Technological Changes Enabling a Shift Toward a Distributed, Decentralized and Diverse Model of Energy Generation and Distribution

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Abstract

This paper provides an overview of the technological changes that can complement the legacy electric grid as the New York metropolitan region shifts towards a more distributed, decentralized, and diverse model of electric infrastructure. Making the transition from a centralized grid to a distributed arrangement incorporating generation from a variety of power sources will require a systematic approach in the region. Interventions must be dynamic and flexible to accommodate legacy infrastructure, changing technology, and increasing proportions of renewable generators with unpredictable and varying power output. Infrastructure planners must avoid technological "lock-in"—using outdated technologies or non-adaptable equipment, which could become obsolete—and allow a graceful transition from the traditional system. The technology solutions that will be addressed in the paper are broken down into the following components: generation, transmission and development, and storage.

The authors acknowledge that while the technologies necessary for a more distributed, decentralized and diverse grid are readily available, regulatory and business models will need to change in order to achieve this shift at-scale. This paper is one in a series of Working Papers produced by the joint program of the Lincoln Institute of Land Policy and Regional Plan Association originally presented on June 26, 2013 in New York City.

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Technological Changes Enabling a Shift Toward a Distributed, Decentralized and Diverse Model of Energy Generation and Distribution

Introduction

As the world's largest man-made machine, the traditional power system relies on centralized generation and transmission with power flowing from large, central-station power plants, connected by a high-voltage grid, to local distribution systems, and from there to customers. Using central-station power plants is inherently vulnerable: any natural or man-made disruption to the plant, fuel system or to key parts of the network can have major and wide-reaching consequences for the cities and regions served. Central-station power plants are also vulnerable to new, energy consuming technologies (e.g., plug-in electric vehicles, or electronics) that were not imagined when the grid was created. This vulnerability is reduced in part by the use of a grid that connects multiple power plants together but can be reduced further by the addition of "microgrids"[1]—smaller, distributed generation[2] systems coupled with energy storage, management and control systems. Microgrids can augment centralized power generation during peak demand periods but can also disconnect and operate independently, "islanding" during a failure of the central grid. The ability of the microgrid to "self-heal"—detect problems with the power grid and isolate the microgrid from the main, or primary grid in the event of a disturbance—increases the overall resilience of the power system. Microgrids can also facilitate cleaner energy production through the use of renewables or by coupling them with heat-distribution networks that use waste heat from the power production process. The communication, command and control capabilities are a key and overarching requirement and element of microgrids. The ability to exchange multiple sets of operational information in real-time via Internet, will be a crucial characteristic of all modern grid operations.

Making the transition from a centralized grid to a distributed arrangement incorporating generation from a variety of power sources will require a systematic approach in the Metropolitan Region. Interventions must be dynamic and flexible to accommodate legacy infrastructure, changing technology and increasing proportions of renewable generators with unpredictable and varying power output. Infrastructure planners must avoid technological "lock-in"—using outdated technologies or non-adaptable equipment, which could become obsolete—and allow a graceful transition from the traditional system.

The technology solutions that will be addressed in the paper are broken down into the following components: generation, transmission and development, and storage.

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[1] Microgrids — small power systems composed of one or more distributed generation units that can be operated independently from the central power system (Barker 2002).

[2] Distributed Generation (DG) — energy supplied by small generators that are close to the demand.

Figure 1. Components of Electricity Generation and Delivery

It will be necessary to integrate generation, transmission and distribution, and storage components with each other and the existing energy infrastructure and supply chain. Although this may complicate ownership, communication, and regulation, it will increase efficiency and the overall value at both the site and system level.

The NY Metropolitan region is in a deregulated energy market where there is conflict between energy generation and energy distribution (Howard 2012). This complicates governance and ownership since utilities that own T&D resources can potentially leverage advantages against generators, and utilities cannot own DG resources unless they can prove “substantial public benefit, [that ownership] does not harm competition and provides measure to mitigate market power” (NYSERDA 2011).

The next steps in implementing DG and other technological solutions requires changes in governance and ownership models, regulations, planning policy, design standards, financial models, technical expertise and communicating the benefits. These next steps for the Region may include:

Governance and Ownership: Reduce the ‘silo’ approach and encourage intra and inter organizational coordination; developing ownership models and selecting responsible parties for running and maintaining the infrastructure.

Regulation/Legislation: Without regulatory changes, newer, cleaner and more resilient technologies may not be implemented. Examples of this type of regulations are: those that may prohibit non-utilities from running power lines to serve local networks of microgrid customers; those that prohibit utilities from owning generation assets (vertical integrated utility). A standard regulatory definition of a ‘microgrid’ is also needed.

Standards: New standards will be required to balance grid supply and demand as penetration levels of non-dispatchable[3] technologies (e.g. solar and wind) reach higher and higher levels; drafting uniform standards which can eliminate uncertainty in the product design; flexible protocols that allow variation in technologies

Economics: Developing economic models that compensate utilities and address capital cost recovery for installing these technologies; developing business models for those who may be subject to “electric poverty”—distributed generation may increase electricity prices for those receiving.

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[3] Electricity sources that cannot be dispatched at the request of the grid operator.

Planning: Streamlining the lengthy permit processes for siting generation, transmission and distribution assets is needed (currently there is a long application and approval process for design and construction); providing rebates, incentives or loans to reduce high cost of real-estate.

Technology: Bringing new technologies to market; increasing guidance and awareness in connecting to an already complex grid.

Communication: Seeding demand for improvements to the power system by improving the understanding of the benefits of the technologies within the community and governing institutions. This will require education and experience in implementation, communication of the benefits of smart meters, distributed generation and microgrids, and coordinated action to ease adoption.

Drivers

Early electricity generation was done at a local scale, with generators capable of powering a single building such as a factory or a cluster of buildings. Economies of scale and a desire to retire polluting generators from population centers led to the development of a centralized generation system. Over time the increase in population and energy demand required more electricity to be transmitted over higher voltage transmission lines. Continued growth in demand has caused transmission congestion issues due to lack of capacity and losses in the lines due over long distances. For instance, large power demand in New York City and Long Island results in congestion issues such as decreased reliability and high electricity prices from upstate New York generators and in New Jersey. Congestion can be mitigated through distributed generation resources closer to the demand, aggressive demand response programs, and energy efficiency programs (USDOE 2009).

> New England has significantly increased their demand resources since the 2008 adoption of its Forward Capacity Market (FCM) auction process, established to procure adequate capacity to meet forecasted installed capacity requirements three years into the future. Under the program, ISO New England projects power needs three years in advance and holds a reverse auction to purchase the resources necessary to meet these requirements. The auctions are open to a variety of bidders, and the entity that can provide the lowest cost power gains the right to supply that capacity. This means that capacity providers other than traditional utility companies may enter the market. Moreover, ISO New England has established rules for qualifying resources that include International Performance Measurement and Verification Protocol (IPMVP)-based protocols to quantify reductions and requirements within specific capacity zones. The use of location-specific pricing concentrates new generation capacity in zones that offer the higher future capacity payments, which reflects areas where demand is expected to be highest. (ISO New England, Inc. 2013; USDOE 2009) .

Recent developments are leading to the evolution of a more decentralized, distributed system. Drivers for this include:

- Favorable economics
    - Decreasing cost of distributed generation technologies
    - Increasing cost of grid-supplied electricity
    - Wish to avoid costs for new or upgraded transmission and generation assets
    - Rebates and other incentive programs, typically offered by utilities or state agencies to reduce peak demand and thus avoid the need for new generation assets

- Regulatory changes
    - Federal regulation, specifically related to emissions combustion
    - Enforcement of state-legislated renewable portfolio standards (RPS)
    - Minimum Installed Capacity (ICAP) requirements in New York City and Long Island

- Environmental
    - Increased interest in environmental and social justice issues
    - Desire for more efficient generation and load optimization offered by DG to reduce overall energy use

- Resilience
    - Increased interest in the reliability and resilience of electricity supply in the light of uncertainty over fossil fuel supply issues and costs and recent failures of the grid

- Technological changes
    - Improved microgrid technologies including advances in power electronics or converters that can switch power from DC to AC and an increased number of charge/discharge cycles that increase battery lifetime and improve cost-benefit analysis (NYSERDA 2010).
    - Increased smart grid technology piloting and deployment such as energy management systems, smart meters, plug-in electric vehicles, automated switches, etc.

Technological Solutions

Enabling a shift from a centralized system to a decentralized system will require a multipronged, sophisticated strategy that benefits both customers and utilities. The shift will require a diverse “mix” of power generation—fossil-fuel based and renewable based—and incentives for both users and generators. There will not be one, “fix-all” technology that will rebuild the grid, nor could the region wait for such a technology. The electric grid will transition to a dynamic and flexible system that allows for future technologies, additional clean energy integration, increased reliability and resilience, and improved efficiencies. New designs should not be dependent on specific technologies and should instead be flexible to incorporate new devices as products are developed.

This section discusses both the existing technologies and anticipated near term technological advances that will further enable the shift from the existing electrical supply model dependent on large, centralized power stations to a new model of distributed, decentralized and diverse energy generation.

Generation Technologies

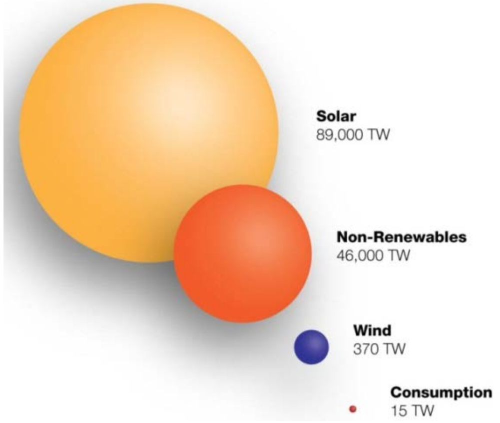
Distributed generation includes a variety of technologies that provide power locally to an area of demand, and are distributed across the grid. DG can be a more energy-efficient solution than centralized power since energy is generated and distributed close to the loads, so transmission and transformation losses are minimized and opportunities such as heat reclaim can be realized because transmission distances are not too long. System size varies but DG technologies can be broken into either hydrocarbon-based technologies that require a fuel supply, or renewable energy technologies. An appropriate mix of DG technologies reduces the impacts of fuel supply-chain disruptions and the exposure of the power price to fuel price volatility.

Figure 2: Mix DG Technologies and Fuel Sources to Introduce Resilience into the Grid

Imported fuels		Renewables
Internal combustion engines		Solar Photovoltaics
Gas turbines		Solar thermal
Microturbines	Biogas, biomass & biofuels	Wind
Fuel cells		Small hydroelectric
		Geothermal
		Ocean energy

Hydrocarbon-based technologies require a reliable supply of hydrocarbon fuel, which could be either fossil or renewable in nature. For instance, both a solid-oxide fuel cell (SOFC) and a combined heat-and-power (CHP) plant will operate with nearly the same efficiency using fossil natural gas methane as they do using renewable biogas methane. Renewable electricity-generating technologies also operate using “fuels”; however their “fuels” vary greatly between technologies. For example, solar PV uses incident sunlight energy to fuel its electricity production, whereas bioenergy facilities use various forms of biomass for their feedstock.

Figure 3: Global Solar Potential Compared to Other Sources and Global Consumption (Arup)



Renewable energy potential dwarfs both fossil and nuclear energy potential by orders of magnitude; Stanford University states that "the amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined" (GCEP 2013).

While renewable energy is plentiful globally, siting of renewable energy plants is most effective when it is driven by the local abundance of the resource fuel, for example solar PV systems should be placed in areas with abundant sunshine, and wind turbines sited in areas with steady winds. This dependence on site-specific conditions means that while one technology might be ideal in one area, a different technology may be preferred in another area with different climatic and demand conditions.

The Bayonne Municipal Utilities Authority (BMUA) completed installation of its Oak Street Pumping Station wind turbine in early 2012 (Steadman 2013). The 262-foot gearless turbine has a nominal power of 1.5 MW; its blades are 252 feet in diameter. Once operational, it is expected to produce 3.3 GWh of electricity per year, resulting in an energy cost savings of approximately $175,000 annually (North American Clean Energy 2011). The authority expects to save an estimated $7 million over the next 20 years through a combination of reduced costs and revenue from the sale of renewable energy credits (RECs) to the local utility, PSE&G (Kowsh 2012). Electricity generated by the turbine will be used on-site to help power Bayonne's Oak Street and Fifth Street pumping stations; excess power will be returned to the local grid through a distribution interconnection (Bayonne Municipal Utilities Authority 2012).

The College of New Jersey installed a 5.2 MW gas-turbine CHP system in 1999 to serve the 39 major buildings located on its 340 acre campus. The system meets approximately 90% of the college's energy needs and uses natural gas as a fuel source. It runs continuously except during routine maintenance; remaining power demand is met by the local utility PSE&G. The system achieves fuel savings of 13% compared to the gas turbine consumption prior to CHP installation; the system provides approximately 47% of the campus's annual electricity needs and saves the college an estimated $3.5 million per year (ICF 2013). During Superstorm Sandy, the College was able to island their central plant and operate off the grid after the 26 kV line feeding power to the campus was severed (IDEA 2012). The CHP system enabled the College to maintain electricity throughout the next week while grid infrastructure was repaired. Although it was unable to provide power for off-campus facilities during the storm, the college was able to use its dual-feed substation equipment to back-feed one of PSE&G's power lines to restore service after the storm (ICF 2013).

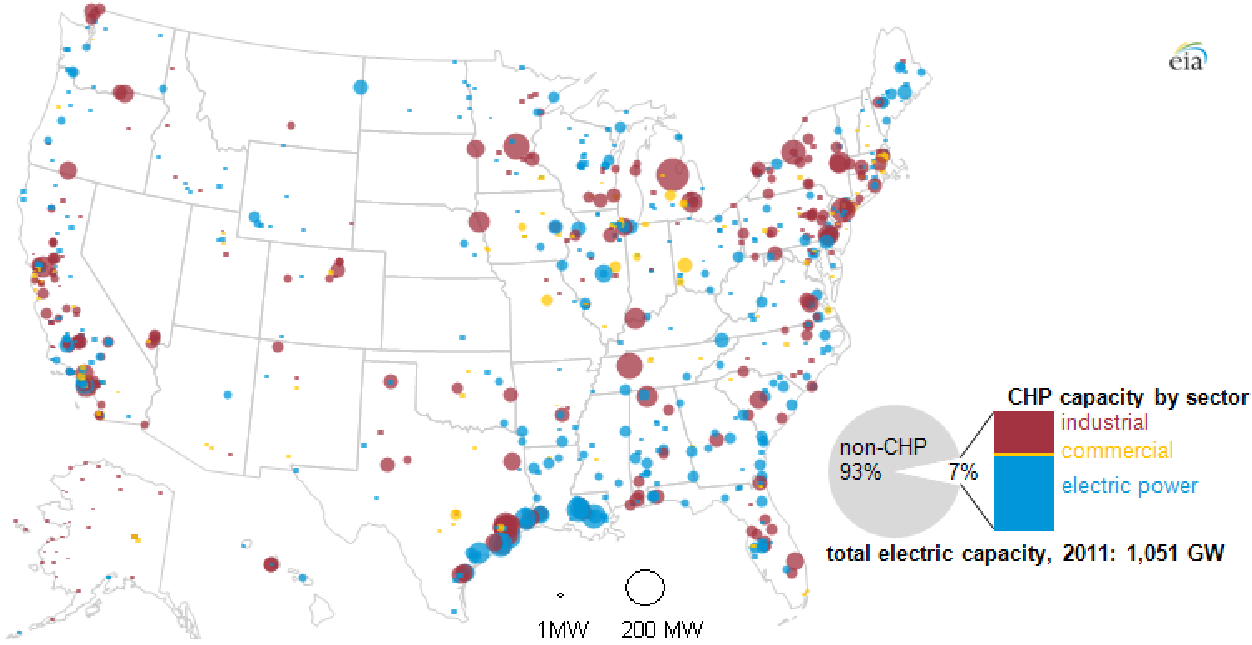
Hydrocarbon-Based Technologies

Combined Heat and Power (CHP)

The location of central power plants in remote areas creates inefficiency in the energy system due to the inability to use waste heat from power stations and the line losses incurred during transmission. Combined heat and power (CHP) is a technology that converts a primary fuel (typically natural gas) into electricity and recovers the 'waste heat' by-product and uses it for heating, domestic hot water, and/or cooling (via absorption chiller) (Howard 2012) for buildings or industrial processes.

CHP accounts for approximately 7 percent of United States electricity generation (EIA 2012). The main driver of CHP growth was the enactment of Public Utility Regulatory Policies Act (PURPA) in 1978 resulting in 340 percent increase in deployment in the following 15 years (Chittum 2011). Recently, the enactment of American Recovery and Reinvestment Act (ARRA) in 2009[4] and the increase in domestic natural gas production promise future growth (Chittum 2011).

Figure 4: CHP Capacity in the United States (EIA 2012)



New York City has also increased CHP (and PV capacity) over the past six years (Figure 5) (Con Edison, 2012).

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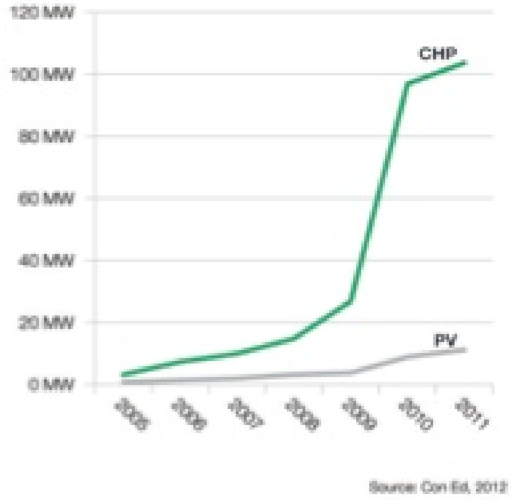
[4] Over $100 million was allocated to CHP projects across the United States (Chittum 2011)

Figure 5: CHP Capacity Increase in NY (Con Edison 2012)



Source: Con Ed, 2012

CHP systems can range in size but are typically sized for meeting the daily and annual electrical or thermal base load rather than the peak demand[5]. In order for the CHP to be most cost effective the buildings being served should have coincident electric and thermal loads, or thermal storage to allow for heat use at a later time.

Table 1: Technology assessment of CHP

	Advantages	**Disadvantages**
Regulations and Standards	▪ Low carbon technology helps reduce greenhouse gases (GHGs) ▪ Reduction on fossil fuels	▪ Barriers for non-utilities to run power lines and serve local network ▪ Interconnection regulations ▪ High pressure gas concerns in municipalities
Economic	▪ Value of the waste heat (hot water, heating, cooling) ▪ Sale of excess electricity to grid ▪ As domestic production increases, natural gas prices have dropped relative to electricity prices	▪ Uncertainty about price of natural gas/price volatility ▪ Fixed Standby Charges and other utility rate tariffs designed to discourage DG ▪ High gas main extension costs if gas is not already available.
Technological	▪ Increased energy efficiency ▪ Local source of power and heating/cooling ▪ Diversity of fuel sources (natural gas can be replaced with biogas) ▪ Improved resilience through diversity of supply paths	▪ Complex nature of existing grid – reliability, timing and demand control ▪ Technical requirements imposed by the utilities to the developer (additional studies, engineering requirements, etc.) ▪ Currently dependent on out-of-state natural gas infrastructure ▪ Smaller systems typically require grid interconnection – increases costs of the

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[5] Peak demand — Maximum load during a specified period of time

<table>
<tr><td></td><td></td><td>project over lifecycle</td></tr>
<tr><td>Environmental</td><td>Low carbon technology</td><td>As the grid becomes less carbon intensive, there will be a point where CHP increases carbon intensity</td></tr>
<tr><td>Planning</td><td>Locations with CHP can be safe havens during power outages</td><td>An appropriate mix of land-uses and load diversity required
Price of real estate may discourage on-site DG</td></tr>
<tr><td colspan="3"><i>Opportunities in New York City Metropolitan Region</i>
The advantage of ‘islanded’ CHP systems was proven during Superstorm Sandy. These systems have the capability of powering buildings using the natural gas supply instead of using grid electricity. CHP works best in buildings with 24-hour load and concurrent heat and power demands such as hospitals, mixed-use developments with an anchor load, university campuses, industry centers, and assisted living centers. NYC’s goal is to increase the amount of distributed generation using CHP (and other DG technologies) by 800MW (City of New York 2011). Connecticut has Energy Improvement Districts to allow multiple participants to form an entity to finance and generate its own energy, which allows shared costs and benefits, issuing bonds and installing wires. New Jersey provides for interconnection of CHP systems up to 2MW.</td></tr>
</table>

Renewable Technologies

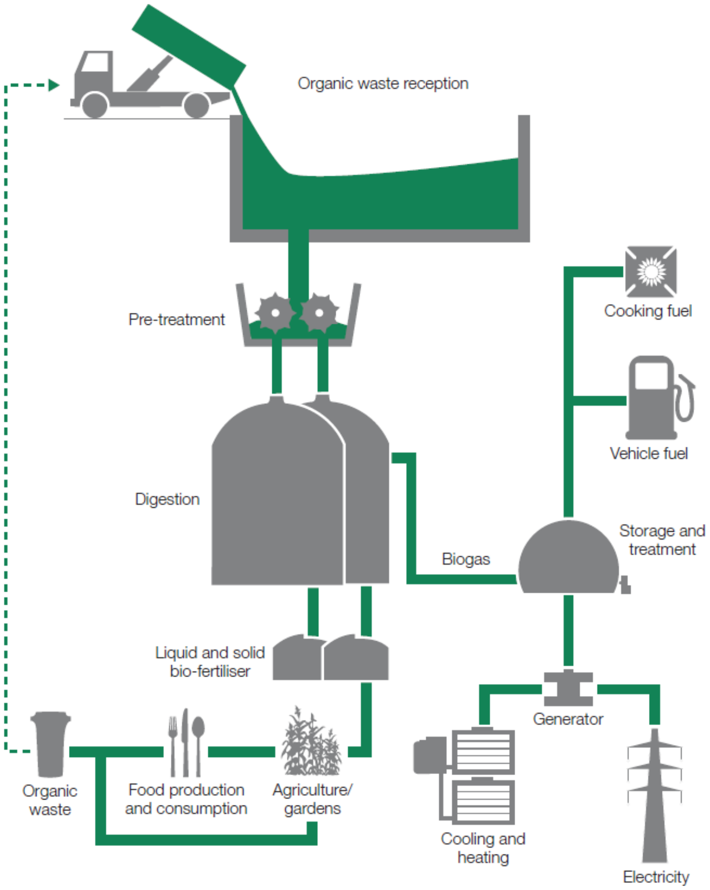
Anaerobic Digestion

Diverse fuel sources for generation will improve the resilience of the region during hazard events and economic change. Most of the electrical generation capacity that has been added in the United States since 2000 has been natural gas fired generation and this will likely continue for the next decade (EIA 2011; NERC 2011). Since the mid-2000s, natural gas prices in the United States have been low compared to historical figures due to increased inexpensive domestic production from shale formations but they are projected to grow as gas recovery becomes more difficult (EIA 2013).

Figure 6: Anaerobic Digesters (Arup)

In addition, natural gas delivered to the region relies on aging infrastructure that extends beyond the metropolitan region into the U.S. and Canada. An alternative, renewable fuel that can complement natural gas is biogas. The organic portion of solid waste, sewage, and plant material can be converted into biogas through anaerobic digestion. Anaerobic Digestion (AD) is a carbon-neutral biological process that uses bacteria to break organic waste into biogas (approximately 60% to 80% methane and 20% to 40% carbon dioxide with traces of hydrogen sulfide, hydrogen and nitrogen) in the absence of oxygen.[6] The biogas can also be "upgraded" to remove the balance gases and impurities, which increase its energy value and reduces corrosion and damage to equipment. The biogas can be used to generate electricity and heat, or be converted into compressed natural gas (CNG) and used as transportation fuel.

Figure 7: Anaerobic Digestion Process (Arup)



The process also produces byproducts such as nutrient-rich compost and fertilizer. An advantage of using organic waste is that the availability of these materials coincides with the population, i.e., the higher the population, the higher availability of organics, enabling more biogas to be generated.

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[6] Biogas can be cleaned and upgraded to natural gas

Table 2: Technology assessment of Anaerobic Digestion

	Advantages	Disadvantages
Regulations and Standards	▪ Waste would no longer need to cross state boundaries	▪ Government has little control over the destination of private waste ▪ Regulations about siting and categorizing an AD as a means for processing food waste
Economic	▪ Potential revenue from byproducts such as nutrients and compost ▪ Opportunities will increase as waste disposal costs increase	▪ Natural gas prices are currently inexpensive ▪ Uncertainty about price of natural gas/ price volatility
Technological	▪ Natural gas can be replaced with biogas ▪ Can be injected into the natural gas network	▪ Requires “upgrading” to remove impurities and increase methane content
Environmental	▪ Biogas is considered a low carbon, renewable fuel ▪ Reduces waste to landfill or incinerator ▪ Reduces transportation emissions (to landfill or incinerator)	▪ Potential odor issues if not properly maintained
Planning	▪ Siting near a Wastewater Treatment Plant (WWTP) ▪ Reduces transportation logistics issues ▪ Increases life of landfills (less waste to the landfill)	▪ Potentially large footprint ▪ Requires communication and support with the community and participation to increase organics (potential public nuisance if not maintained)

Opportunities in New York City Metropolitan Region

Although Anaerobic Digestion technologies have proven successful in Northern European countries due to high participation in organic waste separation, carbon taxes and landfill fees, the technology has not had much success the United States. Currently, New York City anaerobically digests its wastewater at several wastewater treatment plants and is piloting AD for food waste at the Newton Creek WWTP. However, there is a large opportunity to use food waste at a greater capacity. Approximately 47,000 tons of waste leaves NYC each day (Columbia SIPA 2012). If 10% of that waste is organic and converted into biogas via anaerobic digestion then approximately 500 – 1,000 MWh can be generated daily, which is approximately 40 to 80% of city streetlight and traffic light consumption.[7]

In Ansonia CT, a proposed anaerobic digestion plant will be sited adjacent to the wastewater treatment plant and closed landfill, and collect food waste from the City. The city and its private partner plan to export the excess electricity and compost, and set-up a microgrid for the treatment plant, public works complex and retail stores.

Incentives are available for anaerobic digestion in the metropolitan region; however, public-private partnerships (PPPs) will be essential in order to bring this technology to market.

Solar Photovoltaics

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[7] Approximately 1,572,805 GJ (436,767 MWh) is consumed by streetlights and traffic lights (City of New York 2012)

Solar Photovoltaics (PV) is anticipated by many to eventually become the most cost-effective and wide spread technology for DG (WSJ 2013). Solar PV converts incident electromagnetic energy into electric direct current (DC) electricity via the photovoltaic effect. PV systems are comprised of solar PV cells, which are linked to create solar PV modules. There are two available technologies: thin film and crystalline modules, although commercial PV technology is currently dominated by crystalline modules, which typically have 60 to 72 PV cells arranged in series. Modules are connected together in series and parallel to get the voltages and currents needed to feed an inverter, which converts the DC electricity into alternating current (AC) electricity for consumption.

Figure 8: Photovoltaic Array (Arup)

Solar energy is the most abundant energy source available. In any given hour, more solar energy reaches the surface of the earth than humans use over an entire year (Nocera 2006). Thus, for solar PV to become a more prominent energy generation source, it is simply a matter of placing PV modules over enough surface area to collect incident photon energy for our energy needs. Incident solar energy varies by location but while the southwestern United States has more solar resource than the East Coast, all locations in the United States have ample solar resource to make PV an effective technology (Figure 10).

Demand Reduction

The most effective and cheapest solution to a decentralized system is increasing energy efficiency and conservation to reduce consumption and demand. There are numerous building and infrastructure technologies that improve energy conservation and efficiency for new buildings and major renovations; however, it is difficult to transition the existing building stock to low-energy use due to the high cost and disruption involved in doing so. Organizations such as the New York State Energy Research and Development Authority (NYSERDA) and the New Jersey Clean Energy Program (NJCEP) have helped reduce electricity demand and continue to increase energy efficiency by providing guidance, grants, and incentives.

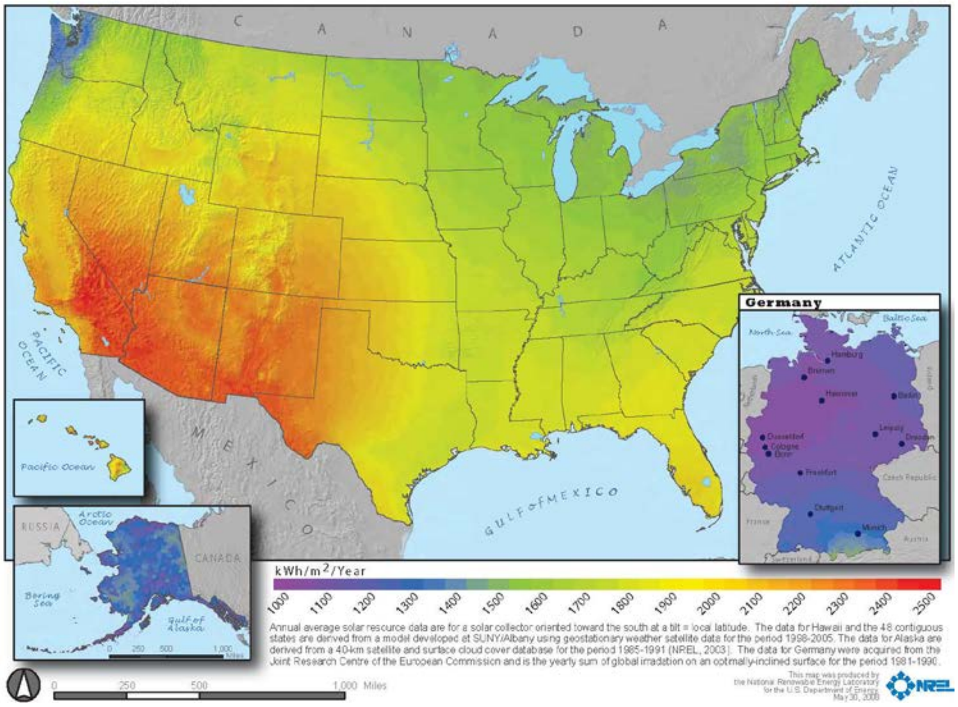
This paper will not focus on these demand reduction technologies and strategies, however the quantity and cost of the technologies discussed in the paper will be reduced due to energy efficiency and conservation.

Transmission and Distribution

The future electric power system should be dynamic and flexible enough to draw from a diverse suite of power sources. The transition from a centralized system to a distributed generation system with storage will require the increased use of the distribution system without heavily relying on the high-voltage transmission system. High-voltage transmission is an issue for the region due losses from aging transmission lines and increased congestion, and siting new transmission lines is difficult.

Creating a smarter grid requires an array of sensors and electronic devices throughout the T&D system to monitor real-time conditions on the grid and from the customers, enhance situational awareness and control, improve the grid's "self-healing" ability, and allow two way communications between the generators and consumers of electricity thus integrating operations technologies with information technologies. Communications technology is the key enabler for improving the T&D component of the grid.

Figure 9: Solar resource in the United States (Kaften 2013)



Annual average solar resource data are for a solar collector oriented toward the south at a tilt = local latitude. The data for Hawaii and the 48 contiguous states are derived from a model developed at SUNY/Albany using geostationary weather satellite data for the period 1998-2005. The data for Alaska are derived from a 40-km satellite and surface cloud cover database for the period 1985-1991 (NREL, 2003). The data for Germany were acquired from the Joint Research Centre of the European Commission and is the yearly sum of global irradiation on an optimally-inclined surface for the period 1981-1990.

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy May 30, 2008

Germany, for example, has inferior solar resource to nearly all 50 states in the United States but is the world's leader in installed PV capacity, with over 32 GW. On Saturday May 26, 2012, solar energy provided nearly half of the peak electric demands in Germany. Contrast this with the U.S., which installed 3.3 GW in 2012 to reach a total capacity of 7.7 GW (Kaften 2013). The important takeaway is that nearly all places in the United States can utilize solar PV technology for their energy needs.

A principal disadvantage of PV with respect to technologies that use a fuel feedstock (e.g. diesel generators) is that the solar modules only generate power when they are exposed to incident light energy, i.e., when the sun is shining. In order for PV systems to be able to provide reliable power at all times, day and night, energy storage is required. Energy storage can be provided either on-site (typically in the form of electrochemical batteries), or if there is a grid connection, it can be via a process known as Net Energy Metering (NEM).[8] NEM allows the electric grid to serve as the battery that both receives excess power from the solar system when there is surplus and supplies loads when the solar PV system cannot meet them (e.g. at night).[9] As the amount of solar power on the grid increases, the use of NEM has the potential to disrupt the grid. The use of microgrids with storage in conjunction with PV minimizes this risk and is a major advantage of using this type of system.

Over the past decade, as PV manufacturing companies have scaled up their manufacturing plants to increase throughput, economies of scale have resulted in dramatic reductions in the cost of solar. For instance, the leading Chinese crystalline PV manufacturers reduced their module costs by more than 50 percent (Lacy 2013). This steady and rapid reduction of costs is projected to continue with an additional 30 percent reduction in costs by 2015, resulting in PV module costs of only $0.42/W (Lacy 2013).

Similar cost reductions are taking place with components of a solar PV system, such as inverters, mounting hardware, and design and installation costs. Simultaneously, as solar PV is becoming less and less capital intensive, the technology itself is improving. Solar cells and inverters are becoming more efficient, and with the advent of microinverters and DC-to-DC optimizers, systems are more optimized and thus generate increased energy. The result of all of these innovations and cost reductions is that solar PV is becoming more economical, with grid parity already reached in some areas and being rapidly approached in others.

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[8] For electric customers who generate their own electricity, it allows for the flow of electricity both to and from the customer—typically through a single, bi-directional meter. When a customer's generation exceeds the customer's use, electricity from the customer flows back to the grid, offsetting electricity consumed by the customer at a different time during the same billing cycle (NC State 2013).

[9] Connecticut Light and Power (CL&P) and United Illuminating Company are required to provide net metering to customers generating Class I renewable energy resources up to 2MW in capacity; New Jersey utilities the same but no specified limit; Con Edison and the Long Island Power Authority offer net metering with restrictions.

Figure 10: The Swanson Effect: Price of Crystalline Silicon Photovoltaic Cells in $ per Watt (Bloomberg New Energy Finance, 2012)

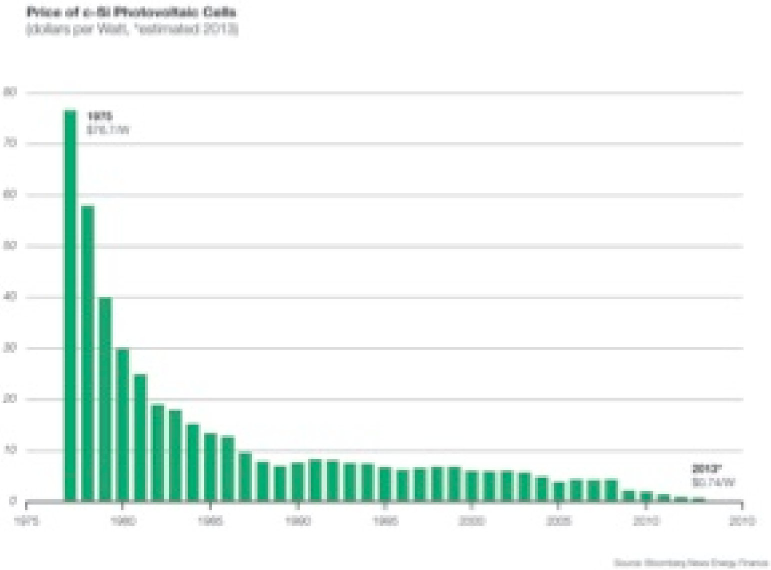
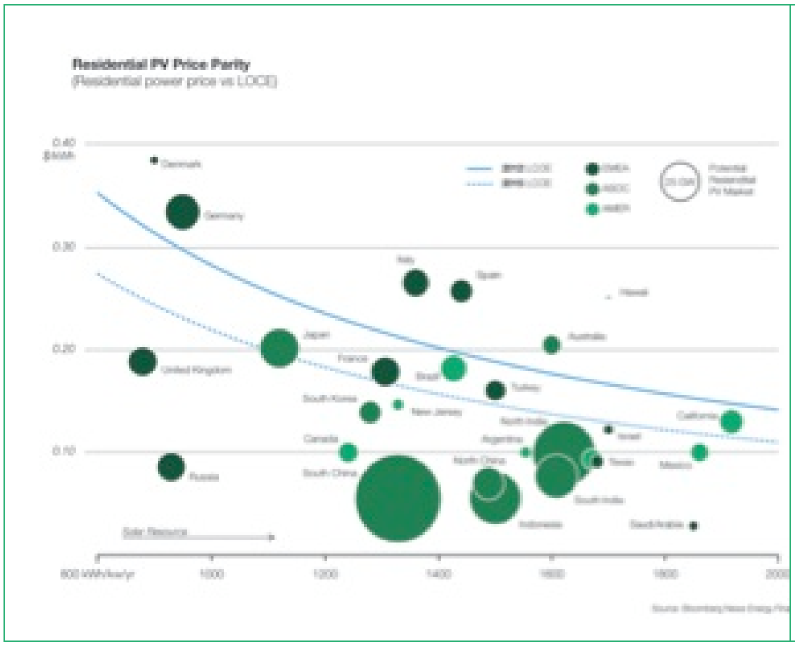


Figure 11: Residential PV price parity



Grid parity is a term used to describe the point at which the levelized cost of energy (LCOE) for a particular technology is less than or equal to the price of electricity of the centralized grid. For areas with higher grid electricity costs, and assuming equal incentives, grid parity will occur sooner. Figure 11 shows the grid parity line of solar PV as a function of both solar resource (on the x-axis) and LCOE (on the y-axis), overlaid on various electricity markets around the world. Solar PV in Hawaii reached grid parity several years ago due to electricity rates approaching $0.30/kWh. It is currently a significantly cheaper source of energy than the grid.

For nearly all grid-connected solar PV systems installed in the United States in DG applications, their current grid-direct inverters are required by codes and are designed to disconnect from the grid in the event of a grid fault or outage. This means that if the grid is out, PV systems will not be able to supply power to the loads, even if the sun is shining.

Microgrids allow "islanding" operation, whereby loads can continue to be served in the event of a grid outage without putting line workers at risk of electrocution. They do this by adding two additional components: the battery storage and the bi-directional inverter, to the PV system, thus making it a grid-tie battery backup (GTBB) system. The battery storage system comprises electrochemical storage batteries—deep-cycle lead acid batteries are most common, although Li-ion batteries are likely to become more economical in coming years (discussed in the *Storage* section). The bi-directional inverter provides DC/AC conversion and allows the battery to charge. These systems are becoming more popular and there has been a large upswing in interest after the power outages resulting from Superstorm Sandy rendered hundreds of conventional grid-tied PV systems useless (Harvey 2012). As the cost of PV and these additional components continues to decrease (particularly batteries), we expect GTBB systems to become more common.

Since solar PV systems have no moving parts and consequently minimal maintenance costs; nearly all of the life-cycle costs of a solar system are capital costs. One way to think about solar PV systems (and other renewables), is that the owner is pre-paying for the energy that will be generated over the entirety of the system's life. While on a life cycle basis solar PV may be the more economical choice, coming up with the capital for the first costs in order to purchase and install a solar PV system remains a barrier for many, a problem that will likely continue going forward as well.

There are several financing methods that help deal with this issue, which can result in increased adoption of solar PV systems (and other DG systems). These include:

- **3rd party financing —** Immediate savings in energy with no upfront cost. Companies own and maintain a system installed on the customer's property (e.g. roof), selling the generated electricity to the customer at a discount to their utility as either a solar lease or solar Public-Private Partnership (PPA). In some markets, up to 80 percent of commercial and residential systems are currently financed this way (SEIA 2013).

- **PACE financing —** Property Assessed Clean Energy (PACE) financing is an alternative to a loan whereby system owners can borrow money from a local government, repaying this debt in increased property taxes, or another locally-collected tax or bill, such as a utility bill. Connecticut has state-wide commercial PACE financing in every municipality, while federal mortgage agencies have effectively blocked PACE funding in New York (DSIRE 2013). While PACE financing does not reduce the total price tag of a solar-energy system, it helps make a system more affordable by spreading the cost of the system over a long time period (DSIRE 2013).

- **Crowd-sourced funding** and other innovative funding mechanisms provide low-interest debt or equity financing for medium to large solar PV projects.

Table 3: Technology assessment of Solar Photovoltaics

	Advantages	Disadvantages
Regulatory and Standards	▪ Net metering credits generators ▪ There are numerous government sponsored incentives and grants available ▪ Interconnection standardized by Standard Interconnection Requirement's (SIR) in NYS by PSC	▪ Currently public sector buildings in New York do not have net metering opportunities ▪ Fire code issues (smoke ventilation and impediments) specifically on multi-family residential
Economic	▪ Cost of PVs have decreased ▪ Incentives are available for customers	▪ Currently PV generation is more expensive than conventional power generation ▪ Lack of incentives for rental buildings ▪ High costs of storage
Technological	▪ Can provide on-grid and off-grid power ▪ Available anywhere	▪ Output degrades over time ▪ Intermittent energy source without energy storage (in its infancy) ▪ Requires storage or grid connection for continuous use ▪ Requires invertor to convert into AC
Environmental	▪ Low carbon technology (no GHGs) ▪ Renewable supply	
Planning	▪ Potential revenue source for urban renewal projects ▪ Opportunity to review and revise land-use policies	▪ Potentially tedious permitting and incentive application process

Opportunities in New York City Metropolitan Region

Solar power generation has been successful in the metropolitan area. For example, New York City has increased its PV capacity to approximately 5.65 MW and is projected to increase up to 75MW by 2015 (Meister Consultants Group Inc. 2011). This is due in large part to the improvement in interconnection and incentives. A solar map has been created in NYC (CUNY 2013). In addition, the public sector utilities should work with local government to create a net metering tariff at parity with the investor-owned utilities located in the metropolitan region (Meister Consultants Group Inc. 2011).

New Jersey, which has installed over 1GW of capacity, has had success with solar power due to its renewable portfolio standard (RPS), solar renewable energy credits (SRECs) and locating PV's on buildings, landfills, parking lots, and utility poles (NJBPU 2013).

Increased opportunities in the Metropolitan region exist through microinverters and AC modules, which simplify installations and designs, DC-to-DC optimizers increasing system performance, improved inverters that can provide ancillary services for the grid, control ramp rates to facilitate central station needs, etc., which will enable a higher penetration of solar PV on the grid, continued improvements in solar cell efficiencies, continued cost reductions in both equipment hard costs as well as installation and other soft costs, improved economics resulting in grid parity, and continued development and adoption of alternate financing methods.

Understanding and Controlling the State of the Grid

Distribution automation technologies integrate the systems discussed below to monitor and control the grid and optimize system performance. Some of the key technologies are discussed below:

- **Distribution management system (DMS)** — a decision support system for utilities to assist control room and field operating personnel to monitor, control and optimize the electric distribution system without compromising safety and assets (EPRI 2011). These systems can utilize geographic information systems (GIS) to track and monitor assets across the grid.

- **Distribution supervisory control and data acquisition (D-SCADA) —** collects and reports voltage levels, real-time demand, apparent power, reactive power, equipment state, operational state, and event logging allowing operators to remotely control capacitor banks, breakers and voltage regulation (NYS 2013).

- **Phasor Measurement Units (PMUs)** — measure current and voltage on the grid at a more frequent rate than existing sensors to determine the "health" of the grid and identify any stresses or vulnerabilities of the grid. PMUs are beginning to be implemented across the region and they will also help enable the integration of renewable energy resources.

- **Voltage and Volt Ampere Reactive (VAR) control on feeders** — help distribution feeders[10] to maintain acceptable voltage at all points and help maintain power. A basic requirement for all electric distribution feeders to maintain acceptable voltage at all points along the feeder and to maintain a high power factor. Recent efforts by utilities to improve efficiency, reduce demand, reduce GHGs, and achieve better asset utilization, have shown the importance of voltage/VAR control and optimization (E. Reinfurt 2013). Utilities continue to face system losses from reactive load, such as washing machines, air conditioners and by optimizing voltage/VAR control great efficiencies can be realized.

- **Intelligent Electronic Devices (IEDs) —** receive data from sensors and power equipment and issue control commands. Smart and automated switches can be installed on distribution feeders to quickly isolate a fault and reduce outages to customers. These technologies use distributed intelligence and use peer-to-peer communications to isolate faults and restore power quickly without the need for field crews in some cases. Other IEDs include Intelligent head-end feeder reclosers and relays, intelligent reclosers and Short-Circuit Current Limiters (SCCL), which allow not only greater fault protection but flexible conversion between different frequencies, phasing, and voltages while still producing a proper AC voltage to the end user.

<u>Communication Between Generators and Consumers</u>

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[10] A feeder circuit carries a large amount of electric power to a sub-feeder or a branch of a circuit or to a point at which the block power is broken into smaller circuits (NYSERDA 2010).

> The Con Edison Smart Grid Deployment project is funded by a federal Smart Grid Investment Grant and involves the deployment of smart grid systems and components throughout the utility's service area. The project will install various types of distribution automation equipment and distribution management systems to reduce overall costs and increase system efficiency and reliability.
> Distributed energy assets will include secure two-way wireless communication networks between approximately 180 network type distribution transformers. This system will allow for distributed generation to be fed safely and reliably back into the grid. The completion of the project, scheduled for early 2013, will allow for distributed resources such as solar power and CHP systems to come online (USDOE 2012).

The transmission and distribution components of the grid form the bridge from the generators to the consumers. Bi-directional communication from one to the other through technology can improve the state of the grid. A secure communication system is important to ensure confidentiality of information and integrity of the grid (EPRI 2011), but the more information that can be passed back and forth across the grid, the better generators can meet consumers' requirements. As noted above, all technology improvements need to provide benefits for both utility and consumer.

Advanced metering infrastructure (AMI) allows two-way communication across the grid through smart meters, customer and operational data bases. It can provide customers with the data that they need both to reduce electricity bills by timing the use of their equipment and to incentivize reductions in energy use. It provides utilities with the ability to operate the electricity system more robustly (EPRI 2011).

One of the main components of AMI is smart metering. **Smart meters** provide communication between the utility and customer; remotely programmable firmware and a remotely manageable service disconnect switch; consumption measurements; voltage measurements and alarms that can be integrated with distribution automation technologies to maximize benefits; and interval data to support dynamic pricing and demand response programs (EPRI 2011). Smart meters can help customers reduce electricity bills by using electricity more effectively and providing utilities the ability to operate the electricity system more robustly. For example, utilities envision the smart meters' ability to communicate with devices and appliances to provide information and control to the customer.

The use of smart meters will particularly benefit customers who program the operation of appliances, heating systems, and other technologies based on electricity prices. Additionally, coupled with a DMS, the increased deployment of smart meters will assist utilities in determining which customers have lost service and inform restoration strategies.

Smart meters facilitate **real-time or dynamic pricing,** rate structures that capture the true cost of energy, by fluctuating throughout the day, based on the costs of generation and transmission at any given time. This is important because electricity can be several times its average cost at times of peak demand, and reducing peak demand can reduce the need for investment in both generation and transmission assets. Typical electric utility rate structures include a basic fee to cover overhead costs (e.g. billing, meters, and equipment), an energy charge based on the number of kilowatt-hours used by a customer over a period of time and a demand charge based on peak power used, typically based on the customer's peak demand for a given month (some commercial and industrial). Standard residential rates (without an additional demand charge) use a block rate structure, which is tiered based on monthly consumption. Although this system discourages excessive consumption, its ability to accurately reflect true energy costs are limited. In addition, those consumers that have little to no peak demand during the day are subsidizing those who have many peaks during the day. This "cross-subsidy" has been calculated at about $3 Billion annual in the United States (The Brattle Group 2011). An alternative rate structure is time-of-use (TOU), which is designed to encourage customers to shift loads from peak demand times by increasing electricity charges during specific periods such as summer afternoons when air conditioner use is high. A TOU rate structure increases electricity rates during these periods to reflect the cost of greater demand, and decrease rates during off-peak times when capacity is idle. However, it is difficult to determine if a TOU rate structures provide customers with greater value compared to standard rate schedules. Through smart meters utilities can offer real time, or dynamic pricing. This provides customers with price information and allows them to implement measures to shift or reduce usage in respond to increased costs. Accurately representing the real cost of electricity incentives customers to reduce consumption during peak periods and can encourage more efficient demand management (Masters 2005).

Once real-time pricing is in place it is much simpler to encourage people to participate in **demand response programs** that enable grid operators to more effectively manage the balance between supply and demand. Large power demands, such as large lighting areas, motors, equipment, etc. are purposefully curtailed. This "load shedding" can be done to avoid costly peak demand energy or in emergency situations to prevent brown-outs due to inadequacy of supply. Typically demand response programs are done through voluntary load reduction programs initiated by the utility communicating with the consumer, however smart meters and a building's Energy Management System (EMS) can create an automated demand response system using the internet or other signal (EPRI 2008).

For most grids, peak demands are growing faster than baseload demands, and thus utilities have to procure additional peaking capacity in order to meet seasonal worst-case peak demands. For utilities and grid operators, peaking capacity is generally both expensive and environmentally destructive.[11]

Utility customers are typically given financial incentives in exchange for agreeing to yield some control to the grid operator for temporary shut-off of large power demands. There are some residential demand response programs available that disconnect power to air conditioning compressors of participating customers in a large area (e.g. an entire neighborhood) for a short amount of time (e.g. 15 min), before power is reconnected. If the grid operator has enough residential load shedding capacity due to demand response, he or she may be able to curtail significant amounts of power from the overall demand.

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[11] Peaking capacity is typically provided with single cycle gas turbine plants, which are much less efficient than most thermal plants designed to meet more than peak demands, such as combined cycle plants.

As a result of demand response programs, the term “negawatts” has been coined to describe the grid operator’s ability to subtract megawatts of power from the demand through active demand response management.

> The Long Island Power Authority (LIPA), Stony Brook University and Farmingdale State College secured funding from the US DOE’s American Recovery and Reinvestment Smart Grid program to create a Smart Energy Corridor along Route 110 in Long Island. The demonstration project (in its third year) integrates advanced metering infrastructure (AMI) technology with automated substation and distribution systems to monitor demand and identify outages.
> The project is assessing the impact of a range of variables on customer behaviors, including alternative rate structures, information and analytics, and energy automation. Demonstration projects at the Farmingdale campus are evaluating the integration of intelligent devices and renewable energy distributed generation. (Long Island Power Authority: Long Island Smart Energy Corridor 2010)

Table 4: Technology assessment of smart grid technologies

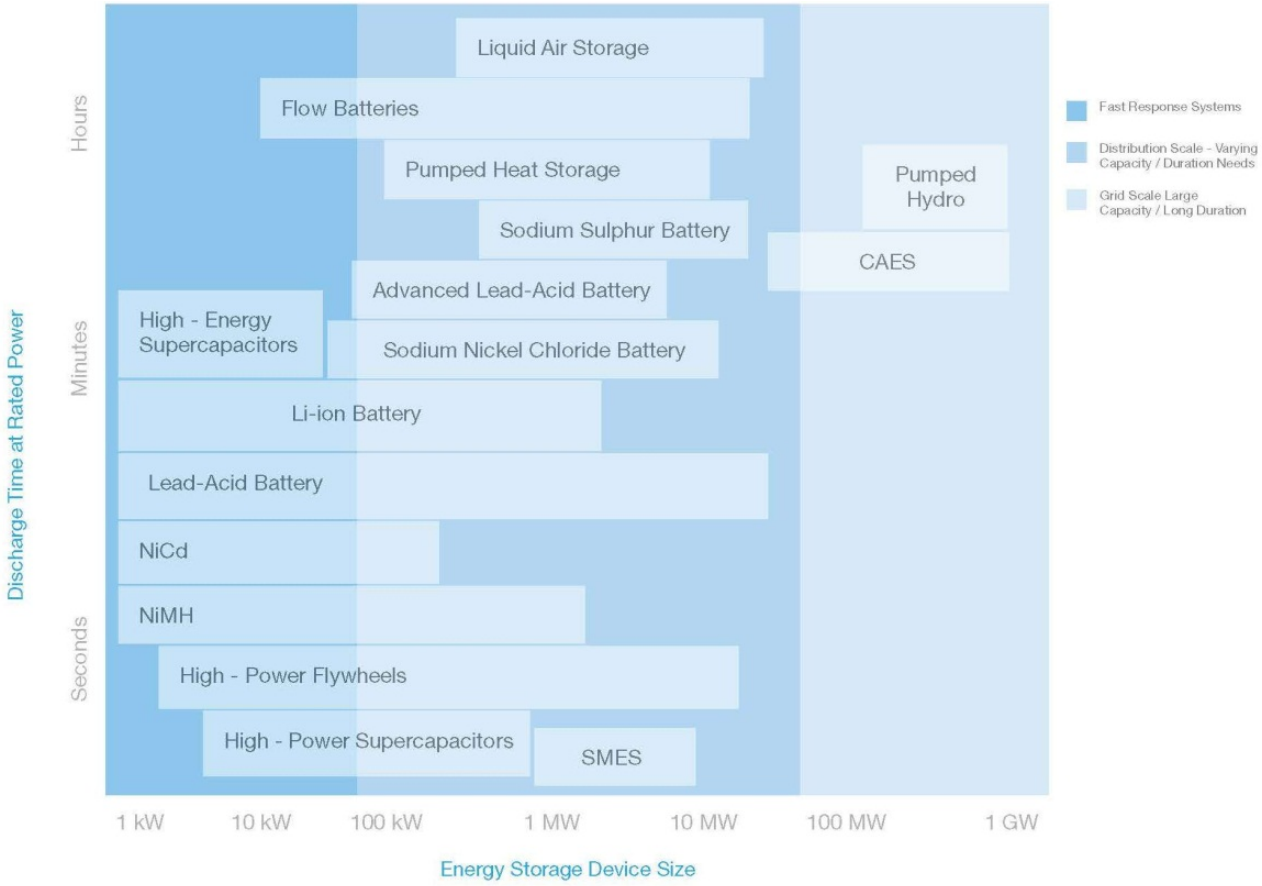
	Advantages	**Disadvantages**
Regulatory and Standards	▪ Promoted by ARRA and Energy Policy Acts of 2005 and 2007 ▪ PMU standards such as IEEE C37.118 ▪ In Connecticut, the Connecticut Clean Energy Fund supports DG	▪ Need for the development of standards (e.g., German Standard – VDE-AR-N – provides a method of frequency-dependent active power control to stabilize the utility grid during periods of excessive renewable energy generation
Economic	▪ Dynamic pricing- lowers electricity costs for consumers ▪ Customer choices for power ▪ Job creation	▪ AMI – burden is ultimately on the rate payer ▪ Dynamic pricing - concern about bill impacts to low income or elderly although studies have shown the contrary (Carson 2012) ▪ High cost eventually paid by the rate payer ▪ Electric utility capital expenditure plans need to include these technologies
Technological	▪ Ability to track, monitor, control and optimize system and assets ▪ Remote control access of the distribution system ▪ Improvement of system performance and reliability and fault location ▪ Improvement in distribution efficiencies ▪ Improvement in converting different frequencies, phasing and voltages ▪ Isolate faults and reduce outages ▪ Dynamic pricing	▪ Rapidly changing technologies ▪ More piloting is needed to assure interoperability of components ▪ Different technologies needed for different utilities (not all of the infrastructure is the same)

<table>
<tr><td></td><td>▪ Improves load factors
▪ Integrates renewables and PEVs
▪ Avoids the need to build new peaking plants
▪ More flexibility in matching supply and demand</td><td></td></tr>
<tr><td>Environmental</td><td>▪ Emissions reductions due to less grid congestion and losses</td><td></td></tr>
<tr><td>Planning</td><td>▪ Improved safety and security
▪ Improved resilience</td><td>▪ Methods to communicate to consumers</td></tr>
<tr><td colspan="3"><i>Opportunities in New York City Metropolitan Region</i>
Recent storm events, the shift to DG and the aging transmission and distribution lines in the Metropolitan Region provides opportunity for smart grid awareness, control and communication technologies. There are many pilot programs supported by governments in the Metropolitan Region and the federal government. In New York, the Energy Highway Blueprint and various pilot projects by NYPA, LIPA and Con Edison are supporting smart grid technologies. In New Jersey, FirstEnergy’s Smart Grid Modernization Initiative project includes AMI, distribution automation and TOUs. In Connecticut, the ConnSMART Program in Norwalk is a pilot program for AMI and dynamic pricing. With the sharing information and potential success of these programs, the utilities in the Region will soon be able to implement these technologies at a larger scale. Integrating smart meters at a commercial scale will take some time due to customer acceptance and cost. In the short-term, allowing consumers who have smart meters to opt-in to dynamic pricing may be the best approach. In the medium to long term, as utilities replace existing assets with “smarter” technologies then the benefits will be increased.</td></tr>
</table>

Storage

As fundamental as the other technologies are to creating a decentralized and resilient grid, energy storage technologies are the game-changing component. Electricity supply and demand must match. As such, the electricity infrastructure must be equipped (and capable of forecasting) from its generation facilities to high voltage to low voltage transmission and distribution lines. This is considerably challenging—peak demand changes seasonally, during time-of-day and from customer preferences, and expensive—the addition of power stations or upgrades to transmission and distribution infrastructure). Optimally, the first goal is to reduce power demand from customers thereby reducing the need for transmission and distribution upgrades, generation stations, or purchasing electricity at very high price during these demand periods. However, the costs can be nearly eliminated and the system can be more resilient by adopting new and emerging storage technologies which may include advanced batteries, flywheels, compressed air energy storage (CAES), plug-in electric vehicles (PEVs) and thermal storage (ice or heat storage).

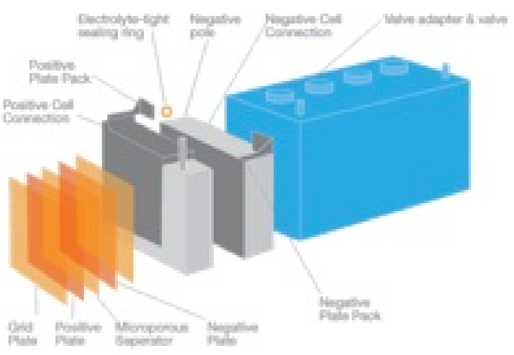
Figure 12: Discharge time at rated power and system power rating of various energy storage technologies (Derived from EPRI 2010)



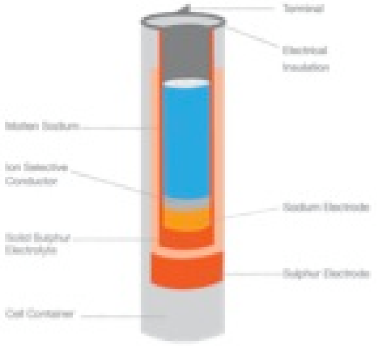
Electro-chemical Battery Energy Storage

Electrochemical batteries are energy storage devices capable of converting between chemical energy and electrical energy. The battery technology discussed, i.e. used for electrical energy storage, reverse the chemical reaction and can both charge and discharge. Common rechargeable batteries include lead-acid, nickel-cadmium (NiCd), sodium sulfur (NaS) and lithium-ion (Li-ion).

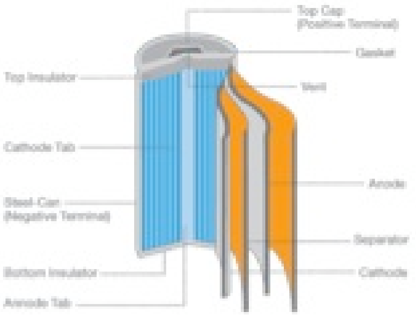
Figure 13: Diagrams of Several Battery Technologies



Lead acid (Eurobat, 2010)



NaS (Arup)



Lithium Ion (Arup)

Batteries can provide energy storage for both small and large systems and can serve to provide on-site dispatchability and firmness to an otherwise intermittent generation facility (e.g. a wind farm with a battery bank facility) or can be used through an electric T&D system to balance supply and demand. From a resilience perspective, stationary systems such as back-up battery banks provide the best support for off-grid power.

Currently, lead-acid batteries are the most common battery technology in battery backup solar systems, but all of the aforementioned technologies have been employed on projects. For example, a NiCd bank in Alaska can provide up to 46 MW of power, NaS batteries have been applied to over 300 grid applications mostly in Japan (34 MW of NaS batteries have been integrated to the Futamata wind farm in Japan) and a 1MW NaS battery system is currently being tested in a Long Island Bus Depot, and a 20MW Li-ion installation has been commissioned in Johnson City NY to provide regulation services to the grid.

> The Barclay Tower in lower Manhattan has been described by property owners Glenwood Management as the first battery-based intelligent energy storage system in a residential high rise. The system, designed by Demand Energy Network, provides 225 kW of power with 2 MWh of storage capacity. Demand's Joule.System™ integrates BMS support, energy market data, and metering systems while managing storage resources and AC/DC conversion. Storage consists of either advanced VRLA or Lithium Ion batteries (Demand Energy Networks 2013).
>
> Glenwood Management initially purchased two trial-sized systems in 2011 for the Barclay Tower and an additional property. Following positive results in demand response and stability, Glenwood moved towards deploying a full-scale system in the Barclay Tower. The system can also be used to manage cost volatility in New York's incentive-based rate structure. The batteries can be used to store power sold at reduced off-peak prices and release the energy during peak periods when costs rise (Energy Manager Today 2012).

Lithium ion batteries are the fastest growing batteries in portable and mobile applications (Battery University 2013). Lithium ion batteries are typically used in smaller applications and will need to be more cost effective at the utility scale.
The selection of the battery is typically based on life-cycle economics, which balances capital costs with other variables such as depth of discharge, maintenance and cycle life, however capital cost is typically the most important factor considered. Energy storage in the form of electrochemical batteries remains an expensive technology but costs continue to decrease with time. For example, in 1999 the price for a Li-ion 18650 cell (the most common and mass produced Li-ion model) was $2,600/kWh and in 2011 the price had reduced to $240 $/kWh (Element Energy Limited 2012). Further, cost reductions are projected to decrease rapidly—automotive lithium-ion battery packs are projected to fall 60 to 70 percent by 2020 and 75 percent by 2025 (McKinsey 2012).

As the need for electric vehicles, renewable energy penetration, and reliable DG has grown, energy storage has become an area of concentrated interest, research and development. Many, in fact, refer to energy storage as the “holy grail” of renewable integration, due to its anticipated importance in balancing the future energy system and meeting both customer and utility needs.

There are myriad different chemistries and architectures that are being researched and developed both domestically and abroad, with some highlights described briefly below:

- Nickel-zinc (NiZn)
- Flow batteries
- Metal air batteries
- Zinc-bromide

Energy storage will become an ever increasingly critical component in our future electric system, not only enabling massive amounts of renewable energy penetration, but also holding the key to reliable, self-sufficient micro-grids that can operate completely independent of a centralized grid.

Figure 14: Diagram of Flow Battery Technology (Arup)

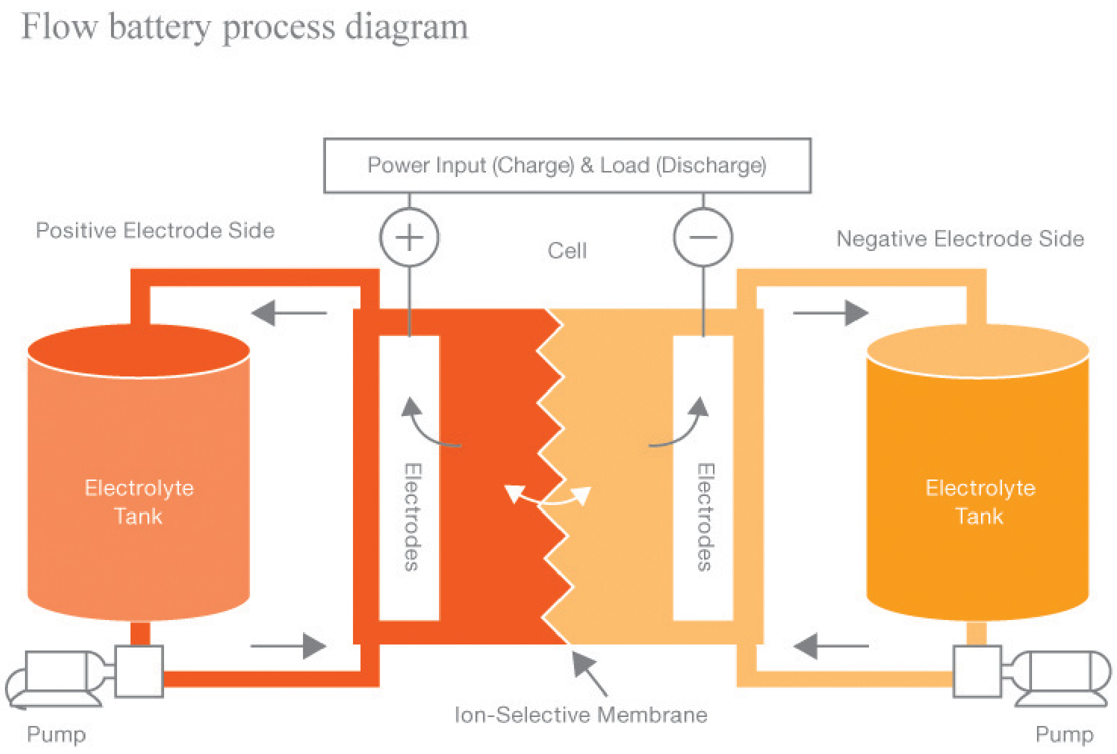


Table 5: Technology assessment of battery storage technologies

	Advantages of battery technologies	Disadvantages of battery technologies
Regulations and Standards	▪ Requires development of pricing arrangements ▪ Integration of battery technology into traditional regulatory classifications ▪ Resale of electricity beyond RECs	▪ Complicated ownership structures due to multi-functional characteristics ▪ Potential bi-directional energy flows create tariff and billing issues ▪ Some Federal Energy Regulatory Commission (FERC) rules prohibit storage from competing with traditional resources
Economic	▪ More economical to purchase power during off-peak periods ▪ Funding available for product development and commercialization in NY and NJ	▪ High capital costs and long return on investment ▪ Difficult to monetize multiple stakeholder benefits ▪ Bi-directional energy flow issues (tariffs, metering and billing)

<table>
<tr><td>Technological</td><td>▪ Numerous benefits depending on technology
▪ Research and development projects supported by NYSERDA and CAIR funding
▪ Modular and scalable technology</td><td>▪ Rapidly changing technologies
▪ Limited deployment of emerging technologies (Li-ion, flow, etc.)
▪ Battery durability
▪ Commercial maturity</td></tr>
<tr><td>Environmental</td><td>▪ Reduction in emissions by using energy that would otherwise be wasted
▪ Increases effectiveness of renewable sources</td><td>▪ Some batteries contain hazardous materials
▪ Grid-connected batteries produce emissions as a result of generation</td></tr>
<tr><td>Planning</td><td>▪ Provides opportunities for other renewable sources to be used
▪ Increases value in areas where power supply is frequently interrupted</td><td>▪ Wide variety of storage options will likely be needed
▪ Space for battery storage in buildings will reduce leasable area</td></tr>
<tr><td colspan="3"><i>Opportunities in New York City Metropolitan Region</i>
During Superstorm Sandy, critical facilities such as New York University Langone Medical Center and Bellevue Hospital Center lost their backup power due essential equipment for the diesel generators located on lower levels. These facilities may have benefited from battery power systems (as opposed to mechanical diesel generation systems). However, the cost of battery systems compared to diesel systems is significantly higher.
Organizations such as the New York Battery and Energy Storage Technology (NY-BEST) Consortium were created to stimulate growth in the energy storage industry by utilizing its diverse group of members from different industries and providing a forum for communication and interaction. It also provides funding and grant opportunities and advocates energy storage policies.
In New Jersey, the Office of Clean Energy at the New Jersey Board of Public Utilities has proposed to reduce the renewable energy budget to provide more funding for energy storage ($10 million over four years) (NJSpotlight 2013).</td></tr>
</table>

Plug-in Electric Vehicles

Plug-in electric vehicles (PEV) are battery powered vehicles charged through the grid. Battery swapping and fast charging as well as other infrastructure technologies are evolving. However, PEVs can help balance the grid during by charging during off-peak periods and can be used as storage devices to provide a reverse flow power capability such as vehicle-to-grid (V2G). The benefit of V2G is that it also enhances the value of a PEV. PEVs can reduce reliance on volatile fuels such as gasoline and reduce the associated emissions with combustion fuels, specifically as grid emission factors decrease over time (due to renewable portfolio standards). Larger batteries and the implementation of smart grid technologies discussed in Transmission and distribution) will enable DG in the form of vehicle-to-grid operation.

> In September of 2009, Delaware’s Governor Jack Markell signed Senate Bill 153 into law. This legislation, the first of its kinds in the United States, required electric utilities to compensate the owners of PEVs for energy sent back to the grid. Under its provisions, electric car owners are compensated at the same rate they pay for grid electricity (University of Delaware 2013). In late 2011, the University of Delaware and NRG Energy began working together to commercialize the technology that would enable a two-way interface between PEVs and the electricity grid. A pilot project was initiated to

equip electric vehicles with two-way chargers, a feature that is generally not included in U.S. electric car models, and aggregate individual cars into a larger power source to create greater storage capacity and provide load balancing capabilities. In April of 2014, the project was adopted as an official electricity resource by the regional transmission organization PJM Interconnection. The technology is expected to initially help large PEV fleet managers to add revenue, and will eventually include private PEV owners (News.Delaware.Gov 2013).

Table 6: Technology assessment of plug-in electric vehicles/vehicle-to-grid

	Advantages	**Disadvantages**
Regulations and Standards	▪ Existing state and local government support	▪ Requires regulatory reform ▪ Will need electricity grid investment to support technology and accelerate deployment ▪ ISO/RTO market will need to evolve to include DG resources
Economic	▪ Grid power is less volatile and faces less escalation compared to gasoline costs ▪ Increased vehicle efficiency and decreased fuel costs	▪ Development of business models for the utility and the consumer ▪ Higher up-front costs for owners ▪ Capital costs of fast-charging stations must be significantly reduced to make immediate investment in public EV infrastructure more economically viable
Technological	▪ Provides load-balancing for electric grid ▪ Acts as distributed storage ▪ Can act as localized backup power ▪ Higher capital expenditures of electric vehicles are offset with greatly reduced operating expenditures over time.	▪ Increased power demand on grid ▪ V2G requires capability for bi-directional power flow (very few examples)
Environmental	▪ Reduced vehicle emissions (as grid emission factors decrease) and increased public health ▪ Reduced pressure on petroleum supply networks by decreasing transportation demand	▪ Increased emissions from generation facilities
Planning	▪ Increased transportation options ▪ Incorporation of adequate and accessible charging infrastructure ▪ Increased air quality and decreased noise pollution in congested areas ▪ Incentivized adoption with EV-specific lanes and parking	▪ Requires expansion of public charging stations ▪ Locating charging stations in dense areas
Opportunities in New York City Metropolitan Region Developing an electric vehicle storage program will provide an alternative option for energy storage in		

the region. The Region, through State's Department of Transportation and private businesses, can increase its electric vehicle readiness by installing more public charging stations in areas where PEV users drive including municipal and private parking lots, transit stations, tourist destinations and workplaces. In the short-term, PEV can take advantage of already-existing electrical infrastructure and region's utilities can offer PEV customers with cost saving measures to reduce their rates for vehicle charging. In the long term, larger batteries will enable DG in the form of V2G and as PEV penetration increases utilities can use PEVs for energy storage and V2G programs, specifically during peak hours.

Pilot Opportunities

Regional advantages and disadvantages to implementation are identified for each of the technologies discussed in this paper. This information should be used as criteria for assessment when considering the feasibility of deployment, including potential barriers and opportunities for engagement. For each technology, pilot programs and case-study projects are identified as a reference for stakeholder groups to use when planning future initiatives. Additionally, a series of potential pilot programs is included for existing sites throughout the region. Knowledge gained from these projects should be published and communicated regularly to political figures, business leaders, professionals and community members to raise awareness and secure support for future opportunities.

Generation	Challenges	Opportunities
Anaerobic digester in Staten Island (Fresh Kills or off Arthur Kill)	• Acquisition or use of the site • Community acceptance • Funding to develop and operate the facility	• The City (and region) generates a substantial amount of organic waste • Export biogas to existing natural gas infrastructure • Reduce legal risks and transportation energy from exporting waste outside the region

Transmission & Distribution	Challenges	Opportunities
Microgrid development with CHP and other Distributed Generation Resources in Stamford CBT using the CT Microgrid Grant and Loan Pilot Program.	▪ Requires municipal, Connecticut Light & Power, private utility and local business support (financial and technical) ▪ Local businesses interest in owning infrastructure (Energy Improvement District issue) and concern with sharing interconnection • Management, maintenance and operation of the microgrid	▪ Stamford is an Energy Improvement District (EID) (Connecticut Public Act 07-242) ▪ High electricity prices and aging infrastructure in the area • EID board can play an active role in educating stakeholders

Storage	Challenges	Opportunities
Battery storage with DG integration	▪ Limited large-scale demonstration projects of battery storage and DG ▪ Insufficient technical progress in battery technology • Lack of standards and/or models for battery and DG	▪ Emergency generation (for critical facilities such as hospitals) ▪ NYSERDA funding to develop advanced energy storage technology ▪ Integration of DG sources into grid • Revenue from energy market
NYC Electric Vehicle fleet	▪ PEV manufacturers are generally unwilling to permit battery discharge – battery life would not be tied to odometer (warranty liability), performance standards would not be compromised, general risk of allowing external control interfaces ▪ Need for aggregation technology that can manage communication between individually connected PEVs and utilities ▪ Standards needed for widespread adoption – a bi-directional charging protocol must include standards for physical components, communications and electricity quality	▪ Large vehicle fleet - the existing NYC fleet includes approximately 6,300 light and 8,100 heavy duty vehicles and 8,300 police vehicles ▪ NREL has demonstrated V2G capacity with a battery converter that provides bi-directional power between PEV batteries and a 480V AC power grid

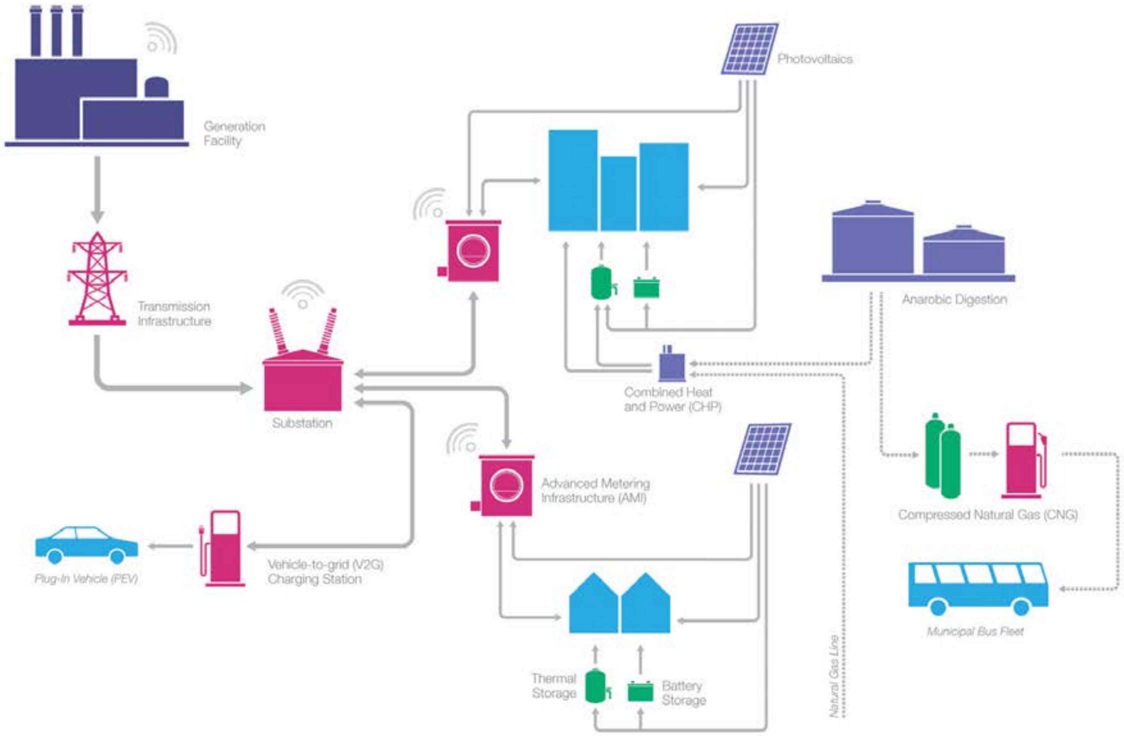
Summary

This paper provides an outlook into future technologies that will enable a shift toward a distributed, decentralized and diverse model of energy generation and distribution. DG is a cost-effective way of augmenting the existing grid. The role of the centralized power grid in the New York Metropolitan Region will still be needed because of its advantages in cost and load management as well as its ability to move power over long distances. In addition, reducing energy consumption and demand will maximize the efficiency and reduce the cost of whichever new clean energy option is chosen, i.e., “negawatts” that aren’t used can be just as important as the megawatts that are supplied by DG (NREL 2013).

There are many different technologies that can be adopted and it is likely that a diverse group will be selected, depending on local goals and conditions. Some of these technologies already exist, while others are being tested by regional utilities so that they can be easily introduced and integrated into the existing system without affecting customer reliability. To be the most cost-effective these strategies will need to deliver energy savings as well as increased reliability and resilience.

The three components of technical solutions suggested in this paper can be added to the Region individually, however the efficiency and resilience benefits will not be gained unless the components are integrated (Figure 15).

Figure 15: Integrated Plan for a Distributed, Decentralized and Diverse Grid



The key advantages of the technologies discussed in the paper are efficiency, reliability and resilience. They include diverse fuel and generation sources, smart technologies to make the grid more flexible and responsive during various climatic conditions. They also provide utilities and customers' feedback to optimize energy efficiency, and technologies that provide redundancy during failures, as well as fuel flexibility and carbon emission reductions.

It is recommended that the transition to DG is accelerated and facilitated through changes to governance, legislation, regulation and incentives because of its many key advantages. It is expected that the transition will not happen at once and pilot projects are important—but this paper shows that most of the technologies are already proven locally. The transition will require leadership and a clear vision of where the Region needs to get to. As these actions occur and the technologies are added to the grid, the New York Metropolitan Region will move towards a more distributed, decentralized and diverse energy system.

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