: Regulation service has historically been provided by natural gas generation facilities, so ERCOT regulation protocols and regulation dispatch signals are designed around the capabilities of gas generation. Flywheels and lithium-ion batteries are able to respond to regulation signals more quickly than gas generation but have a lower total energy capacity. Regulation protocols, reliability requirements, and dispatch signals need to be modified to take these two differences into account. Requiring a quick response storage device to maintain power output for as long as a gas turbine, without accounting for the value of faster, more flexible response, creates an economic barrier against participation of storage technology in the regulation market.

Because storage can respond to regulation signals more quickly than gas generators, storage can replace traditional generation as a regulation provider, reducing the use of fossil fuels, reducing regulation costs, and improving grid efficiencies. Fossil generators take several minutes to respond to the automatic generation control (AGC) signal governing regulation, during which time the signal may have already changed so that the generator response may be working against the action required by the grid. A study by California ISO shows that regulation provided by energy storage is twice as effective as regulation by fossil fuel generation. This means that an energy storage facility rated at 10 megawatts can do the work of 20 megawatts of regulation by fossil fuel generation. In order to fully enable the benefit that storage can provide to the grid, system operators need to work with storage companies to optimize regulation dispatch signals for the capabilities of energy storage.

Reliability requirements in some markets require that regulation resources be able to provide one hour of continuous energy. The one hour requirement is not a NERC (North American Reliability Council) requirement, nor is it necessary for all regulation resources from a reliability standpoint. Because regulation involves rapid charge and discharge around a baseline energy level, one hour of continuous discharge does not reflect the standard operation of regulation resources during real world use. Lowering the requirement from one hour to fifteen minutes for storage resources would make it more economical for storage to provide regulation service without impacting the reliability of the grid. The Federal Energy Regulatory Commission (FERC) has encouraged market rule changes to enable participation of batteries and flywheels in other markets, and both the NYISO and PJM have adopted market rules to facilitate the participation of quick response storage. New York ISO and the Northeast Power Coordinating Council made this change in December 2008, and other markets around the country are in the process of studying and adopting similar changes.

Work is under way in ISO New England, California ISO, and Midwest ISO to modify regulation operations and dispatch signaling to accommodate the new capabilities offered by storage resources. ERCOT has recently formed a Power Storage Working Group, in response to direction from the Public Utility Commission chairman who is an ex-officio member of the ERCOT board, to address such barriers to storage providing regulation, and participating in other ancillary services markets down the road.

Market Forecast: The North American market for regulation is estimated at more than $1 billion for 2009[27], and ERCOT currently requires roughly 600 to 1200 megawatts of regulation service. Under the new nodal settlements system to be launched in December 2010, the total amount of ancillary services that will be required will decrease, but the need for fast response services will increase, favoring storage over generation. The quantity of regulation demanded will be cut almost in half, but the ramp time (time required to supply the quantity bid) will be reduced from 10 minutes to 5 minutes, reducing the capacity of regulation capable units by at least half of their previous regulation capacity. In addition, increasing reliance on wind and solar resources will increase the demand for regulation as well as other ancillary services. Because regulation commands a higher price than other ancillary services and can be cost-effectively provided by existing storage technology, regulation will be the first widely successful application of energy storage in the ancillary services market.

Flywheel manufacturer Beacon Power has demonstration facilities in New England and Ohio each providing one megawatt of regulation service, and Beacon is now developing two 20 megawatt regulation facilities in New York. AES, a global power company with diverse generation and distribution businesses, has partnered with lithium-ion battery manufacturers A123 and Altairnano on one megawatt regulation projects in California and Pennsylvania and has ordered 44 MW of batteries for new projects.[28]

A number of project developers are also investigating the potential for developing compressed air energy storage systems (CAES) in Texas as well. These systems, like pumped hydro plants used in parts of the country with more rain and elevation, can provide both ancillary services and grid support discussed here, as well as shift large quantities of power from off-peak. There are numerous sites in West Texas and along the coast that are suitable for development of compressed air caverns. In West Texas, such a facility could be located in proximity to wind farms, to allow smoothing of fluctuations in output from wind turbines as well as providing support for the grid in a region where voltage support is needed.

It will take some time for ERCOT to make adjustments to accommodate energy storage in its market rules. In the next two or three years, storage could make up around 20 to 30% of the regulation market in ERCOT, or between 100 to 200 megawatts. Other markets for load following, voltage support and spinning reserves could increase this opportunity by a factor of

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[27] Beacon Power Annual Report. 2008. See http://216.139.227.101/interactive/bcon2008/ . Accessed August 2010.
[28] WSJ MarketWatch Press Release. August 2010. See http://www.marketwatch.com/story/a123-systems-solidifies-leadership-position-in-delivery-of-lithium-ion-technology-for-the-power-grid-with-order-of-44mw-of-smart-grid-stabilization-systems-sgsstm-2010-08-10?reflink=MW_news_stmp . Accessed August 2010.

10 over the next decade. In addition, according to the Sandia Lab report referenced earlier, storage can provide additional related services:

> Energy storage used for transmission support improves T&D system performance by compensating for electrical anomalies and disturbances such as voltage sag, unstable voltage, and sub-synchronous resonance. The result is a more stable system with improved performance (throughput). It is similar to the ancillary service (not addressed in this guide) referred to as Network Stability. [29]

The provision of transmission and distribution support services may be straight forward for vertically integrated utilities, but storage use in the competitive areas served by investor owned utilities in ERCOT is complicated by the unbundled structure of the electricity market. Wires utilities are prohibited from owning energy generation and storage systems sometimes act like generation. Despite the fact that over 100,000 batteries are in use at substations to power switches and station communications, this has prevented utilities from expanding their use to enhance delivery services or defer T&D costs. Under market protocols storage systems are forced to be considered as either generation or load, depending on their mode of operation (charging or discharging), and are penalized by being forced to comply with protocols for both types of resource. Until a new asset category is developed, and storage finds its own place in the system, this may continue to be a problem.

Customer Applications and On-site Generation Support

End users can turn to energy storage to help improve the power quality or assure power reliability at their premise, especially where such has high value. Energy storage can help support frequency, voltage, power factor and poor harmonics as well as ride-through rare interruptions of service. Batteries and flywheels are best for such applications. Storage can also be used to respond to time of use rates or avoid demand charges. Thermal storage has most often been used for this purpose, but we know of new services being contemplated to shift electric loads using electric storage as well.

In addition, with the proliferation of distributed generation (solar, small wind, fuel cells, and small generators), energy storage is sometimes used to store excess generation or improve the on-site system's production profile. Currently, lead-acid batteries are the most commonly used storage technology for these applications due to their simplicity and low cost. New batteries characterized by slower charging and discharging, and deeper discharge capacity, however, are beginning to make inroads into these markets. Flow batteries and metal air batteries are two categories of technology for which great hopes are held out, because of their potential low cost.

Regulatory Issues and Market Barriers: There are no immediate barriers to energy storage for customers, and storage is even a qualifying measure for energy efficiency incentives under

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[29] Sandia Report, SAND2010-0815, printed February, 2010. See http://prod.sandia.gov/techlib/access-control.cgi/2010/100815.pdf . Accessed August 2010.

programs operated by the investor-owned utilities. As always the viability of these applications depend on finding a business proposition, in which sufficient benefits can be captured, to justify the cost of the installation. Because the utility and/or load-serving entity benefit if storage shifts peak or improves power quality locally, storage may not prove economical to the end user unless these benefits can be compensated in some way. Today, thermal storage may make sense for large commercial customers, who can take advantage of time of use rates and utility incentives for load shifting when they are made available. Deployment of smart meters will help enable smaller customers to explore these options, which may prove viable if load serving entities are able to provide time of use pricing or load shift incentives that reflect total benefits.

Some vertically integrated utilities see energy storage as a utility resource, a potential replacement for peaking generation, which they might own and operate themselves, even at a customer's premise. Storage can simultaneously meet peak demand and provide other T&D support and ancillary services, and it can be located nearer load because it has little or no air emissions. San Antonio's CPS Energy is evaluating a new thermal storage system for smaller commercial customers with EPRI, with this in mind.

Market Forecast: Some Austin solar photovoltaic installers estimate that electric storage is currently installed in about 15% of residential and commercial solar PV installations. With U.S. installed PV capacity predicted to increase from 1,111 MW in 2008 to 5,293 MW in 2013, the growth in solar should drive corresponding growth in storage[30]. Since PV output peaks at noon (1 PM under daylight savings time) but summer temperatures in regions like Texas peak between 4 PM and 6 PM, lower storage costs combined with the penetration of time of use pricing or other incentives could facilitate the pairing of PV and storage.

The relatively young market for stationary grid-connected storage, though smaller than the mature market for UPS systems and the rapidly growing EV battery market, is nonetheless expected to grow to almost $2.5 billion in sales over the next six years, with storage capacity expanding from approximately 190 megawatts to 2500 megawatts over the same period[31].

One initiative that could drive residential distributed energy storage is American Electric Power's (AEP) Community Energy Storage (CES) initiative, which calls for widespread distributed storage installations using lithium-ion batteries recycled from electric vehicles. If implemented, the CES plan could mean hundreds of thousands of residential and commercial storage installations nationwide, although CES is likely a year or two away from use in large-scale pilot projects or commercial deployments. AEP envisions employing used EV batteries, which would be purchased at low cost since they would have little alternative economic value,

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[30] PRLog Press Release. June 2009. See http://www.prlog.org/10250298-globaldata-the-us-solar-pv-market-analysis-and-forecasts-to-2013-on-reportsresearchcom.html . Accessed August 2010.
[31] GTM Research, "*Grid Scale Energy Storage: Technologies and Forecasts Through 2015*", August 2009. See http://www.gtmresearch.com/report/grid-scale-energy-storage-technologies-and-forecasts-through-2015 . Accessed August 2010.

to establish small storage devices along feeder lines or even serving a small group of homes. CES installations could provide protection against transient fluctuations at the distribution level and short duration outages.

Many thermal storage systems were installed by large commercial customers with heavy air conditioning loads in the 1980s and 90s. The restructuring of the electric market interrupted that trend, and many of the older systems were idled as customers tried to adjust to the new regime and anticipate the best method to control loads and costs. These systems are beginning to come back on line now and new technologies are emerging to provide thermal storage to smaller customers. This will likely be a special niche market for the next three to five years, but as gas prices return to long-term levels, advanced meters are deployed and construction of new power plants proves more difficult, this technology holds great promise. Simply increasing the utilization of the existing ERCOT assets from about 53% to 63% of capacity, whether from electric or thermal storage, represents a $2 billion plus opportunity.

INTEGRATING RENEWABLE GENERATION

Renewable energy generation, not only large wind farms in remote sections of the grid, but also distributed renewable installations on commercial building and residences, are creating a new level of complexity for the electric system operators. Integrating these new resources will open opportunities for storage beyond ancillary services markets. Storage can be used to help absorb excess generation when it generated and hold it until it is needed. Just an hour or two of storage capacity can be used for firming the output of solar plants, which tend to hit their peak production just prior to the peak of demand, or to smooth production of solar PV installations that exhibit short-term variations in power based on clouds or other environmental factors. Local storage can also ameliorate voltage fluctuations from intermittent generation at the distribution level, maintaining power quality.

As wind generation increases on the ERCOT grid, for example, there will increasingly be times when the combination of wind generation and that of existing base load plants (coal and nuclear) will exceed loads during off-peak hours. It is very inefficient to ramp coal plants up and down like peak generators and regulators are unlikely to allow nuclear plants to be impacted. Rather than shut down the wind generators or force coal plants to operate inefficiently, storage could be used to capture these low cost power resources for delivery at a later time. This function would most likely be provided by bulk storage technologies, such as CAES.

Regulatory Issues and Market Barriers: Market protocols will likely have to recognize a new asset category for storage before these applications will be adopted by market participants. And, although investment in storage can avoid the need for transmission and distribution system investments, there is no mechanism to transfer any share of the resulting benefits to a storage provider. Unless storage becomes a routinely considered alternative for T&D planners, developers will have to make the economics work based on peak to off-peak price differentials in the market plus ancillary services fees. A flow battery is currently being used to defer transmission investment to Presidio Texas, but regulatory uncertainty has discouraged wider application of batteries for reliability applications by deregulated wires companies in Texas.

Additional questions involve the various tax credits and incentives available for renewable generation and storage resources. What incentives can storage receive, and how does the use of storage impact the collection of related incentives for generation? For example, if a storage system is receiving a storage investment tax credit, does wind energy put into that storage system also qualify for the Production Tax Credit and Renewable Energy Credit?

Market Forecast: There are only two operating CAES installations worldwide, with two new facilities under development in Iowa and California. Flow batteries are currently too expensive to be used to shift energy supply in most markets, but falling prices could make them more competitive. As the performance of storage technology improves and the price falls, and as the amount of wind generation in ERCOT rises, a market for hundreds of megawatts of storage capacity could develop.

Power Control Systems

Although every storage system will require power control equipment installed to interconnect to the on-site loads and grid systems, our research suggests that this technology/product/service area is also deserving of some attention in and of itself. This is particularly true because PCS systems work also accompanies the increasing volume of solar systems being installed across the country. There are no independent regulatory issues or market barriers, other than those that hinder the technologies these systems serve.

Market Forecast: The worldwide PV inverter market is about $4.5 billion in 2010.[32] There is also a substantial market for high power electronic power converters for VFDs for motor drives, wind converters, grid storage inverters, and power converters for electric and hybrid electric vehicles.

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[32] PV inverter market grew 17.4 percent last year to USD$2.8 billion, says IMS Research; predictions are this will change however, PV Magazine, July 29, 2010. See http://www.pv-magazine.com/news/details/beitrag/pv-inverter-market-grew-174-percent-last-year-to-usd28-billion--says-ims-research-predictions-are-this-will-change-however_100000621/, accessed August 2010.

WHAT TO TEACH IN A SHORT COURSE

Here is an outline of topics to be covered in a short course designed to provide an overview and introduction to energy storage and PCS, which could be developed into a module within a larger curriculum for electricians, engineers, automotive technicians, electricians, PV installers, renewable energy integrators, and utility operations personnel.

As these applications become more commonly accepted and demand for workers with skills related to specific energy storage types increases, the applications that are most in demand can be further developed and expanded through collaboration with emerging new technology manufacturers.

The course content below appears in a Sandia National Laboratories' Report entitled "Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide "by Jim Eyer and Garth Corey. The list of suggested course topics, and explanations, can be found at http://prod.sandia.gov/techlib/access-control.cgi/2010/100815.pdf.

Course Content:

Introduction

Application *versus* Benefit
Internalizable Benefits
Societal Benefits
Grid and Utility-related General Considerations
Real Power *versus* Apparent Power
Ancillary Services
Electricity Transmission and Distribution
Utility Regulations and Rules
Utility Financials: Fixed Charge Rate
Standard Assumption Values
Standard Assumption Values for Financial Calculations

Electric Energy Storage Technology Overview

Overview of Storage Types

Electrochemical Batteries
Capacitors
Compressed Air Energy Storage
Flywheel Energy Storage
Pumped Hydroelectric
Superconducting Magnetic Energy Storage
Thermal Energy Storage

Storage System Power and Discharge Duration

Transmission Capacity Constraints
Expected Proliferation of Electric Vehicles
Increasing Use of Intermittent Renewables
Increasing Use of Modular Distributed Energy Resources
Reducing Generation Fuel Use and Air Emissions
Storage Technology Innovation

Energy Storage Occupations

Below are some examples of trades and occupations that would benefit from a short course on energy storage. At present most emerging technology companies provide their own training with respect to their specific technologies, and this will not change very much for some time. However, attendance at an introductory class as outlined previously here would provide a glimpse of the diversity and dynamics of an emerging industry and provide interesting career ideas for existing professionals or students contemplating their futures.

Engineers

Utility and power systems engineers involved with the planning and maintenance of the transmission and distribution system is another audience for professional short courses on energy storage. These engineers know grid operations and power systems but have little experience with designing energy storage projects, and integrating them into their other operations, and could therefore learn to evaluate the potential of storage for their own systems. Similarly many mechanical engineers would do well to have an overall introduction to energy storage system options applications and benefits, a course which could lead to additional specific training on thermal storage systems.

Researchers

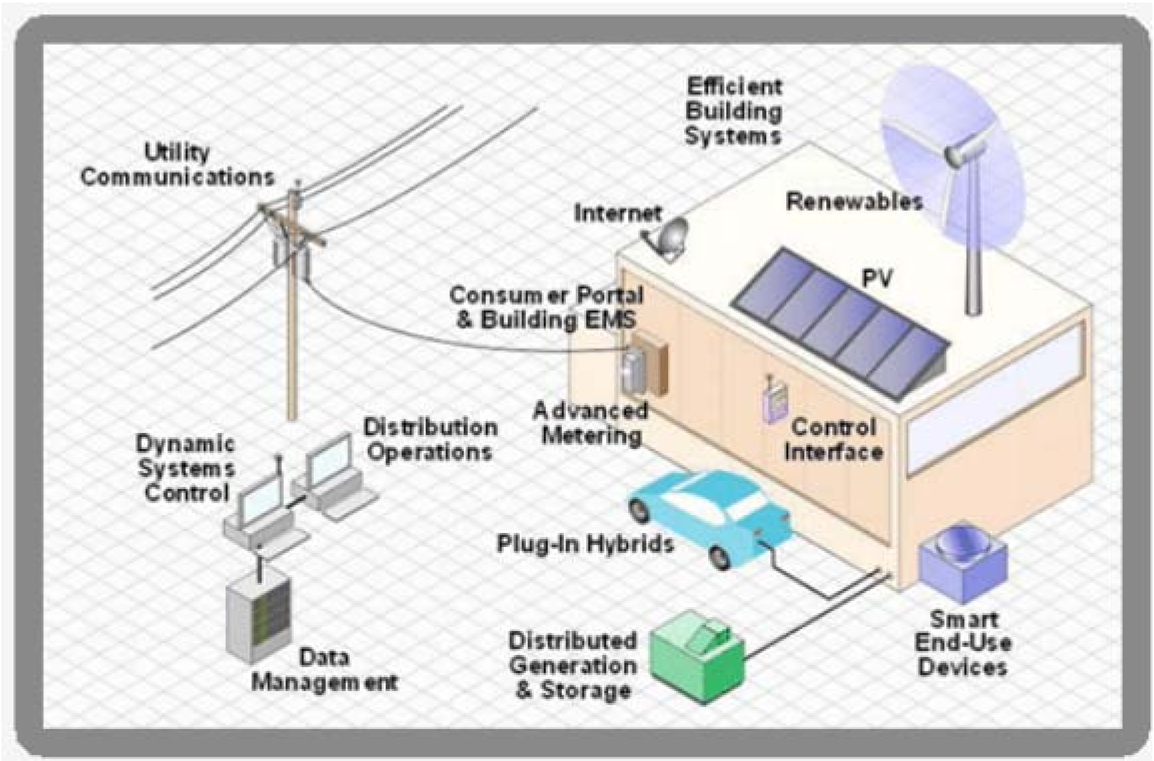
As storage companies refine their technologies and work toward commercialization of new storage products, many of the jobs created in energy storage will be highly-skilled positions in research and development and product design. Employees with backgrounds in materials science, electrical engineering, battery engineering, electromechanical engineering, and process engineering will be in high demand. It would make sense to develop course modules to give such professionals a clearer view of potential new career horizons and open up new opportunities.

Electricians

In the short term, energy storage training efforts should focus on areas where jobs are already available. Curriculum for electricians and electrical technicians should be augmented with coverage of emerging energy storage technologies and applications. Students would have the confidence of knowing there will be a market for their skills, while also gaining a head start on further specialization and employment in the energy storage industry as the industry grows and develops. Power systems engineers in particular could begin learning about utility scale applications that may become common sooner than some think.

Solar Installers/Solar Sales Reps/Renewable Energy System Integrators.

As distributed renewable energy systems become more common, so will the use of energy storage, and both require many of the same skills. The chart below illustrates the many facets of the envisioned smart grid, and includes distributed storage. Solar and small wind installers should be able to install storage as they install renewable energy systems, and solar sales representatives should understand the various technologies available enough to be able to sell them. Jobseekers with those skill sets will have an advantage in the marketplace.



FACILITY MANAGERS

As the key decision makers regarding energy use in commercial buildings, facility managers will be critical to driving the adoption of energy storage from the demand side. Curriculum for facility managers should communicate the applications and benefits of energy storage technology for facility energy savings, cost savings, power quality, and reliability. A facility manager who is able to identify ways to reduce a building's energy costs through the intelligent application of energy storage will be in high demand by employers.

UTILITY LINEMEN AND OTHER TRANSMISSION/DISTRIBUTION UTILITY STAFF

As new storage technology begins to be directed toward substations (only 5% of substation storage today is NiCd rather than lead-acid) and in Community Energy Storage applications in neighborhoods and near commercial buildings, utility linemen and other utility staff will need to understand the attributes of various types of energy storage, and be aware of its potential applications.

Storage associated with local behind the meter applications will have all the same dangers as distributed solar systems and be more difficult to see. It is uncertain if linemen will be allowed under state regulations to install, maintain, and/or service storage applications in the field, or if that will a function relegated to electricians. However, linemen and other utility staff will need to understand storage and its properties in order to diagnose potential problems and ensure safety.

Automotive Technicians

Lithium and Nickel batteries will be used in both electric vehicles and stationary energy storage applications, so students who can work with electric vehicle batteries will have a head start in careers that include working with stationary energy storage systems. Some community colleges and training organizations already offer automotive engineering programs in partnership with local dealerships where students obtain real world experience. Training organizations could extend these courses to cover electric vehicle batteries with crossover opportunities to stationary storage applications. A123 announced its first Texas certified installer, ZWheelZ, which has received training to convert Prius cars to plug-in hybrid electric vehicles, largely through the installation of additional storage capacity.

Mechanical Contractors

Licensed mechanical contractors and technicians could benefit from an overview of energy storage technologies, and particularly to see the context within which their HVAC operate. Understanding the potential customer benefits and utility programs, incentives or rate options that could impact the net value to their customers of thermal storage would be helpful to build more interest in this application among the professionals that are likely to be called upon to address commercial and residential building energy needs. Greater understanding of the potential benefits could lead individuals to seek additional detailed training on thermal systems.

STANDARDS

There are however many standards with which energy storage devices and power control systems must comply. There are many more currently under development at the National Institute of Standards and Technology (NIST).

For now, here is a partial list, gathered from industry participants, of standards governing energy storage. Below that are descriptions of a few certifications related to storage (e.g., NABCEP PV installer, etc).

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS

- IEEE 979, Guide for Substation Fire Protection
- IEEE C62.41.2-2002, I EEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits
- IEEE 80, IEEE Guide for Safety in AC Substation Grounding
- IEEE 142-2007, Recommended Practice for Grounding of Industrial and Commercial Power Systems
- IEEE 1547-2003 "Standard for Distributed Resources Interconnected with Electric Power Systems" (also 1547.1, 1547.2, 1547.3, 1547.4, 1547.5, 1547.6)
- IEEE 519-1992 "IEEE Recommended Practices for Harmonic Control in Power Systems"
- IEEE C62.92.4 "IEEE Guide for Application of Neutral Grounding in Electrical Utility Systems – Part IV Distribution"
- IEEE C37.90.1 "IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus"

AMERICAN NATIONAL STANDARDS INSTITUTE

- ANSI C84.1, American National Standard for Electric Power Systems and Equipment—Voltage Ratings (60 Hertz)
- ANSI/IEEE C2-2007, National Electrical Safety Code (NESC), 2007 Edition
- ANSI C37.06, Switchgear - AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities

NATIONAL ELECTRICAL CODE

- NEC Article 480, "Requirements for storage batteries "
- NEC Article 690 "Solar Photovoltaic Systems"
- NEC Article 250 "Grounding"
- NEC Articles 445, 700, 701, 702 and 705

OTHER RELEVANT CODES

- NFPA 79, NFPA 79: ELECTRICAL STANDARD FOR INDUSTRIAL MACHINERY

- FCC Title 47 part 15 Class A, Part of Federal Communications Commission (FCC) rules and regulations regarding unlicensed transmissions. It is a part of Title 47 of the Code of Federal Regulations
- UL 1741-2001 “Inverters, Converters and Controllers For Use in Independent Power Systems”
- FERC Order 2006A – Small Generator Interconnection Procedures (for Generating Facilities No Larger than 20 MW)

CERTIFICATIONS

Currently, the only certifications for energy storage topics are designed for solar photovoltaic installation; there are no certifications designed exclusively for the design and installation of energy storage systems at this time.

NABCEP SOLAR PV INSTALLER CERTIFICATION

The most widely used solar PV certification is provided by the North American Board of Certified Energy Practitioners (NABCEP). The NABCEP solar PV certification covers all aspects of solar PV system design and installation, including the use of battery storage. Storage is not the primary focus of the certification, but the certification does cover storage concepts in sufficient detail that a certified installer should be able to install and maintain a battery storage system used in support of a solar PV installation. Some of the storage-related concepts tested by the certification include choosing battery capacity to meet system needs, proper battery wiring, and the use of charge controllers and low voltage disconnect controllers to avoid overcharging or overdischarging. The certification also covers other power system concepts relevant to all energy storage systems, including interconnection with the utility and the use of inverters to convert DC power to AC power.

The NABCEP certification track has two levels. The entry level certificate program is appropriate for individuals entering the solar field and requires only the completion of a test demonstrating knowledge of core concepts required for solar PV installation work. The master-level NABCEP certification requires two to four years of experience in solar PV installation or electrical contract work, and the candidate must have served in a responsible role overseeing the installation of at least two solar PV systems. Candidates also have to pass a written exam that covers solar PV system concepts in greater depth and difficulty than in the entry level exam.

In Texas, master-level solar PV installers are required to have two credentials: a master electrician license and the NABCEP PV certification. Of the approximately 14,300 master electricians[33] currently licensed by the state of Texas, less than 50 have the NABCEP PV certification[34].

NABCEP SOLAR PV INSTALLER TRAINING

There are three training institutions in Texas registered with NABCEP to provide instruction for the NABCEP entry-level and professional-level exams, all located in Austin: Austin Community College, the Austin Joint Apprenticeship and Training Committee, and Adven, LLC. Austin Community College offers two courses. HART 1071, Solar Electric Systems, Entry-Level,

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33 Texas Department of Licensing and Regulation. http://www.license.state.tx.us/LicenseSearch/licfile.asp
34 NABCEP Installer Locator. http://www.nabcep.org/installer-locator>.

prepares students to take the NABCEP entry-level certificate exam at the end of the course[35]. HART 1072, Advanced Solar Photovoltaic Installer, prepares students for the NABCEP Solar PV Installer certification.

HYBRID AND ELECTRIC CAR TRAINING

Electric vehicles such as the Nissan Leaf and Chevy Volt, which are expected to debut within the next year, may represent another avenue for storage-related training with near-term employment prospects. Community college students could use the emerging market for hybrid and plug-in electric vehicles as a starting point for further education in stationary energy storage.

COMMUNITY ENERGY STORAGE STANDARD

The only storage device standard at this time is the Community Energy Storage (CES) standard, a functional specification for a neighborhood storage resource created by American Electric Power. Each CES unit would be about the size of a neighborhood transformer and would serve four or five houses or a single commercial building. AEP and the Electric Power Research Institute (EPRI) are developing the CES specification as a standardized design that could be deployed cheaply in large numbers. The CES design calls for used lithium-ion batteries from electric vehicles to be repackaged into CES units. After years of use, an electric vehicle's lithium-ion battery degrades to the point that it is no longer usable in a vehicle but could still be usable for stationary storage applications. The CES plan takes advantage of these used batteries as a low cost source to provide distributed energy storage.

Individual CES units could provide backup power and improved power quality to consumers, and the aggregation of thousands of CES units represents a significant grid-scale storage resource for utilities. CES devices, if deployed in large numbers, would create new jobs in installation, maintenance, and battery recycling.

[35] Austin Community College Renewable Energy Industry Certification Courses. See http://www.austincc.edu/ce/renewable/industry/ . Accessed August 2010

APPENDIX A: ENERGY STORAGE COMPANIES

A123

1819 employees
Revenue (trailing twelve months, 2008-2009): $89.5M
Li-ion batteries for transportation and grid stabilization. Awarded $250M DOE stimulus funding August 2009.

ActaCell

10 employees, all in Texas
Pre-commercial
Developing high power lithium-ion batteries using technology licensed from the University of Texas at Austin.

Active Power

149 employees, all in Texas
Revenue (ttm): $42.5M
Flywheel UPS systems.

AES

25,000 employees, some in Texas
Revenue (ttm): $14.7B
Diverse generation & distribution businesses. Uses storage products to support its operations.

Altairnano

92 employees
Revenue (ttm): $3.65M
Li-ion batteries, battery nano materials, integrated energy storage systems.

Axion Power

50 employees
Revenue (ttm): $893K
Lead-carbon batteries.

Beacon Power

61 employees
Revenue (ttm): $412K
Manufactures flywheel storage systems for providing frequency regulation service.

Deeya Energy

Redox flow batteries.

DTE Energy Services

10,471 employees
Revenue (ttm): $8.07B
Energy project development & operation for large energy users.

East Penn

Manufactures lead-acid batteries, (CSIRO, Deka, Unigy brands).

EEStor

33 employees
Pre-commercial
Developing novel capacitor-based energy storage. Extremely high storage densities claimed but not yet proven.

Electrovaya

Lithium-ion batteries for transportation.

Ener1/Enerdel

486 employees
Revenue (ttm): $22.0M
Automotive Li-ion batteries. Awarded $118.5M DOE stimulus funding August 2009.

Energy Storage & Power

Next generation CAES.

EnerSys

7,500 employees
Revenue (ttm): $1.56B
Lead-acid batteries for utility, UPS applications.

EnerVault

Pre-commercial
Flow batteries.

Exide Technologies

12,081 employees , some in Texas
Revenue (ttm): $2.94B
Industrial UPS, lead-acid batteries, battery recycling.

Expansion Energy

Pre-commercial
Holds intellectual property regarding liquid air in low-pressure cryogenic containers, as an alternative to CAES.

FireFly Energy

Carbon-graphite foam lead-acid batteries.

Fluidic Energy

Utility-scale and customer-sited energy storage. The technology used is not known.

General Compression

CAES.

Graphene Energy

Pre-commercial
Austin startup developing graphene-based ultracapacitors.

Greensmith Energy Management

Distributed energy storage management system using Li-ion $FePO_4$ batteries.

Grid Storage Technologies

Utility-scale zinc/air battery technology.

Maxwell Technologies

346 employees
Revenue (ttm): $93.3M
Ultracapacitors for energy storage.

Mechanical Electric

Mechanical energy storage via gravity and compressed springs.

NGK Insulators

Japanese company
11,205 employees
Revenue (fiscal year ending 2009): $2.8B
Large, diversified company that manufactures and installs sodium-sulfur batteries.

Nilar

NiMH batteries.

Pentadyne Power

Flywheel UPS and power recycling systems.

Powergetics

Energy storage solution provider for commercial customers.

Premium Power

Zinc-flow battery for utility use, peak shaving, bulk storage, UPS.

Primus Power

Pre-commercial

Utility-scale flow-battery technology.

Prudent Energy

Vanadium-redox battery energy storage systems.

Red Flow Systems

Zinc-Bromine flow battery

ReVolt Technology

Zinc-air batteries for portable electronics.

S&C

Utility-scale power controller for managing 2-4MW batteries.

Saft Batteries

French company

4004 employees

Revenue (fiscal year ending 2009): €609.4M

Lithium and nickel based batteries.

Utility Savings & Refund

Sell and install the VRB-ESS flow battery.

Valence Technology

352 employees, some in Texas

Revenue (ttm): $19.9M

Li-ion battery manufacturer for automotive, utility, industrial, and military applications.

Velkess

Pre-commercial

Developing flywheel storage.

Vycon

Flywheel storage for energy recycling, UPS/power quality.

Xtreme Power Solutions

100 employees in Texas, more at new manufacturing facility in Michigan

Provides integrated power management and storage using dry cell lead-acid batteries.

Primary focus is utility-scale installations.

Yuasa Battery

Lead-acid batteries for motorcycles, ATVs, and watercraft.

ZBB Energy Corp.

35 employees

Revenue (ttm): $1.78M

Zinc-bromine battery energy storage.

APPENDIX B: INVENTORY OF ENERGY STORAGE COMPANIES IN CENTRAL TEXAS

Several energy storage companies are headquartered or have major facilities in Central Texas, including Active Power, Xtreme Power, Valence Technology, and Exide Technologies. Some other Texas energy storage companies are in the pre-commercial phase of development, including ActaCell, EEStor, and Graphene Energy.

ACTIVE POWER

Active Power, a manufacturer of flywheel energy storage systems, was founded in 1992. Its headquarters and manufacturing facility are located in Austin, Texas, with international offices in the U.K., Germany, and Japan. Active's flywheel storage systems range from 250 to 2000 kW each and can be operated in parallel to scale to multiple megawatts of capacity. Active offers uninterruptible power supply (UPS) systems for use in datacenters, health care, industry, and other settings requiring protection from power disturbances and disruptions. Active also offers flywheel based DC energy storage systems for use in conjunction with UPS systems and generators to provide ride-through power during a blackout. In addition to product sales, Active also provides storage-related services including project engineering, installation, monitoring, and repair.

Active has deployed more than 2,100 flywheels providing more than 500 MW of power in over forty countries. Active's headquarters, R&D lab, testing facility, and 80,000 square foot manufacturing facility are located in Central Texas. At the end of 2008, Active had 149 employees[36]:

- 21 engineers and technicians in research and development
- 72 in manufacturing, sourcing, and service
- 39 in sales and marketing
- 17 in administration, information technology, and finance

XTREME POWER

Xtreme Power was founded in 2004 and is headquartered in Kyle, Texas, just south of Austin, where it employs approximately 100 people. Xtreme sells integrated storage solutions based on solid state advanced lead-acid batteries. Their primary focus is on very large scale utility storage systems ranging from 500 kW to 100 MW. Xtreme also sells medium size storage systems to commercial and small industrial customers through a network of sales reps and wholesalers. To install its storage systems, Xtreme uses a combination of in-house installers and local contractors.

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[36] United States Securities and Exchange Commission, Form 10-K, Active Power, Inc. 2008. See http://www.activepower.com/fileadmin/documents/financial_reports/2008_Form_10K.pdf . Accessed August 2010.

In September, 2009, Xtreme and partner Clairvoyant Energy announced an agreement with Ford and the state of Michigan to renovate the 4.7 million square feet of space at Ford's Wixom Vehicle Assembly Plant for use as a manufacturing facility. Xtreme will use over 1 million square feet to manufacture energy storage products, and Clairvoyant will use a portion of the site to manufacture solar panels. The plant, which had been closed since 2007, is expected to generate more than 4,000 direct jobs and thousands of indirect jobs as a result of the redevelopment. The deal brokered by Michigan to win the project includes battery tax credits, Michigan Economic Growth Authority employment tax credits, Renaissance Zone tax incentives, and brownfield tax credits. Xtreme and Clairvoyant will together be investing more than $725 million to redevelop the Wixom site.

Xtreme sees some growth of the storage market in Texas over the next couple of years, but believes that the Texas market is being held back by the ERCOT ancillary services market structure, which is optimized for traditional generation and is not well suited to participation by energy storage technologies. In comparison to ERCOT, markets such PJM and NYISO have a more granular ancillary services market that makes it easier for storage to participate in the market and provide services such as regulation.

VALENCE TECHNOLOGY

Valence Technology manufactures and sells lithium ion batteries based on lithium iron magnesium phosphate chemistry. Valence is headquartered in Austin, Texas and has a materials research and development center in Las Vegas, Nevada. Valence employs 39 people at its Austin and Las Vegas locations, and another 313 people work at Valence's manufacturing and product development center in Suzhou, China. Valence was founded in 1989.

Valence had $24.8 million in battery and systems sales for the fiscal year ending March 31, 2009, up from $20.2 million for 2008 and $16.0 million for 2007. For the year ending March 31, 2009, 46% of Valence's battery sales were custom batteries designed for Segway, and 45% were large-format battery systems for motive applications such as personal transporters, delivery vehicles, and buses.

Valence applied for $225 million in federal stimulus money from the $2.5 billion allocated by the American Recovery and Reinvestment Act for Advanced Battery Manufacturing, but Valence was not chosen to receive funding. Valance planned to use the money to build a battery manufacturing plant in Leander. Valence claimed that the plant would create up to 2,700 jobs when it opened in 2012 and would create another 1,300 jobs by 2016[37].

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[37] Hawkins, Lori. Austin American Statesman. November 11, 2009. See http://www.statesman.com/business/content/business/stories/technology/2009/11/11/1111actacell.html . Accessed August 2010.

EXIDE TECHNOLOGIES

Exide is one of the world's largest manufacturers, distributors, and recyclers of lead-acid batteries and has dozens of locations in countries around the world. Exide's only presence in Texas is a battery recycling facility in Frisco.

ACTACELL

ActaCell is an Austin-based start-up working to commercialize the lithium-ion technology developed by Professor Arumugam Manthiram's Material Science and Engineering lab at the University of Texas at Austin. ActaCell currently employs about five people[38]. ActaCell's goal is to increase the cycle life and decrease the cost of its lithium ion battery technology for use in the electric vehicle (EV) and plug-in hybrid electric vehicle (PHEV) markets. In 2008 ActaCell closed $5.8M in Series A financing from DFJ Mercury, Google.org, Applied Ventures, and Good Energies. In November 2009, ActaCell received a grant worth up to $1 million from the Texas Emerging Technology Fund (ETF). The ETF will give ActaCell $250,000 initially, with further funding tied to performance benchmarks[39].

EESTOR

EEStor is a small company based in Cedar Park, Texas with approximately 33 employees. EEStor claims to have developed a new type of energy storage technology capable of much higher energy densities than competing technologies such as lithium ion batteries. EEStor's design, which uses a capacitor with a novel combination of ceramics and barium titanate powder, is claimed to have energy storage capacity that exceeds the storage capacity of current capacitors many times over. EEStor has not yet demonstrated a working prototype or had its technology publicly tested by an independent authority.

EEStor has received investments from Kleiner Perkins ($3 million in 2005) and the electrical vehicle company Zenn Motors ($2.5 million in 2007 and smaller payments more recently). In January 2008, Lockheed Martin signed an agreement obtaining exclusive rights to use EEStor's technology in military applications, but did not invest any money in EEStor.

GRAPHENE ENERGY

Graphene Energy is a start-up located in Austin that was founded in December 2008. Graphene Energy is working to develop graphene ultracapacitors based on research performed at the University of Texas at Austin.

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Appendix C O*NET Occupations Related to Energy Storage

The Department of Labor's Occupational Information Network (O*NET) identifies "Green New and Emerging" occupations[40]. Those most relevant to the development of the energy storage industry are listed in Table 1.

Table 1. O*NET Green New and Emerging Occupations Related to Energy Storage

O*NET-SOC 2009 Code	O*NET-SOC 2009 Title	Classification
17-3029.02	Electrical Engineering Technologists	New and Emerging
17-3029.03	Electromechanical Engineering Technologists	New and Emerging
17-3029.04	Electronics Engineering Technologists	New and Emerging
41-3099.01	Energy Brokers	New and Emerging
13-2099.01	Financial Quantitative Analysts	New and Emerging
13-2099.03	Investment Underwriters	New and Emerging
13-1081.02	Logistics Analysts	New and Emerging
13-1081.01	Logistics Engineers	New and Emerging
11-9199.06	Logistics Managers	New and Emerging
17-3029.06	Manufacturing Engineering Technologists	New and Emerging
17-2199.04	Manufacturing Engineers	New and Emerging
17-3029.09	Manufacturing Production Technicians	New and Emerging
17-3029.07	Mechanical Engineering Technologists	New and Emerging
17-2199.05	Mechatronics Engineers	New and Emerging
17-2199.06	Microsystems Engineers	New and Emerging
17-2199.09	Nanosystems Engineers	New and Emerging
17-3029.12	Nanotechnology Engineering Technicians	New and Emerging
17-3029.11	Nanotechnology Engineering Technologists	New and Emerging
51-9199.01	Recycling and Reclamation Workers	New and Emerging
53-1021.01	Recycling Coordinators	New and Emerging
11-9199.01	Regulatory Affairs Managers	New and Emerging
13-1041.07	Regulatory Affairs Specialists	New and Emerging
19-2099.01	Remote Sensing Scientists and Technologists	New and Emerging
19-4099.03	Remote Sensing Technicians	New and Emerging
13-2099.02	Risk Management Specialists	New and Emerging
41-3031.03	Securities and Commodities Traders	New and Emerging
47-1011.03	Solar Energy Installation Managers	New and Emerging
17-2199.11	Solar Energy Systems Engineers	New and Emerging

[40] O*NET Resource Center. Green New and Emerging Occupations. See http://www.onetcenter.org/green/emerging.html . Accessed August 2010.

47-4099.01	Solar Photovoltaic Installers	New and Emerging
41-4011.07	Solar Sales Representatives and Assessors	New and Emerging
11-9199.04	Supply Chain Managers	New and Emerging
17-2199.02	Validation Engineers	New and Emerging
11-9199.09	Wind Energy Operations Managers	New and Emerging
11-9199.10	Wind Energy Project Managers	New and Emerging

APPENDIX D: BIBLIOGRAPHY

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