The purpose of this New York Energy Storage Roadmap is to provide a reference document to all stakeholders in the growth of energy storage in New York. Its objective is to identify the state’s specific needs and to recommend potential strategies to meet the challenges of expanding the development, manufacturing and deployment of energy storage in New York. It is intended to enable industry, academic, and government participants to plan ahead as they put in place investments, legislation, business plans, research programs, learning arrangements and commercial cooperative ventures.

Creation of this roadmap was spearheaded by NY-BEST and was initiated with a workshop held at NY-BEST’s “Capture the Energy 2012” conference in Troy, NY on March 7-8, 2012. A group of 45 experts convened and discussed the development of a statewide roadmap for the energy storage industry. Following the workshop, the present document was developed with support from the contributions and comments of a diverse set of stakeholders in the New York energy storage community.

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EXECUTIVE SUMMARY

Energy storage technology is poised to be a game-changer for two of the world’s largest and most essential industries: the electric grid and transportation. Cost-effective, reliable energy storage on a large scale will dramatically change how the entire electricity industry functions and how vehicles are powered. New York’s economy already employs thousands of workers in the battery and fuel cell industry and the state is home to the New York Battery and Energy Storage Technology Consortium (NY-BEST), which is a rapidly growing, industry-led, private-public coalition of over 100 entrepreneurial, academic, corporate, and government partners. New York State, with its leading universities, global companies and world-class markets, has the potential to become the national leader in the advanced energy storage sector. Over the next ten years, the energy storage industry in the state could add 15,000 to 20,000 jobs, billions of dollars in revenues, and significant improvements in the quality of life in New York.

This Roadmap for Energy Storage was commissioned by NY-BEST to assess the current landscape for energy storage technologies and to outline a strategy for growing the energy storage industry in New York State. This industry encompasses a wide range of technologies including batteries, fuel cells, ultracapacitors, flywheels, pumped hydro, superconductors, and thermal storage. The roadmap examines the roles of technology, industry and policy in the state and establishes key recommendations for each of these areas. Over the past twenty years, portable computers, smart phones, tablets, and other handheld devices have become essential parts of business and daily life around the world. Driven by advanced semiconductor fabrication, plentiful and inexpensive data storage, and powerful computer technologies, these devices have made small-scale energy storage (i.e., batteries) crucial to how we live. These modern devices have established a huge market for rechargeable batteries and have driven development in advanced battery technologies.

The same improved capabilities are now ready to transform both the electric grid and transportation. The same forces that have steadily lowered costs of consumer energy storage technologies will make energy storage for transportation and the grid increasingly affordable.

The power grid needs to be transformed into a more reliable, secure, efficient and clean network capable of dealing with massive changes over the next two decades. Energy storage can relieve grid congestion, reduce greenhouse gas emissions, increase efficiency and provide a more effective way to provide necessary capacity on the grid. The global automotive industry is beginning to move away from the internal combustion engine and toward electric drivetrains. Electric vehicles can also reduce emissions, dependence on fossil fuels, and reduce geopolitical tensions created by the petroleum economy. Energy storage is the key to these transformations.

New York is already an important center for established energy storage technologies. In particular, the commercial and military battery industry is an important business in the state. However, over the next ten years, New York has the opportunity to play a much greater role in the dramatic growth of the new energy storage industries. The State is well positioned to become a preeminent location for research, development, design, production, deployment, operation, and reuse of energy storage technology for both the electric grid and for electrified transportation.

New York is home to a network of world-class universities and state and federal research centers. The State Government, through NYSERDA, has spearheaded research and development of energy storage based on a broad range of technologies. New York’s companies have invested hundreds of millions of dollars in growing the industry. A wide spectrum of product industries, from basic materials, to battery modules, to integrated storage systems, and to complete platforms such as lift trucks to locomotives are being developed in New York State. New York has a substantial electric power and transportation infrastructure along with supporting providers of test services, manufacturing equipment, legal and financial services, venture capital, and more. New York has the largest metropolitan area in the country, the largest transit system for both metro and bus, and the largest commuter rail system in North America. These attributes give New York a unique opportunity to lead in the application of electricity storage for the grid and to lead the electrification of transportation for heavy road vehicles, metro and commuter rail. The State is also positioned to be a major adopter of electric passenger vehicles.

New York can distinguish itself as a leader in the energy storage field by undertaking key actions in technology development, in business development, and in policy over the course of the next ten years. To establish this leadership role in energy storage, key stakeholders in New York from industry, small businesses, government, academia, research centers and other interested groups need to work together to pursue three major goals:

+ Establishing robust New York markets through the use of appropriate technologies, policies and incentives.
+ Creating value chain clusters of companies that will provide the manufacturing capability to grow the energy storage industry in support of New York and global markets.
+ Continuing technology leadership and stimulating commercialization of advanced technologies through R&D funding, collaboration and leveraging of resources.

New York policy-makers and regulatory agencies should put in place long-term operating rules that allow companies—including utilities along with independent power providers—to capture the full value of energy storage technology and short-term incentives that drive market transformation.

Storage also should become a part of the state’s Renewable Energy Portfolio Standard. By doing these things, over the next ten years, New York can achieve the goal of adding 1 GW of new storage capacity including substantial installations of community energy storage.

New York’s transportation industry, transit agencies and companies should continue the widespread adoption of hybrid buses and fleets throughout the state and pursue the electrification of medium- and heavy-duty commercial vehicles and the utilization of storage technology in its public transportation systems. The State should also set aggressive goals for electrification of passenger vehicles over the next 10 years culminating with a goal of 25% of new vehicles sold in New York in 2022 having electric drive. To encourage the adoption of electric drive vehicles, New York should continue its efforts to accelerate the development of electric vehicle charging and hydrogen fuel cell recharging infrastructures.

New York’s electric utility sector, government agencies and other interested groups should work together to achieve the goal of having New York State capture 15% of the North American grid storage market over the next ten years and potentially create 10,000 to 16,000 jobs up and down the value chain in the process. Economic development incentives—at the State and local level—should be used to encourage the location of energy storage-related manufacturing in New York State. New York should focus on its strengths and its diverse assets that can support a growing energy storage industry.

New York’s numerous private and public research institutions should use their considerable technology resources to further the development of cost-effective storage applications for the grid. New York can further strengthen its position as a leading center for research and development of energy storage technologies by establishing an independent diagnostics, testing and prototyping center to ensure that innovations in materials and methods can be demonstrated to potential users and find their way to market in the most efficient way possible.

By pursuing these goals, New York can attain significant growth in jobs, revenues and in the deployment of energy storage. The State can capitalize on its great potential and become a preeminent location in the growing energy storage industry.
Modern civilization has developed based upon our ability to access stored energy resources and put them to use when and where needed.

Since the Industrial Revolution, converting energy resources in the form of fossil fuels such as coal, gasoline and natural gas has enabled us to produce heat, mechanical energy and electricity from energy long stored in the chemical makeup of these fuels. Faced with the growing negative environmental impact of fossil fuel use and the ever-increasing role of electricity in society, the future of the developed world will increasingly depend on our ability to store electrical energy. Commercial, cost-effective energy storage technology is essential for the advancement of two of the world’s largest and most essential industries: the power grid and transportation. Storage technology can enable the widespread effective use of solar, wind and other renewable sources, while alleviating grid congestion, enhancing the effectiveness of existing resources, increasing grid efficiency, reducing the environmental impact of the grid, and enhancing sustainability. Energy storage products are the key to pervasive hybridization and electrification of transportation, from automobiles and buses to trucks and trains. The transformation of these trillion-dollar industries will provide environmental benefits, reduce energy costs and act as powerful economic drivers for the places that are home to the energy storage industry.
he ability to supply electrical power is relatively fixed over short periods of time, but demand for that power fluctuates throughout the day. The system must constantly seek balance between the supply and demand of electricity both on an overall level and across the grid. The conventional approach to achieving grid balance is to use dispatchable power generation assets during periods of high demand. Energy storage represents an alternative approach to grid management. If electrical energy can be stored so it can be available to meet demand whenever needed, the operating capabilities of the electrical grid would be greatly enhanced. This capability provides flexibility in generation and distribution, thereby improving the economic efficiency and utilization of the entire system while making the grid more reliable and resilient and less volatile. A substantial capacity for electrical energy storage will moderate the grid for today’s needs and create a grid capable of handling a high penetration of intermittent renewable generation (such as solar and wind power). Regardless of the energy source (fossil fuels or renewables), the grid needs to be more efficient in using the energy captured.

Energy storage in the form of pumped hydro storage has been in place on the grid for decades. Energy storage for the grid is facing a turning point. New storage technologies are under development and new forces are shaping the power grid. Advanced storage technologies are increasing in performance and coming down in price. As a result, energy storage represents a major opportunity for utilities, grid service providers, and grid equipment installers.

Energy storage can solve and deliver value in a number of applications, ranging from very short-term power requirements to much longer duration energy needs. It can provide generation services, act like transmission, and provide support on the distribution network. This flexibility in design and configuration is extremely beneficial but there are currently complexities in the market environment that may restrict storage device owners from fully realizing all of the benefits. Energy storage technologies must compete with traditional solutions on the grid both in performance and in cost. Technology improvements, the impact of external costs, and increasing adoption will all improve the competitive position of storage. The Electric Power Research Institute (EPRI) has identified up to 17 grid applications for energy storage, although not all are applicable to the current marketplace. The most compelling near-term applications include capacity, load leveling and peak shifting, arbitrage, renewable energy grid integration, ancillary services, transmission and distribution upgrade deferral, and community energy storage. These grid applications are discussed in detail in the Guide to Energy Storage at the end of this document along with an overview of energy storage technologies and markets.

The U.S. spends over $300 billion annually on imported foreign oil—accounting for about half of the total U.S. trade deficit—and emissions from transportation are responsible for about one-third of all greenhouse gas emissions. Clearly, our nation has compelling reasons to reduce its consumption of oil. Electric drive vehicles—hybrid, plug-in hybrid, pure battery electric, and fuel cell vehicles—contribute to both trade deficit reduction and greenhouse gas reduction by replacing petroleum with electricity drawn from the grid. Globally, the automotive industry has begun a slow transition away from the internal combustion engine (ICE) and toward electric drivetrains. Reducing environmental emissions and reducing the geopolitical influence of oil are on the top of the agenda of many countries across the world. As a result, vehicle electrification increasingly receives governmental support in the form of incentives offered to consumers, subsidies to manufacturers, increasingly stringent emission standards, and support for research and development of advanced battery technologies. In the US, the 2025 Corporate Average Fuel Economy (CAFE) standard is set at 54.5 miles per gallon, which creates a strong incentive for vehicle electrification.

The electrification of vehicles is undergoing a gradual evolution from hybrid vehicles that more efficiently utilize the energy provided by fossil fuels to plug-in hybrids that obtain some energy from the grid to battery and fuel-cell vehicles that have no internal combustion engines at all. Passenger cars and light trucks have been the major focus for vehicle electrification but heavier vehicles from buses to heavy trucks to trains can also use stored electricity to boost propulsion, improve fuel economy and reduce emissions. The electrification of trucks and commercial vehicles is following the same evolution as that of passenger vehicles. There is wide-spread use of hybrid buses in urban areas, there is increasing use of all-electric delivery vehicles, and the energy-saving benefits of hybridization and electrification are becoming increasingly attractive for many forms of rail transport. Further details are discussed in the Guide to Energy Storage.
New York State represents a prime market for energy storage. It is home to the largest metropolitan area in the country. Furthermore, New York City is the most transit-dependent city in the United States whose system carries more passengers than the next five largest systems in the U.S. combined. New York State has a large and aging electricity infrastructure. Most of the state’s transmission lines were built more than 50 years ago and two-thirds of the state’s generating facilities are at least 30 years old. New York has substantial and growing clean generation resources upstate and growing demand downstate, a situation that puts particular stress on aging transmission resources. Fortunately, New York is a state where regulatory agencies have recognized the potential value of energy storage.

New York is one of the national leaders today for energy storage with 3.6% (1,400 Megawatts) of its capacity in pumped storage versus 2.2% (22,500 MW) nationally. Most of the power generated from pumped storage resources in New York comes from the Bierheim-Gibson facility located in the Catskill Mountains west of Albany. This New York Power Authority (NYPA) facility is the fifth largest in the U.S. on a capacity basis. The New York Independent System Operator (NYISO) has recognized the value of integrating energy storage resources into the state’s electric system, and both the New York Public Service Commission (PSC) and the Federal Energy Regulatory Commission (FERC) see important roles for storage in a modern grid. In 2009, the NYISO became the first grid operator in the nation to implement regulations that enable storage systems to participate in the markets as frequency regulation providers, providing reserve capacity for grid operators. To provide these systems access to the market, a new type of regulation service provider was defined: a Limited Energy Storage Resource (LESR). Additionally, NYISO has deemed that four-hour duration resources, such as pumped hydro, can participate in the market as an Energy Limited Resource (ELR), a type of qualified capacity resource.

NYSERDA has provided consistent, long-term and critical support for both electric vehicle and grid storage projects with more than 100 energy storage projects ranging from batteries and ultracapacitors to flywheels and compressed air. In this environment of agency support, private sector companies have launched multiple grid storage projects in the state. For example, in late 2010, AES Energy Storage invested in an 8 MW battery-based storage system located in Johnson City, New York. This lithium-ion battery system is the first commercial grid-scale battery-based storage system to operate as a generator in the U.S. In 2011, the Long Island Power Authority (LIPA) issued a request for proposals to add 2,500 MW of capacity to its network. In response to this request, AES proposed a 400 MW battery-based system that would provide capacity with no emissions, no water usage, no fuel lines and no noise. Also in 2011, Beacon Power built and deployed a 20 MW flywheel energy storage system at its frequency regulation plant in Stephentown, New York. This is the first full-scale flywheel energy storage facility to provide frequency regulation service on the U.S. electricity grid.

In his 2012 State of the State address, Governor Andrew M. Cuomo announced a broad public-private initiative to upgrade and modernize New York State’s electric power system. This proposal for an “Energy Highway” seeks to ensure the availability of reliable, economical power in New York State over the next 50 years while creating jobs, energizing private-sector investment and protecting the State’s environment and the health of its citizens. A key emphasis is developing the potential for new cleaner sources in upstate New York in order to meet the increasing demand for energy in downstate New York.

Since the beginning of 2007, more than 1,200 megawatts of wind capacity has been added to the New York grid. The NYISO Interconnection Queue includes about 7,000 megawatts of potential wind power projects, most of which are located at the northern end of the state. The aging transmission system needs rebuilding and upgrading in order to utilize such new resources. Effective energy storage technology represents a solution to this problem. If lower-cost, clean energy can be generated at off-peak times upstate and transmitted downstate when transmission line utilization is low, bottlenecks and weaknesses in the system would be minimized.

New York is also well positioned for leadership in the use of energy storage in the transportation sector. New York City has been the world leader in the deployment of hybrid electric transit buses for quite some time. The New York City Metropolitan Transportation Authority (MTA) uses hybrids for nearly 30% of their 6,000-bus fleet. These buses are supplied by Orion Bus (Oshkosh, WI) and powered by BAE System’s (Johnson, City, NY) hybrid propulsion system. This early successful deployment in New York City has led to BAE Systems and Orion becoming overall industry leaders in hybrid electric buses.

MTA has also been involved in testing other storage applications including a battery storage system capable of discharging and receiving regenerative braking energy from subway cars. In this system, braking action feeds energy back into the Third Rail that would otherwise be lost as heat when the train stops. MTA was funded to install an 800 kW battery-based storage system at an in-service substation in Manhattan and has also conducted a peak-shifting demonstration project that used stored off-peak power for bus refueling at a compressed natural gas facility during peak hours. Furthermore, of the approximately 4,300 yellow cabs in New York City, roughly one-third of them are hybrids.

In June 2012, Governor Andrew M. Cuomo announced that New York would spend up to $4.4 million to install approximately 326 charging stations for battery-powered vehicles. The program will install charging stations in public places around the state to accommodate the needs of electric vehicles and to raise public awareness of them. The project is funded by NYSERDA, with some help from the U.S. Department of Energy.

Other recent projects sponsored by NYSERDA in electric vehicles include development and demonstration of electric bus systems, electric transit and conversion of hybrid vehicles to plug-in hybrids, as well as larger applications such as feasibility studies of electrified short-run shipping and refrigerated barges powered by battery systems. Along with the subway demonstration system, NYSERDA has also sponsored other demonstrations of Wayside Energy Storage Systems on the Long Island Railroad and the Metro-North Railroad.

PlaNYC is New York City’s comprehensive sustainability plan and it has established an aggressive strategy to reduce the city’s greenhouse gas emissions in 2030 by 30% from 2005 levels. Part of the overall goal is to reduce transportation emissions by 44% by 2030. Electric vehicles have the potential to significantly reduce fuel usage, greenhouse gas emissions, noise, and local air pollution. The PlaNYC market study concluded that New York City represents a particularly attractive market for early sales of electric vehicles. It identified 21% of customers as potential early adopters who would be willing to pay more to purchase and find charging facilities for their EVs. They concluded that by 2015, up to 16% of all new vehicles purchased by New Yorkers could be electric vehicles. These study results are in keeping with the recent actions of automakers that are consistently making the initial stock of electric vehicles (such as the Chevrolet Volt and the Nissan Leaf) available to New Yorkers before nationwide rollouts.

addition to being a leader in deploying energy storage, New York is also home to a broad range of research institutions advancing energy storage technology. These include a diverse set of public and private higher education institutions, world-class corporate and industrial research facilities, three Department of Energy (DOE) Energy Frontier Research Centers focused on energy storage, and one national laboratory. As a whole, this statewide enterprise ranks among the top few centers of excellence in the world in terms of research capability across multiple disciplines ranging from nanomaterials and energy technologies to information technology and science. More than a dozen colleges and universities across the state have active research programs in energy storage technology.

Industrial and corporate research capabilities range from those of medium-sized and smaller enterprises such as American Aerogel Corporation, Bren-Tronics, Greatbatch, Hollingsworth and Vose, Momentive Performance Materials, NDH/SAS Technologies and Prima Precision Materials. Multiple companies in the state are working on batteries themselves including Bren-Tronics, General Electric, Greatbatch and Ultrafine. New York companies such as Luxo and Graphene Devices are active in ultracapacitor technology. In addition, over a dozen companies are focused on storage system integration and development including a number of the component developers already mentioned plus such companies as BAE Systems, Electrowaya, Electrical Power WorX, Electromotive Designs, Green Charge Networks, the Raymond Corporation Division of Toyota, and Triple-Point Energy. Research on energy storage in New York is happening up and down the value chain.

Enabling technology for energy storage is much broader than a single component like a battery cell. It extends to power electronics, mechanical packaging, cooling, controls, communication, and system design. In addition, systems integration into a vehicle or into the electric grid is no less critical. Innovations in manufacturing, testing and evaluation are also important. There are significant contributions from supporting equipment and services as well. Research and development needs are diverse and will continue to call upon multiple resources within the state.

New York provides a large and well-educated workforce that includes nearly 16,000 science, engineering and technology graduates each year from public and private colleges and universities throughout the state. There are also workforce training centers and community colleges contributing manpower resources. Major market studies have identified New York as the national leader in two important established energy-storage industry sub-clusters: batteries and electronic capacitors. This existing base provides a solid foundation for expansion into newer energy storage industries.

New York’s research institutions are among the nation’s leaders in many aspects of energy storage science and technology. As examples, there are active programs aimed at research and development at Alfred University, Binghamton, Clarkson, Cornell, CUNY, CNSE at Albany, RIT, RPI, Stony Brook University at Buffalo and the Brookhaven National Laboratory. Research focused on improving the materials for batteries is underway at Binghamton, Clarkson, Cornell, CNSE at Albany, RIT, RPI, Stony Brook, U Buffalo, and Brookhaven. Energy storage system research is a highlight at CUNY and RPI. Projects on improved supercapacitors are underway at Cornell and CNSE. Clarkson and RPI are working on electronics and control systems. RIT has a focus on remanufacturing and recycling of battery and fuel cell components. Many institutions are also actively involved in fuel cell and hydrogen research, particularly Clarkson, Cornell, CUNY, RPI, RPI and Brookhaven. In many cases, research institutions have established successful mechanisms to collaborate with industry partners, to the benefit of New York businesses.

Three DOE Energy Frontier Research Centers (EFRCs) are located in New York that focus on energy storage. DOE created 46 of these integrated, multi-investigator centers across the country in 2009 in order to conduct fundamental research focusing on one or more of several “grand challenges” and use-inspired “basic research needs.” The Center for Electrocatalysis, Transport Phenomena, and Materials for Innovative Energy Storage is led by General Electric Global Research in Schenectady. The Energy Materials Center at Cornell works on advancing the science of energy conversion. The Northeastern Center for Chemical Energy Storage is led by Stony Brook. The charter of these EFRCs is to harness the most basic and advanced discovery research in a concerted effort to establish the scientific foundation for a fundamentally new U.S. energy economy.

Corporate research is widespread, diverse, and very active in New York. More than a dozen companies in the state are working on battery materials research. They range from large corporations like General Electric and Oak-Mitsui to a variety of medium-sized and smaller enterprises such as American Aerogel Corporation, Bren-Tronics, Cerion Enterprises, Greatbatch, and use-inspired “basic research needs.” The Center for Electrocatalysis, Transport Phenomena, and Materials for Innovative Energy Storage is led by General Electric Global Research in Schenectady. The Energy Materials Center at Cornell works on advancing the science of energy conversion. The Northeastern Center for Chemical Energy Storage is led by Stony Brook. The charter of these EFRCs is to harness the most basic and advanced discovery research in a concerted effort to establish the scientific foundation for a fundamentally new U.S. energy economy.

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New York is home to many companies involved in the battery and energy storage industry. These include companies involved in multiple aspects of energy storage products: battery materials, cells, systems integrators, materials suppliers, electronics and controls, applications, and key end users such as vehicle manufacturers. New York also has hundreds of small and mid-sized companies that produce billions of dollars worth of equipment and materials that can be used to supply and support the manufacture of energy storage devices and systems. This supply chain includes metal fabricators, roll-to-roll manufacturing centers, chemical and materials production, electronics design and manufacturing. Energy storage technologies are a ripe target for the creation of startup companies throughout the State.

All told, New York companies have invested hundreds of millions of dollars in growing this industry and generate more than $150 million in annual wages in the State.

The New York Battery and Energy Storage Technology Consortium (NY-BEST) is a rapidly growing, industry-led, private-public coalition of over 100 entrepreneurial, academic, corporate, and government partners across the state. New York already employs thousands of workers in the battery industry, which places it among the leading states in this regard. Battery manufacturers in the state include Bren-Tronics, General Electric, Greatbatch, and Ultralife. There are also multiple companies that supply components for batteries. These include Hollingsworth and Vose, Oak-Mitsui, and Primet. New York is also home to manufacturers of ultracapacitors (toux) and fuel cells (including Delphi, EnRG, General Motors, Plug Power and Solid Cell).

The current battery manufacturers in New York concentrate on specialized markets. Ultralife is headquartered in Newark, NY and is primarily focused on commercial and military batteries. The company also has activities in custom engineering design and services, tactical communications systems and a wide range of power accessories for global government and defense markets. Greatbatch, based in Clarence, NY, specializes in medical batteries such as those in cardiac pacemakers. Bren-Tronics of Comack, NY, is a supplier of military batteries and charging systems.

General Electric has made a substantial commitment and investment in New York’s energy storage industry by building a manufacturing plant in Schenectady for the sodium metal halide battery product line that it calls Durathon. The $100 million plant was initially targeted to employ more than 350 people when it reaches full capacity by the end of 2015. In June 2012, GE announced a new investment of $70 million to double the production of the plant. The expanded facility will employ 450 workers when it reaches its full capacity. The company is initially developing three different models to be used in cellphone towers, data centers and utility grids. For the grid, GE sees an attractive market for its Durathon battery for various ancillary services applications as well as for peak shaving.

Later, it plans to move toward vehicle storage applications such as hybrid locomotives, forklift trucks and mining vehicles. Regenerative braking for freight trains is a particularly promising application for this battery technology. GE’s announced goal is to grow the battery business to $500 million annually by 2016 and $1 billion by the end of the decade.

BAE Systems of Johnson City, NY manufactures the HybriDrive system for buses. So far, the majority of these drives have been used in Orion buses by Daimler in North America, but have also begun to be used in Alexander Dennis Ltd buses in the UK and Europe’s Irisbus Ivec. In total, this HybriDrive technology currentlypowers more than 3,500 buses in cities across North America and in the United Kingdom and has transported more than a billion passengers in New York, San Francisco, Toronto, Ottawa, Houston, Seattle, London, and Oxford, U.K.

Smith Electric Vehicles is a privately held company headquartered in Kansas City, Missouri that builds and markets electric-powered medium-duty trucks for such applications as food & beverage, utility, telecommunications, retail, grocery, parcel and postal delivery, and school transportation. The vehicles (the Newton and the Edison) can be configured with battery packs tailored to the required range. The company sees a large target market in New York City and is establishing a manufacturing plant in the Bronx.

The Raymond Corporation of Greene, NY is an industry leader in forklifts and related material handling vehicles, manufacturing over 30,000 per year. A part of Toyota Industries Corporation, Raymond employs over 500 people in New York. Their claim to fame is “Eco-Performance” offering efficient battery-operation with their “ACR System” as well as a fuel cell alternative to battery power.

Ice Energy is a California-based company with manufacturing facilities in Hammondsport, New York that sells the Ice Bear Energy Storage System, a thermal form of energy storage. When added on to a commercial air conditioning system, the unit freezes hundreds of gallons of water around cooling coils in an insulated tank during the night when electricity is cheaper and demand is low. During the heat of the day, the ice system is used to cool the refrigerant instead of the compressor in the AC unit thereby dramatically reducing electricity usage during peak hours.
The extraordinary potential of the battery and energy storage industry to transform the economy of New York State was recognized early on by state leadership and led to the founding of NY-BEST, the New York Battery and Energy Storage Technology Consortium. Funded with an initial investment of $25 million in Clean Air Interstate Rule (CAIR) allowance proceeds, NY-BEST is an independent, not-for-profit industry organization charged with leading the creation of a vibrant, world-class advanced battery and energy storage sector in New York State. NY-BEST brings together more than 100 industry, university and government partners from all facets of the energy and energy storage industries and spans every region of the state and beyond. The consortium is on the scene helping to shape policies in the state that impact energy storage.
GOALS AND RECOMMENDATIONS

Energy storage will dramatically change how vehicles are powered and how the entire electricity industry functions and New York State has the potential to become the national leader in advanced energy storage. Over the next ten years, the state’s energy storage industry could add 15,000 to 20,000 jobs, billions of dollars in revenues and bring about significant improvements in the quality of life in New York.

New York needs to undertake key actions in technology development, in business development, and in policy over the course of the next ten years in order to establish a leadership role in energy storage. To accomplish this, key stakeholders in New York from industry, small businesses, the finance community, government, academia, research centers and other interested groups need to work together to pursue three major goals:

- Establishing robust New York markets through the use of appropriate technologies, policies and incentives.
- Creating value chain clusters that will provide the manufacturing capability to grow the energy storage industry.
- Continuing technology leadership and stimulating commercialization of advanced technologies through R&D funding, collaboration and leveraging of resources.

New York State is already a leader and home to a sizeable energy storage industry. Companies in New York manufacture components for advanced lead acid auto batteries, implantable medical batteries and ultracapacitors, lightweight and portable lithium-ion batteries for military applications, industrial and fork lift trucks, and fuel cells for stationary and vehicle applications. These product areas support over 2,700 jobs in the state and represent $500 million in annual sales for New York companies, or roughly 5% of the total domestic market. Projections created by ECG Consulting Group1 call for steady growth on the order of 5% per year in these established markets for both jobs in the state and revenues.

The emerging energy storage industries for the grid and transportation sectors represent a significant new opportunity for New York to capture and retain considerably larger shares of the market. The current grid and vehicle storage markets are still small compared with the conventional markets, but are expected to grow significantly over the next decade. According to Pike Research2, grid storage markets could reach $22 billion by 2022 and transportation energy markets, driven by the sales of HEV, PHEV and BEV vehicles could be at $45 billion by that year. Globally, this dramatic increase will put these new markets on the same level as the long-established storage businesses.

The economic development model developed by ECG Consulting Group projects that New York industry has the potential to capture 15% or more of the North American market for both grid energy storage and for medium- and heavy-duty transportation energy storage. The state’s role in the manufacture of light-duty (i.e., passenger) transportation storage is likely to be less substantial as a result of significant capabilities already being in place elsewhere in the country. On the other hand, in terms of deployment, New York is expected to be a leading market for electrified passenger vehicles. These emerging storage markets are projected to surpass the existing markets in New York in terms of both jobs and revenue within five years and will be a major contributor to New York’s manufacturing base. The state also has the potential to more effectively utilize its growing renewable energy resources, while alleviating grid congestion and increasing efficiency. Furthermore, the widespread use of electric vehicles in New York will provide significant economic, environmental and security benefits to the state.

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1 ECG Consulting Group, 2012
2 “Energy Storage on the Grid”, Pike Research, 3Q 2011
**INDUSTRY AND JOB GOALS**

**EXPANSION OF GRID STORAGE INDUSTRY:** New York should set the goal of capturing 10% of the North American grid storage market over the next 5 years. Based on overall market projections, this could result in a $3.5 billion market for the state over that time period. That this job growth and the market growth are contingent on the extent to which various recommended actions get implemented.

**EXPANSION OF TRANSPORTATION STORAGE INDUSTRY:** New York should set the goal of adding 1 GW of a broad portfolio of technologies in grid storage industry over the next 10 years. Goal: 25% of new vehicles sold in New York by 2022 should contain advanced energy storage technology.

**GRID DEPLOYMENT:** This should include substantial installations of community energy storage, particularly in the New York City area. New York should upgrade its aging infrastructure through deployment of energy storage devices in key locations around the state. The amount of storage needed will depend on various factors that will otherwise require an increase in grid peaker plants.

**ELECTRICITY OF TRANSPORTATION:** New York should set the goal of reducing vehicle emissions by 10% through the electrification of public transit systems. New York should continue its widespread adoption of hybrid electric vehicles including the world leading electric vehicle city bus manufactured by New Flyer.

**JOB GROWTH:** Based on the ECG economic development models, New York can create between 15,000 to 20,000 jobs in the energy storage industry over the next 10 years.

**DEPLOYMENT AND MARKET SIZE GOALS**

**GRID DEPLOYMENT:** New York should set the goal of adding 1 GW of capacity using technologies other than pumped storage (see note on storage capacity below). This should include substantial installations of community energy storage, particularly in the New York City area. New York should upgrade its aging infrastructure through deployment of energy storage devices in key locations around the state. The amount of storage needed will depend on various factors that will otherwise require an increase in grid peaker plants.

**ELECTRICITY OF TRANSPORTATION:** New York should set the goal of reducing vehicle emissions by 10% through the electrification of public transit systems. New York should continue its widespread adoption of hybrid electric vehicles including the world leading electric vehicle city bus manufactured by New Flyer.

**ELECTRIFICATION OF COMMERCIAL VEHICLES:** New York should set the goal of capturing 10% to 15% of all North American plug-in hybrid vehicle sales during the next five years. The PlaNYC Electric Vehicle Market Forecast Report offers an aggressive goal for electrification of passenger vehicles of 25% of new vehicles sold in New York by 2022.

**PUBLIC TRANSPORTATION:** New York should set the goal of electrification of public transit systems. New York should upgrade its aging infrastructure through deployment of energy storage devices in key locations around the state. The amount of storage needed will depend on various factors that will otherwise require an increase in grid peaker plants.

**CHARGING AND HYDROGEN REFUELING INFRASTRUCTURE:** New York should set the goal of deploying advanced electric vehicle charging and hydrogen fuel cell refueling infrastructure with a combination of public financial incentives for consumers, public charger installations, and various forms of direct support for infrastructure development. By the year 2022, every parking lot with more than 100 spaces should have a charging station and the nearest publically accessible hydrogen refueling station should be no more than 10 miles away from any place along a major route in New York.

**TECHNOLOGY LEADERSHIP:** New York should set the goal of deploying advanced electric vehicle charging and hydrogen fuel cell refueling infrastructure with a combination of public financial incentives for consumers, public charger installations, and various forms of direct support for infrastructure development. By the year 2022, every parking lot with more than 100 spaces should have a charging station and the nearest publically accessible hydrogen refueling station should be no more than 10 miles away from any place along a major route in New York.

**TESTING AND PROTOTYPING FACILITY:** New York should set the goal of deploying advanced electric vehicle charging and hydrogen fuel cell refueling infrastructure with a combination of public financial incentives for consumers, public charger installations, and various forms of direct support for infrastructure development. By the year 2022, every parking lot with more than 100 spaces should have a charging station and the nearest publically accessible hydrogen refueling station should be no more than 10 miles away from any place along a major route in New York.
RECOMMENDATIONS

In order to meet the specific goals set forth in this roadmap, there are many actions that should be taken by all stakeholders, including technology developers, manufacturers, and policymakers. There is a strong interdependence among technology development, the growth of the economic ecosystem, and the impact policies. Some of the more important recommendations are outlined here and are color-coded with reference to the three areas of specific goals.

INDUSTRY DEVELOPMENT ACTIONS

Creating an ecosystem: New York is home to companies involved in every aspect of energy storage. New York industry must take the lead in achieving this goal. New York to be a national and global leader in energy storage for applications in grid storage and transportation. By 2018, New York must be in the best position to have the best chance to succeed.

Focus on strengths and opportunities: New York’s stakeholders should focus on the state’s strengths and on its greatest opportunities. Some of the more important recommendations are outlined here and are color-coded with reference to the three areas of specific goals.

Economic development: Economic development incentives should be used to encourage the location of manufacturing in New York State. By 2018, successful companies should have a strong position to help bring manufacturing to New York by 2018. New York businesses in these growing new industries. New York’s educational institutions will not and cannot solve all these problems on their own, but the extraordinary concentration of capability within the state must be exploited in order for the industry to have the best chance to succeed.

Utilize economic incentives/make capital investments: Economic development actions should be used to encourage the location of manufacturing in New York State. By 2018, sufficient manufacturing should be established in the state to build a strong position in these growing new industries.

Create value chain clusters: In order to succeed in the dynamic world of the energy storage industry, stakeholders should encourage the creation of clusters of companies up and down the value chain. These clusters should include storage devices and components, but also other elements such as power electronics, mechanical packaging, and software and systems integration and optimization. Value chain clusters result in a vibrant, stable ecosystem, strong local knowledge bases, the ability to collaborate and share resources, and a strong attraction to customers. New York companies need to understand the needs of this growing industry and be in a position to bring new technologies on line in a timely fashion.

Establish commercialization center: The third early testing and validation capability that NY-BEST is establishing as an important contribution to the technology development plan for the state can also provide additional critical services to industry. These services include advanced diagnostics, failure mode analysis, manufacturing process development and even pilot manufacturing. Such a facility will be a key tool for leaps in the commercialization of existing and new technologies.

Develop and recruit a skilled workforce: New York has an extensive network of world renowned universities and other educational institutions that will foster the future growth of the energy storage industry. These institutions need to expand their programs in battery and energy storage, fuel cell, grid and other related areas. Energy storage companies, clean energy and environmental groups, and other relevant partners must the general interest of educational institutions, and highlight companies with specific technical or HR needs.

Technology development actions

New York is a major center for energy storage technologies. NY-BEST has a broad range of research institutions, graduate and 10,000 students in science, engineering and technology each year, and to a diverse set of companies both large and small advancing the state in the art in energy storage technology. These powerful resources must be effectively brought to bear in order for New York to reach its potential in the energy storage industry.

Leverage technology resources: New York’s educational institutions must perform basic and applied research to improve energy storage technologies. This includes enhancing the energy density of storage devices, improving materials technologies, manufacturing techniques, and reaction pathways for more efficient energy storage. New York’s intellectual property can be a huge asset in establishing the state’s role in these growing new industries. New York’s educational institutions will not and cannot solve all these problems on their own, but the extraordinary concentration of capability within the state must be exploited in order for the industry to have the best chance to succeed.

Promote collaboration: By collaborating, university and other researchers can focus on salient issues and technical barriers, and thus, benefits will flow from the establishment of teams with diverse approaches, skills, and tools. New York institutions can benefit domestically from the increased dissemination of information that comes from networking, forums, and international events, as well as from its role in leading an organization, collaborating with companies, universities, and other stakeholders across the state sector. New York companies need to continue interacting at all levels with both customers and policy makers to ensure that the increased dissemination of information that comes from networking, forums, and international events, as well as from its role in leading an organization, collaborating with companies, universities, and other stakeholders across the state sector.

Fund critical research: Finding resources need to continue to support areas of high impact to the energy storage industry. Organizations within New York State—including government agencies such as NYSERDA, as well as private industry—must continue to fund research and development activities the State. By 2018, the state can also provide additional critical services to industry. These services include advanced diagnostics, failure mode analysis, manufacturing process development and even pilot manufacturing. Such a facility will be a key tool for leaps in the commercialization of existing and new technologies.

New York has an extensive network of world renowned universities and other educational institutions that will foster the future growth of the energy storage industry. These institutions need to expand their programs in battery and energy storage, fuel cell, grid and other related areas. Energy storage companies, clean energy and environmental groups, and other relevant partners must the general interest of educational institutions, and highlight companies with specific technical or HR needs.
POLICY ACTIONS

ENLIGHTENED POLICIES DRIVE PROGRESS >> Policy actions on the part of the federal government, the state, local governments, and regulatory agencies are critical for the health and growth of the energy storage industry in New York. Durable, predictable, long-term policies provide stability that encourages investment. Short-term incentives provide a bridge for new technologies to achieve cost-competitiveness and gain market acceptance.

PROVIDE INCENTIVES: The state should provide tax and other incentives to encourage R&D investment to lower the cost of energy storage technologies, to attract energy storage manufacturers to the state, and to incentivize the early stage deployments in the state, helping the industry advance to the point where government incentives are no longer necessary to deploy wide scale energy storage solutions in the marketplace. For potential users of energy storage, incentives, similar to those proposed at the federal level in the STORAGE Act (H.R. 4096) that was introduced to Congress in March 2012, are critical to the growth and development of the industry in New York State. This legislation would provide tax credits and access to financing for individuals and businesses when they invest in energy storage facilities attached to the grid. Legislation has been proposed in New York as well that would provide various tax credits for energy storage manufacturing and facilities. Another approach to consider is to allow storage to qualify for renewable energy credits as is done in some other states.

REMOVE REGULATORY BARRIERS: Regulatory agencies need to recognize the value of energy storage and treat it on par with other energy resources. NYISO’s recent rulings on LSRs and treatment of pumped hydro as an ELR capacity resource are examples of how regulations have been adapted to successfully incorporate storage technology. Article X of the New York Public Service law governs the siting of major electric generating facilities over 25MW. Energy storage facilities do not have direct emissions and have dramatically less environmental impact than conventional generating plants. They therefore should be treated differently under this law so as to encourage the development and use of storage technology. All durations of energy storage should qualify as capacity resources. In general, all of the benefits created by deploying energy storage should be evaluated and included in the analysis of each project. Vehicle emissions regulations should exempt electrified vehicles from the upcoming on-board diagnostic requirements being levied by CARB & the EPA just as they are already exempt for natural gas vehicles.

BUILD STORAGE INTO STATE ENERGY POLICY: Energy storage targets should be part of the state’s Renewable Portfolio Standard. It might even be appropriate to carve out a Storage Portfolio Standard (SPS) as a percentage of the RPS. Major strategic documents such as the forthcoming 2013 New York State Energy Plan and the Energy Highway Action Plan should explicitly include energy storage among the critical technologies to be evaluated in the state. Whereas the 2009 state plan discussed the potential value of energy storage, the successor plan should explicitly include storage in the state’s portfolio of energy resources. Since New York’s electric grid represents a single-state control area, the state has an exceptional opportunity to develop a comprehensive and cohesive state-focused energy strategy that incorporates energy storage as part of its short-term and long-term plans.

CREATE LONG-TERM POLICIES: Policies that encourage the development and deployment of energy storage need to be structured over a multi-year period. Long-term, stable policies are essential in attracting investments because the investment community is disinclined to fund projects that cannot provide investment security.

OTHER ACTIONS

ALL STAKEHOLDERS HAVE A ROLE TO PLAY >> There are other actions that should be taken by stakeholders in the State. Economists, government buyers, educators, journalists and others all have a role to play in supporting, promoting and helping to establish energy storage in New York. NY-BEST can play an important part in many of these activities.

DEVELOP COST-BENEFIT METHODOLOGIES: Stakeholders should support the development of a cost-benefit methodology for utility and independent power producer deployment of energy storage that includes the full range of energy storage costs and benefits. Energy storage must be a factor in any review or consideration of the development of distributed generation, demand response mechanisms, and energy efficiency cost-benefit methodologies.

HAVE GOVERNMENT AND INDUSTRY LEAD BY EXAMPLE: Government agencies can help stimulate the storage industry by being leaders in facilitating and encouraging the adoption of storage technologies. For example, government vehicle fleets should incorporate as many electric vehicles as possible. Similarly, industry should also adopt storage technologies in its own fleets. In addition, charging infrastructure developed for these fleets by the government and by the private sector could also be made available to the general public thereby making consumer adoption of the technology more attractive. Government and private sector facilities should also incorporate storage technologies for their power needs. These facilities could contract with energy storage providers for capacity, energy, and ancillary services. They also could help establish the viability of community energy storage and micro-grids.

INVOLVE ALL STAKEHOLDERS: It is essential that the value of energy storage be communicated to renewable energy suppliers, system integrators, researchers and equipment developers, other members of the electric power industry, government agencies, and the general public. Since regulators and policymakers develop the tariffs and rules that shape the energy storage market, it is essential that they be fully informed and actively participate in the process. Educating all these stakeholders on what is happening in energy storage and on its positive impact on people’s standard of living is an important activity. The more people who are engaged in the topic, the better.

UTILIZE THE UNIQUE BENEFITS OF NY-BEST: NY-BEST should serve as a center for communication, education and interaction amongst stake-holders. It should promote collaboration and foster information sharing among its members. NY-BEST should help leverage New York’s world-class intellectual and manufacturing capabilities that can drive market leadership. It can provide direct business assistance/consulting to member companies and organizations to facilitate funding, understanding of markets, technology development, supply chain access and business relationships. Doing so can support and accelerate the commercialization process of energy storage from research and development to products and widespread deployment. And NY-BEST should continue to be a strong voice in the advocacy of policies that promote the energy storage industry.
ENERGY STORAGE APPLICATIONS, TECHNOLOGIES AND MARKETS
GRID STORAGE APPLICATIONS

CAPACITY
Energy storage can provide capacity to the market to help utilities meet their resource obligations. These resources can replace the most expensive, inefficient, and emission generating plants on the grid and provide an emissions-free alternative. As seen in the load duration curves shown below, a very small fraction of the time. As a result, there are significant savings to be realized by not requiring additional generating plants for these periods of high demand but rather to be able to store energy generated during times of lower demand.

LOAD LEVELING AND PEAK SHIFTING
Related to the capacity application described above, load leveling and peak shifting are key elements of managing supply and demand on the grid. Often these practices take place on the demand side whereby the user shifts heavy electrical usage away from peak demand periods whenever possible, or in response to dispatch notices or market pricing signals. Energy storage technology, on the other hand, can facilitate load leveling and peak shifting on the supply side (i.e. transparent to the user) by storing surplus energy over a particular interval and releasing that energy to the grid when it is needed. With this capability, generation facilities can operate in a highly efficient manner, at maximum capacity, and can meet reserve requirements in the most cost-effective way. This application has relatively few technical and regulatory barriers and can provide significant value.

ARBITRAGE
Arbitrage is an application related to load leveling and peak shifting but is not practiced by generation sources. Instead, a third-party purchases and stores electricity and subsequently resells it at a profit by taking advantage of the price differential between off-peak and peak electricity. The primary purpose of arbitrage is not to enhance the performance of existing generation assets on the grid (although it generally does) but is rather a way to provide a value-added service to end-users. Nonetheless, it does have a similar impact to load leveling and peak shifting to the extent that purchasers of arbitrated power are attempting to reduce the impact of their peak demand. From an economic standpoint, arbitrage represents an energy storage opportunity for a separate group of businesses.

RENEWABLES INTEGRATION
Multiple forms of renewable energy (hydroelectric, geothermal, wind, solar PV, and solar thermal) are a rapidly growing presence on the grid. Some types are suitable for baseload generation, meaning that operators can initiate generation when it is needed. However, the two most rapidly growing forms of renewable energy—solar and wind—are intermittent sources for which generation is dependent on the state of the resource itself. While the power grid has managed to incorporate variable load resources, renewable resources add a new complexity since both generation and demand can change. Large amounts of such intermittent resources may cause instability on the grid thus driving the use of energy storage for grid stabilization. Shifting renewable energy to be available when it is needed is likely to be a large potential application for grid energy storage.

ANCILLARY SERVICES
Ancillary services are a variety of services performed by generation, transmission, system control, and distribution system equipment in order to meet requirements for stability, frequency regulation and renewable power quality. Regulations require that for every megawatt of generating capacity on the grid, there is some specified fraction of a megawatt secured elsewhere for frequency regulation, spinning reserves, and other functions. The growth of renewables on the grid also drives growth in the ancillary services market. The relative instability and intermittency of renewable sources dictate a relatively higher percentage for ancillary services. Energy storage technology can provide an effective way to deal with this issue.
TRANSMISSION & DISTRIBUTION UPGRADE DEFERRAL

Transmission and distribution upgrade deferral refers to adding energy storage assets to transmission and distribution (T&D) assets in order to manage increased demand on the T&D infrastructure. Advanced energy storage technology holds significant promise in helping to defer new investment in T&D assets and to optimize costly T&D upgrades. The approach is to temporarily or permanently install a storage unit on the grid in a location where the need for a T&D upgrade is forecast. The electricity storage system allows the existing transmission line or substation to be used for a longer time, either because it is not replaced or is not upgraded. In general, T&D assets are sized to meet peak demand, but are rarely used at those levels. The cost of adding T&D assets can be significant but in most cases, the increased capacity of the T&D asset is not needed immediately. Upgrades are generally planned to support projected demand several years ahead of time. An alternative, energy storage could be deployed to defer the costs associated with adding T&D capacity by offering a solution that can be added to the grid incrementally, tracking the increase in demand. By incorporating an energy storage asset, system operators, transmission owners and/or distribution companies can add or contract for incremental capacity where it is needed, and that storage asset can even be moved to another site at a future date.

COMMUNITY ENERGY STORAGE

In addition to large-scale grid applications, energy storage can be effective in designing smart microgrids on the residential or commercial building level, with storage as part of an integrating controller system contributing to grid stability. Community Energy Storage (CES) improves electrical service to residential customers by using small, distributed storage installations. Two forms of this application are essentially defined by whether the storage is in front of the meter (community storage) or behind the meter (residential storage). CES is employed to deliver better quality power, provide distributed load management resources, and provide uninterruptible power for residential users. This distributed, modular approach to grid performance improvement is intended to be more cost-effective than building centralized power plants, large transmission lines, or upgrading distribution networks.

Community storage systems are installed between the customer meter and the power substation. Such systems can address local grid issues, such as voltage support, islanding, and load-leveling/peak-shifting. In contrast, residential storage systems are integrated behind the meter at a home. This type of energy storage is often used in commercial buildings as a means of energy cost management, load-leveling, and as uninterruptible power systems. For the residential user, such systems would primarily be used for energy cost management. Forces driving the development of residential energy storage include the growing adoption of residential solar and other intermittent generation sources, the forthcoming spread of plug-in vehicles, and the increasing use of dynamic electricity pricing such as time-of-use pricing and demand charges. Convergence of a number of issues, such as community energy storage, grid use of vehicular batteries (“V2G”), smart charging for plug-in electric vehicles, and the increasing use of rooftop solar are changing the dynamics of the grid which both creates challenges and provides opportunities for the development of optimized storage systems.

PASSENGER VEHICLES

There is a hierarchy of energy storage applications for passenger vehicles based on the amount of energy storage required.

E-BIKES

As a result of a huge Chinese market, e-bikes completely dominate the vehicle-energy storage market in terms of unit sales. These electric-motor-assisted bicycles require only about 0.5 kWh of electrical energy on board, but there are over 120 million of them on the road today in China alone.

MICROHYBRIDS

These are also known as “start-stop” vehicles or “mild hybrids.” In start-stop, the engine is shut off during idling so that the battery supports electronic loads (lights, radio, air conditioning, and so on) at that point, and then has to restart the vehicle. Some microhybrids also provide some regenerative braking to further enhance fuel economy. These systems require 0.5-1 kWh of battery storage and provide as much as a 10% boost in fuel economy. This approach has been widely adopted in Europe, where emission reduction is being vigorously pursued. Worldwide, about 5 million microhybrids have been sold. According to a Lux Research report, these vehicles could reach 39 million vehicles by 2017.

HEX HYBRID ELECTRIC VEHICLES

HEVs generate all their power on board, either in a parallel configuration in which both an electric motor and an internal combustion engine (ICE) can deliver power to the wheels, or in a series configuration with no connection between the ICE and the wheels. The battery pack in an HEV needs to provide power for the vehicle’s electrical system, start the vehicle, assist the engine with acceleration, and enable the vehicle to drive on electric power only at low speeds for very short distances. Generally a 1-2 kWh battery is utilized for this purpose, but one that can supply as much as 75kW for full traction motor power. The significant fuel economy enhancements provided by HEVs are driving a rapidly growing market for these vehicles. In 2011, over 800,000 HEVs were sold worldwide and a Pike Research report predicts that this market will double over the next five years.

PLUG-IN HYBRID ELECTRIC VEHICLES

Plug-in hybrid vehicles (PHEVs) get some of their energy from the grid, but also have an internal combustion engine (ICE) that extends the range of the vehicle. Some PHEVs, such as the Chevrolet Volt, are even described as range-extended electric vehicles. PHEVs require enough storage capacity to power the vehicle using the electric motor only for somewhere between 10 and 40 miles. This requires a battery pack of 5-15 kWh capacity for a passenger car. Plug-in hybrid capability has been offered as an after-market retrofit to existing hybrid vehicles for a number of years. The introduction of production model PHEVs from major automakers has only recently begun but is expected to accelerate over the next few years.
BATTERY ELECTRIC VEHICLES

Battery electric vehicles (BEVs) have no internal combustion engines. BEVs get all of their power from the grid and they store that power on the vehicle. Such vehicles require large batteries that necessitate relatively long recharging times. The battery packs in passenger BEVs determine their maximum driving range; the relatively modest range of the Nissan Leaf requires a 24 kWh battery while the longest-range version of the Tesla S sedan utilizes an 85 kWh battery. Israeli company Better Place is promoting a BEV approach based on a swappable battery pack that can be quickly replaced at “switch stations” in order to provide extended range. The initial implementation of the scheme is based on a specific car built by Renault. Taking into account the current mix of generation sources in the grid, BEVs reduce carbon emissions by 40%; “grid greening” will reduce emissions further.

FUEL CELL ELECTRIC VEHICLES

FCVs produce electricity with a fuel cell in order to power their electric motors. Fuel cell cars were first demonstrated in 1959 and have seen continuous development since then. Improving fuel cell technology has reduced the size, weight and cost of fuel cell electric vehicles. Driving ranges up to 250 miles have been demonstrated and refueling FCVs is as quick as refueling gasoline cars. The first production FCVs are expected to be introduced in 2015 by five leading auto manufacturers including General Motors in the US. The emissions associated with FCVs are primarily those generated in producing hydrogen.

Among other small vehicles, electric or battery forklifts are in common use in indoor warehouses because they produce no emissions, run clean and quiet, and have an overall lower cost per hour of operation than internal combustion engines. The complexity and time required for charging the batteries of these forklifts is creating a growing market for fuel cell powered electric forklifts.

HEAVY-DUTY TRANSPORTATION

Passenger cars and light trucks have been the major focus for vehicle electrification but heavier vehicles from buses to heavy trucks to trains can also use stored electricity to boost propulsion, improve fuel economy and reduce emissions. Essentially the same progression of electrification described for passenger vehicles is applicable to heavy-duty vehicles. Hybrids are becoming the buses of choice for public transit systems trying to improve efficiency and reduce environmental emissions, despite their higher initial capital costs compared with conventional buses. New York City alone had over 1,600 hybrid buses in operation as of 2010. Hybrid buses offer reduced emissions (both of carbon dioxide and of smog-producing pollutants), quieter and smoother operation, and enhanced fuel economy. Smaller numbers of all-electric buses have also gained entry into the marketplace and are on the increase. Buses were also among the first vehicles to use fuel-cell systems for power.

The Center on Globalization Governance and Competitiveness projects that replacing 60,000 conventional trucks with hybrids would save as much as 130 million gallons of fuel and reduce up to 1.4 million tons of carbon dioxide emissions per year. The applications for electrification for medium-duty and heavy-duty trucks include the same categories as for passenger cars (HEV, PHEV and BEV) as well as the truck-specific category of electric power take-off hybrids (EPTOs). These systems do not supply any locomotive power to the truck but rather operate power take-off (PTO) equipment such as coolers, blowers, pumps, and so forth. By using storage, EPTOs do not require the engine to idle while this equipment is in use. There are also hydraulic hybrid trucks that store and recover otherwise wasted energy in the form of fluid compression instead of electrical energy.

For much of the 20th century, British milk trucks were electric vehicles. In the present day, an increasing number of companies are using BEVs for many types of delivery vehicles, particularly for well-established urban routes where the range is fixed, and for such uses as garbage trucks. What all these vehicles have in common is a driving pattern in which most of their time is spent stopping, starting or idling, which is where internal combustion engines are the least efficient. Rail transportation in the form of heavy rail and subway transit, light rail transit and commuter rail transportation is experiencing an extended period of growth that is taxing the ability of rail power substations and the grid in general to handle the increased traffic. The use of trackside and on-car energy storage systems is a potential solution to this problem. Energy storage can be used to recycle regenerated energy from braking, to reduce voltage sag between existing substations, to reduce peak power demands that help to decrease system-wide electric utility costs, and as a possible replacement for traditional power substations. Trackside energy storage using batteries, electrochemical capacitors, and flywheels is being developed in test programs in several countries. In general, rail and subway cars use enormous amounts of electricity for traction power. Energy storage technology would permit the widespread use of regenerative braking, which would save substantial amounts of energy.
ENERGY STORAGE TECHNOLOGIES

Energy storage technologies basically fall into four categories: electrochemical, mechanical, electrical, and thermal. Each has its own properties and accompanying advantages and disadvantages. Central to any storage technology is the electrical performance provided in terms of both energy and power density. Depending upon the nature of the application, one or the other of these parameters may be the dominant issue. Apart from electrical performance, size and weight, capital costs, efficiency, cycle life, and operating costs are all factors that greatly influence the use of storage technologies. The amount of energy that can be stored using different technologies and the time associated with extracting that energy vary tremendously. For example, there are both long duration and short duration applications. Ancillary services applications for the grid are often only minutes in duration and in any case are no longer than an hour or two. In contrast, bulk storage applications such as renewable energy time shifting and peak shifting in general have much longer durations.

LEAD ACID BATTERIES

Deep-cycle lead acid batteries have been the mainstay for residential renewable energy storage for decades and advanced versions of lead acid technology are under development for many storage applications. It remains the lowest-cost battery technology and continues to have multiple applications in the transportation sector.

LITHIUM ION BATTERIES

Lithium ion batteries are widely used in consumer electronics for such applications as cell phones and portable computers. There are a number of different combinations and mixtures of cathode materials used that compete on the basis of their power and energy density, safety, and reliability. Because of the tradeoffs in these areas, no one formulation has become the standard one. Lithium ion batteries are the main focus for transportation energy storage and the economies of scale provided by the growth of those applications is the primary reason to seriously consider the technology for the grid. The 1980s saw the introduction of the nickel metal hydride (NiMH) battery, which has been the mainstay for hybrid electric vehicles since they entered the market. Although both NiMH and lead acid batteries continue to improve, one or another type of lithium-ion battery is likely to power a growing percentage of electric vehicles throughout the next decade.

The energy density of lithium-based batteries is about twice that of NiMH batteries (which themselves have twice the density of lead acid batteries.)

FLOW BATTERIES

A flow battery is a rechargeable battery that converts chemical energy directly to electricity using an electrolyte that flows through an electrochemical cell. Flow batteries can be recycled repeatedly and have lengthy (10-20 year) operating lives. The systems can readily be scaled up in size, and costs are typically reduced with increased size. The storage capacity of these systems is limited only by the size of the storage tanks. Such large systems are attractive for use in storage applications at the subsystem level. Vanadium redox flow batteries (VRB) are considered to be the most commercially viable large-scale flow battery. Zinc bromine (ZnBr) flow batteries are attractive from a $/kWh perspective and are more likely to see widespread application on the commercial or residential level rather than the utility level.

SODIUM METAL HALIDE BATTERIES

Sodium metal halide batteries marketed under the name Durathon are a major initiative by General Electric aimed at both grid and transportation applications. These molten salt batteries have a small footprint, a long operating life, high energy density and require minimal maintenance. They are very tolerant of temperature extremes as well. They do not vent any gases or other hazardous materials and do not contain dangerous materials such as lead, cadmium or acids.

Based on their characteristics, these batteries are attractive for remote unattended operation as in UPS systems as well as for large-scale transportation applications such as locomotives and stationary (grid) applications.

SODIUM SULFUR BATTERIES

Sodium sulfur batteries use sodium and sulfur separated by a ceramic electrolyte. They operate at an elevated temperature (300°C) at which the active materials are molten and thereby resist corrosion. These NaS batteries are the most widely used technology to date on the grid and have primarily been manufactured by NGK Insulators in Japan. The intrinsic high energy density and high power density of these batteries make them one of the most compact battery technologies for grid storage. They have seen a significant amount of deployment in Japan as well as in Europe, Latin America, and the Middle East.

ULTRACAPACITORS

Ultracapacitors, also known as supercapacitors, are similar to batteries in that they store energy and use electrolytes, but they store charges electrostatically instead of chemically. Compared to batteries, they have much lower energy density but much higher power density. They also can be charged and discharged hundreds of thousands of times, unlike batteries. Ultracapacitors can be used in tandem with batteries in vehicles for the purpose of handling the short bursts of power to and from the electric drive system. To date, applications for ultracapacitors have primarily been for vehicle storage, but there are potential applications on the grid such as for wind turbine pitch control as well.

HYDROGEN

Hydrogen provides a way to continue to use a chemical fuel for energy storage that eliminates carbon from the equation. Hydrogen technology is a long-term goal in the automobile industry. Demonstration fuel cell cars have been around for quite a while and most major automakers still envision such vehicles as the ultimate technology for future cars. As a storage technology, hydrogen would ideally be obtained by using surplus energy to electrolyze water. The hydrogen can then be stored indefinitely on an arbitrarily large scale, transported, and used either directly as a transportation fuel...
or used to regenerate electricity by using a stationary fuel cell or a modified natural gas turbine. The recent upsurge in natural gas resources associated with shale-gas and other discoveries is significant because natural gas reforming is currently the primary means for producing hydrogen. However, there are environmental issues with reforming since the process produces carbon dioxide.

SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Superconducting Magnetic Energy Storage (SMES) systems store energy in the magnetic field created by current flowing through a superconducting coil. Once a current is established in a closed loop of superconductor, it will flow without losing energy or the magnetic energy will be stored for as long as the cryogenic operating temperature of the superconductor is maintained. Both the cryogenic refrigeration and the superconducting coil are quite expensive, which limits the use of SMES to short duration energy storage. Its most important advantage is that the time delay during charge and discharge is quite short with power being available almost instantaneously and at very high output levels for a brief period of time.

PUMPED HYDRO STORAGE

Pumped hydro storage utilizes conventional hydroelectric technology. The facility consumes electricity (usually at inexpensive off-peak times) and uses it to pump water from one reservoir to another at a higher elevation. When needed, the water stored at higher elevation is released and runs through hydraulic turbines that generate electricity. This system can provide very large amounts of long-term storage and has been in use in the US since 1930. Pumped hydro storage is limited to the uncommon locations having two closely situated large reservoirs with an appropriate elevation difference. Construction costs are high, so pumped storage only makes sense for large installations. There are more than 150 installations around the world that account for over 125 GW of energy capacity.

COMPRESSED AIR ENERGY STORAGE

Compressed air energy storage (CAES) converts off-peak electrical energy into a mechanical form of energy by compressing air using a motor and compressor. The compressed air is then stored in underground air pockets, caverns, or large tanks. When electricity is required, the air is taken from the storage volume, heated with natural gas, and put through expanders to power an electrical generator. With suitable large caverns, CAES can be implemented in systems with very large amounts of storage capacity ranging from 50 MW to 300 MW. The advantages of CAES include its very quick response time and its flexible cycling options. These make it suitable for such applications as spinning reserve for generating plants.

FLYWHEEL STORAGE

Flywheel energy storage (FES) systems convert electrical energy into mechanical energy by accelerating a rotor to a very high speed and maintaining the energy in the form of rotational energy. Energy is extracted from the system by running a generator, which gradually reduces the flywheel’s rotational speed. High-performance flywheels can come up to speed in a matter of minutes, which is much quicker than many other forms of energy storage. Individual flywheels can only provide tens of kilowatt-hours of energy, so the technology is best suited to high-power, short-duration applications such as frequency regulation.

The potential market for grid energy storage is enormous but difficult to precisely forecast. In part this is because energy storage is but one of several ways of addressing specific market needs. While there are significant existing installations primarily based on pumped hydro technology, there has been a great deal of momentum in the market based on other newer storage technologies. Part of this investment was jump-started by the American Recovery and Reinvestment Act (ARRA), which committed $185 million to energy storage projects. This and other direct government funding has underwritten more than a third of all new grid storage programs around the world since 2009. The Department of Energy has funded more than $175 million in projects to improve battery technology. Along with government investment, the impact of government policies upon the energy storage market is very significant. In particular, mandates for renewable energy penetration could greatly increase the need for energy storage. However, while energy storage can facilitate the integration of variable renewable sources into the grid, the ownership and business models for recovering the cost of the storage units is unsettled today. The key market drivers relate both to the economics of storage as well as regulatory and other forces that will ultimately determine whether energy suppliers choose storage as a means to provide their grid service.

The current market for grid storage is on the order of a few billion dollars annually. Various industry forecasts expect this annual revenue to grow to as much as $20 billion to $40 billion over the next ten years. Currently there are more than 125 GW of pumped hydro storage installations around the world, which supports less than 2% of the world’s generating capacity but still constitutes the overwhelming majority (99%) of current storage capacity. Forecasts for storage capacity call for alternatives to pumped hydro to play a growing role during the course of the decade. Many studies identify renewable energy shifting to be the largest driver for industry growth, accounting for perhaps half of the market. This growing demand for storage is a result of the need for utilities to manage intermittent renewable energy sources.

Studies indicate that peak shifting is likely to have the second largest impact on demand for grid energy storage.

A major factor in the evolution of the grid energy storage market is the impact of the development of potentially translatable storage technology between the grid and transportation markets—e.g., lithium-ion battery technology. Vehicle battery costs are forecasted to drop dramatically over the next twenty years (see graph) and as battery performance improves and costs come down, storage technologies become increasingly competitive. To the extent that the transportation market provides economies of scale, the adoption of battery technology for grid storage may be accelerated. On the other hand, alternative battery technologies that are not suitable for many transportation applications but are attractive for grid storage may well ultimately dominate that market.
TRANSPORTATION STORAGE MARKETS

The market for vehicle energy storage is rapidly growing. As discussed earlier, the market is currently dominated by e-bikes and microhybrids (particularly with respect to unit volumes), but the other segments such as HEVs, PHEVs and BEVs are all seeking steady growth. Five major auto manufacturers are planning commercial release of FCEVs by 2015. The overall market for vehicle storage was $13 billion in 2011 and research reports forecast this figure to double or even triple over the next five years. The key issues for market growth are cost, performance and reliability of storage technologies. The extent to which electric vehicle technologies are adopted in the passenger car market is highly dependent upon the cost of batteries and the price of gasoline. The high gasoline prices in effect in 2012 have already stimulated significant growth in the HEV sector. In a recent Consumer Reports poll, 73% of Americans said they would consider purchasing an alternative fuel vehicle.

The global market for PHEVs and HEVs is forecast to reach nearly 3 million units in the next five years. The BEV market is expected to expand rapidly in Asia and Europe, with North American demand ramping up more slowly. The premium cost of PHEVs and BEVs is likely to continue to dampen the demand for these vehicles unless the cost of lithium battery technology reaches targeted levels in a timely fashion. On the other hand, factors increasing demand for these vehicles include the spread of global emissions reduction regulations, which are providing impetus for many organizations to adopt electric vehicles for fleet use. More demanding fuel economy standards are also driving the transition to electric vehicles. These regulatory issues along with geopolitical and environmental concerns are leading to a variety of government incentives for electric vehicles around the world. These incentives are being offered on both the supply and demand side of the industry. The Federal government set a goal to have one million plug-in electric vehicles on the road by 2015 and DoE has implemented various initiatives designed to foster the development of electric vehicles.

While the level of and pace of adoption of EVs is still unclear, there are clear benefits for a robust EV presence. The positive effects of a vibrant EV market include the expectation that customers will charge their EVs during off-peak hours (primarily at night), which not only would increase electricity sales, but also would make more efficient use of existing power plants by flattening the current peaks and valleys that currently characterize daily load demands. However, if charging occurs during the day, when power demand would be much higher, utilities may be forced to produce or buy extra electricity at a time when it is most costly or to build new plants to handle the new extended load (this is particularly true if it occurs during the peak summer period). In order to address such issues, utilities are likely to design rate structures that not only make EVs an economically attractive option, but also provide incentives for off-peak charging to maximize the positive impact of this new technology for utilities.

PHOTO CREDITS

Pg 2 (left) Schenectady battery manufacturing plant, courtesy General Electric.
Pg 6 (top left) Powerline photo courtesy of National Grid.
Pg 6 (top right) Chevy Volt and Volt battery pack, courtesy General Motors.
Pg 6 (bottom right) Hybrid bus diagram, courtesy BAE Systems.
Pg 10 National Medal of Technology recipient Prof. Esther Takeuchi, courtesy Brookhaven National Lab.
Pg 11 Duration battery cells, courtesy General Electric.
Pg 13 Engine for fuel cell car, courtesy General Motors.
Pg 13 Schenectady battery manufacturing plant, courtesy General Electric.
Pg 16 Los Andes power station, courtesy AES Energy Storage.
Pg 1 Power station photograph by Claire Mulkey.
Pg 4 Load duration curves from NYISO.
Pg 8 Right) Flywheel storage installation, courtesy Beacon Power.
Pg 9 Electric delivery truck, courtesy Smith Electric Vehicles.
Pg xi (left) Hybrid bus, courtesy BAE systems.
Pg xi (left) Schenectady battery manufacturing plant, courtesy General Electric.
Pg xi (right) Ultracapacitor photograph courtesy Titan.
Pg xi (left) Grid control center photograph courtesy National Grid.

1 “Electric Vehicle Growth Forecasts”, Pike Research, 10 2011
The New York Battery and Energy Storage Technology Consortium (NY-BEST™) is a rapidly growing, industry-led, private-public coalition of corporate, entrepreneurial, academic, and government partners whose goal is to catalyze and grow the energy storage industry and establish New York State as a global leader. NY-BEST serves as a center for communication, education and interaction amongst stakeholders; leverages New York’s world-class intellectual and manufacturing capabilities and market leadership; supports and accelerates the commercialization process from research and development to products and widespread deployment; and advocates for policies that promote the energy storage industry. NY-BEST was initiated with $25 million in seed funding from NYSERDA using Clean Air Interstate Rule (CAIR) proceeds. Its diverse membership includes Fortune 500 companies, start-ups, universities, national research centers and laboratories spanning all facets of the energy sector. NY-BEST is a community of leaders dedicated to changing the way we use energy.