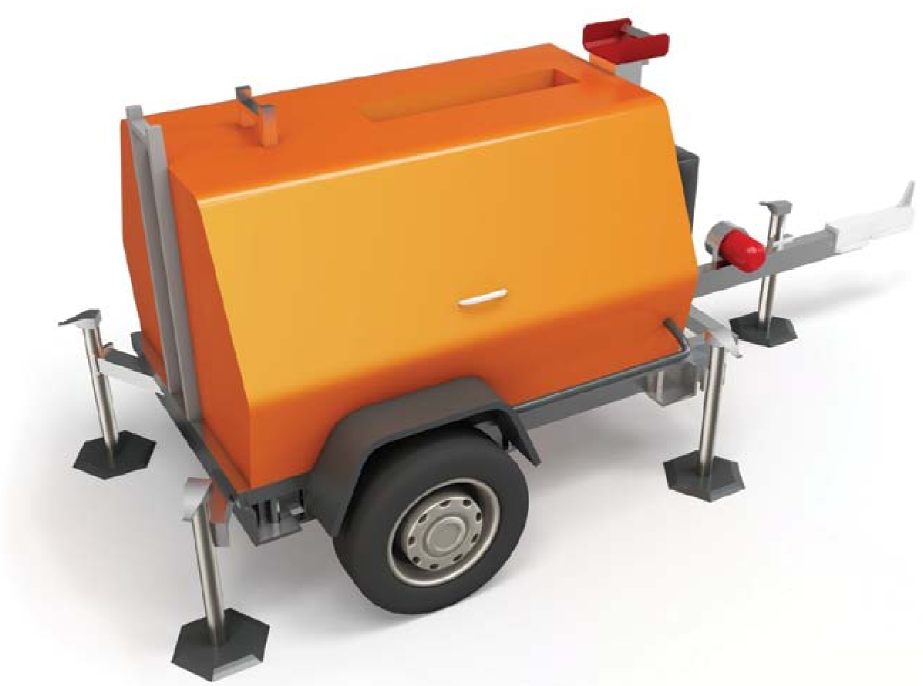
Low Tech Resilience



Portable small-scale generators could keep vital services on line during a major power outage.

By William Zarakas, Frank Graves, and Sanem Sergici

The recent severe storms in 2011, 2012, and 2013 in the Northeast and the Mid-Atlantic States have demonstrated that critical infrastructure isn't always able (nor is it typically designed) to withstand extreme events. The resulting effects also have served to sharpen the discussion about electric system reliability, storm preparation, and storm responses. Making an electric system more reliable typically means two things: a) carrying generation reserves and b) hardening transmission and distribution assets, so that they can stand up in the face of high winds and ice storms. The recent storms involved disruptions to the wires – not to the supply pool. Indeed, the delivery system is more often the cause of outages than generation.

Hardening the wires could involve a combination of redeploying power lines (from overhead to underground), fortifying or raising substations, and trimming trees that could damage aerial lines when they sag or fall under the weight of snow and ice. It could also be accomplished, at least in part, by incorporating intelligence into the grid so that power flows can be reconfigured to islands of customers within the overall system, bypassing troubled areas. However, no solution can promise to eliminate power outages. At some point, extreme conditions will inevitably compromise parts of any electric system. Very extreme events will likely result in prolonged and widespread power outages. These prolonged outages can have social costs far beyond the normal notion of economic inconvenience associated with shorter interruptions in service.

Electric system resiliency involves how quickly and effectively a system can come back on line. Frequently, discussions on resiliency are concerned with storm preparedness and responsiveness, so that recovery teams and equipment are pre-positioned to repair lines and restore electric service as quickly as possible. Resiliency planning needs to also consider extreme circumstances when distribution lines are down haphazardly and unpredictably throughout broad areas of an electric system. In these cases, power cannot be expected to be restored quickly, even when intelligent solutions such as smart grids or micro-grids are in place. Furthermore, the unpredictability of where service will be interrupted and the extent of breaks in distribution lines means that communities might lose power that supports basic elements of their social infrastructure – such as gas stations, grocery stores and even ATMs – as well as power to individual homes.

Recent events have shown that protracted, extreme circumstances place entire communities under high levels of stress. That could be moderated somewhat if customers at least could have access to the basic social and commercial services that they routinely have taken for granted. Some community institutions have procured backup power, usually in the form of backup generators, but many others don't do so because of affordability or other issues. The analysis here concerns the costs and benefits of providing backup power to some of the key facilities that provide these services during times of prolonged power outages. We consider the situation in which significant portions of one or more large utility service areas have been put out of service as the result of a major storm, with some areas expected to be without power for a prolonged period of time. Specifically, this analysis will examine the costs and the benefits associated with acquiring and maintaining a fleet of portable generators, which we refer to as mobile distributed generation,[1] or mobile DG, that can be deployed as needed to locations that house key services, those that are considered "critical."[2]

Deploying mobile DG to key locations would allow customers to fill gas tanks, charge cell phones, and buy groceries.

What We Pay for Gen Reserves

Electric utility systems are designed with redundancies and back-ups, which naturally tend to be utilized primarily in times of stress and crisis. While that increases the price of electricity to customers, it's well established that such preparations – and their associated costs, up to the point of matching expected benefits – represent prudent and appropriate business practices. The full cost of backing up an electric utility system is difficult to estimate, as there are many dispersed pieces of redundant

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1. We use the term "mobile DG" instead of portable generators because utilities and regulators refer to generating resources of this capacity as distributed generation resources. In most cases, these resources are affixed to a specific location and are referred to simply as DG. Mobile distributed generation isn't an entirely new concept; there are various examples of commercial applications that are already in place. Currently, they're widely employed in the construction, gas and oil field operations, and telecommunications fields. Their sizes range from 15 kW to as large as 500 kW.
2. Services such as grocery stores and gas stations are referred to as "critical" because they assist in the maintenance of social order during times of stress. It isn't to be confused with "critical infrastructure" as defined in the Patriot Act of 2001.

Fig. 1 Breakdown of Cost of Power Delivery

Bill Component	% of Total
Fuel and power supply	**70.0%**
-Energy	52.5%
-Firm capacity	15.8%
-Reserve capacity	1.8%
Electric delivery	**30.0%**
Total	**100.0%**

Source: Author's analysis

inventory, cross-trained staff, and even financial reserves to cope with rainy days.

The cost of ensuring that an extra cushion of power generation is on hand to meet unexpected failures can be more directly estimated, and this can serve as a benchmark as to how regulators and customers value reliability insurance practices. Electric utilities hold additional reserves above and beyond their expected peak load in order to ensure that there is sufficient capacity available to serve the load at any point in time. Like an insurance policy, it might never or rarely be used, but it's nonetheless secured to make sure that adequate resources are on hand in the event of most of the possible unforeseen disruptions to power supply. This power adequacy insurance policy is paid for by customers in their electric rates by covering the fixed costs of reserve peaking capacity. Reserve requirements are typically around 15 percent of generation capacity; the associated carrying costs represent a modest portion of utility revenue requirements.

Based on our financial review of the cost structures at a cross section of U.S. coastal utilities, we estimate that the cost to customers of carrying this reserve requirement – that is, the insurance burden in customer bills – is typically slightly less than 2 percent of a customer's total bill for electric service, as shown in Figure 1.[3]

The average per kWh rate for delivered power varies considerably across the country, with a representative rate of about 15 cents per delivered kWh for some coastal cities and parts of the northeast – areas particularly prone towards disruptive storms. Of this, roughly 0.3 cents per kWh (*i.e.,* nearly 2 percent of the total rate for electricity) would typically be associated with reserve requirements, based on the above cost breakdown – that is, with high voltage generation insurance.[4]

In practice, outages caused by problems with generation adequacy at the high voltage end of an electric system are relatively rare, representing only a small portion (less than five percent) of the overall major service disruptions in a given year. The vast majority of power outages aren't system-wide but are caused by failures in downstream portions of the electric system; that is, the distribution system, where downed lines and damaged substations are responsible for the origins of more than 95 percent of power outages. Backup in the distribution system (the equivalent of reserve requirements) are largely in the form of redundant equipment and systems, built in to cushion unanticipated loads or voltage deviations.

What We Could Pay for Low-End Backup

Designing electric distribution systems to be tolerant of the more extreme of conditions is an expensive job at best and an impossible one at worst. Stated differently, even the best of electric distribution systems will fail under extreme stress, such as a debilitating weather event. Moreover, such vulnerability is probably economically optimal – at least up to some point. That is, we would not want to pay for a system which was virtually immune from such disruptions, as it would divert resources from other legitimate opportunities for risk reduction.

We estimate overall cost – the gen unit, installation, interconnection, and a few days' operation – at about $2,500 per kW.

Outages caused by extreme weather events might be becoming more frequent. Catastrophic storms that could interrupt power delivery and disrupt social services for several days were (or seemed) quite rare. This might not be the case going forward. A recent study by researchers at MIT found that 100-year storms, in which tides surge by two meters or more, are becoming much more frequent – now on the order of one such storm every three to 20 years, instead of one every 100 years.[5]

Prolonged outages cause considerable personal stress and inconvenience. In addition to the inability to obtain light and heat for individual homes and businesses, prolonged outages also restrict the operation of common facilities and critical social

3. This estimate was based on review of the FERC Form 1 data for a panel of roughly 30 integrated electric utilities – that is, utilities that are responsible for both providing and delivering power – because these utilities report the costs of power and the costs of delivery in one place and on a consistent basis.
4. In practice, the optimal level of reserve requirement isn't just a function of load vs. capacity, but is also an economic question of providing the lowest cost of reliable power to customers, which requires weighing the expected and potential extremes of production costs and the costs of emergency purchases of power against the costs to customers associated with the loss of load. See: Kevin Carden, Johannes Pfeifenberger and Nick Wintermantel, *The Economics of Resource Adequacy Planning: Why Reserve Margins Are Not Just About Keeping the Lights On*, National Regulatory Research Institute, April 2011.
5. Ning Lin, Kerry Emanuel, Michael Oppenheimer, Erik Vanmarcke, "Physically based assessment of hurricane surge threat under climate change," *Nature Climate Change*, 2012.

services: most notably, gas stations, grocery stores, schools (as a possible shelter and place to charge cell phones), and cell phone towers. In the face of prolonged outages, perhaps additional steps could be taken to retain or allow quick repowering of at least a basic core of these critical services: some police stations, schools, gas stations and grocery stores. Powering these services before relief can be brought to the area at large could be accomplished through a mobile DG program, similar to the way a home owner might fire up a portable generator. Portability, or mobility, is a very important dimension of such a program because the locations and extent of the critical facilities that need powering will fluctuate depending upon the circumstances concerning the specific outage.[6]

Under one possible scenario, an electric utility or a governmental entity might acquire a fleet of mobile generators with capacities sized to support a variety of facilities that provide critical services. These units could be deployed in advance of or immediately after major storms, where and as needed. The town (or utility) would need to prioritize the specific types of facilities that it considers to be of greatest importance, reflecting the area's unique circumstances and based on its own, local views of social importance. Portability also allows sharing of assets among jurisdictions, which provides for smaller local fleets with higher asset utilization and lower costs per customer.

Providing backup power to a portion of these entities is quite different from providing customers with heat, light and comfort in their own homes. Deploying mobile DGs to the facilities that house critical services allows customers to fill their gas tanks, charge their cell phones and buy groceries – conveniences that could be life-saving in the aftermath of a devastating storm. The mobile DG assets directed to these needs are then public goods, unlike the assets used for backup power by individual homeowners, because they are put in place to keep commonly used facilities available for the general public. Accordingly, the cost for such a public good should be shared among all potential beneficiaries, and not paid for primarily (or exclusively) by the recipients of this power or by the operators of the facilities that deliver the subject critical services.

Estimating Costs for a Small City

To put some data on paper, we consider the electrical needs of a stylized largely suburban small city, comprised of about 40,000 households (or about 100,000 people) and associated commercial and industrial businesses. This city, we estimate, would have a peak demand of roughly 195 MW and total annual energy consumption of 1,150 GWh, with electricity sales split relatively evenly across residential, commercial and industrial sectors.

Of particular interest are services regarded as critical to maintaining social order in times of crisis or stress. We estimate the number of such facilities by building upon prior work in this area. Thus, our stylized city of 40,000 households would feature about 64 gas stations, 16 grocery stores, 8 police stations and 32 schools, as well as fire stations, hospitals, cell towers and street lights.[7] In this analysis, we focus on gas stations, grocery stores, police stations and schools – in part because frequently fire stations and hospitals have back-up generation in place, and backing up certain other facilities, notably cell towers, is subject to current policy discussions and regulatory proceedings.[8]

Based on typical peak demands, we estimate that providing power to all of the gas stations, grocery stores, police stations and schools in the city would involve placing slightly more than 6.2 MW of mobile DG resources in service. However, meeting immediate community needs (and maintaining social order) doesn't necessarily require that all such facilities be fully in operation. While we assume that all city police stations should be powered by backup generators, we suggest that only one in four gas stations and schools and one-half of grocery stores would need such powering to meet community needs.

For a city of 100,000 (with 40,000 customers), mobile DG to maintain critical services would cost only about $8 a year per customer.

This partial powering brings the non-coincident demand for power down from the full requirement level of 6.2 MW to roughly 2.7 MW, the derivation of which is summarized in Figure 2.

The 40 facilities designated as critical, shown in Figure 2, require varying levels of power ranging from relatively low requirements to power a basic gas station, to comparatively larger requirements to power a grocery store, which could involve

6. Portability of generators and microgrids has been a critical factor in power related planning for the U.S. military. See: *Military Microgrids: Market Potential, Case Studies, Provider Profiles*, a report by Red Mountain Insights LLC.

7. The assumptions used herein regarding the extent of critical service facilities in a small city (or medium sized town) is taken from an analysis by Narayanan and Morgan (See: *Sustaining Critical Social Services During Extended Regional Power Blackouts*, Anu Narayanan and M. Granger Morgan, Risk Analysis, Vol. 32, No. 7, 2012). Specifically, the authors estimated the number of police stations, grocery stores, gas stations, schools, cell towers and street lights and grocery stores, as well as their associated power requirements for a community of 5,000 households. In the current analysis, we 1) extrapolated the number of facilities estimated in the Narayanan and Morgan to cover 40,000 households (for a population of 100,000) and 2) made minor modification to the number of facilities included in that study, notably increasing the number of schools required to support the population.

8. Of course, the mix of facilities with back-up power already in place will vary with location and will inevitably be different across cities and towns.

FIG. 2 **STYLIZED ANALYSIS OF CRITICAL FACILITIES**

Source: Author's analysis

Small city population = 100,000; Households = 40,000

	Unit Demand (kW)	Number of Facilities	Total Demand (kW)	Critical Facilities (% of Total)	Number of Critical Facilities	Total Demand (kW)
Police	60	8	480	100%	8	480
Grocery	200	16	3,200	50%	8	1,600
Gas station	5	64	320	25%	16	80
School	70	32	2,240	25%	8	560
Total (kW)		120	6,240		40	2,720

significant refrigeration and lighting loads. We assume that the fleet of portable generators that will used to back-up critical service facilities will be composed of units sized at 10 kW, 20 kW, and 50 kW.[9] A 20-kW portable generator (powered by diesel or gasoline) costs about $25,000; costs for smaller or larger sized units are correspondingly lower or higher, but with larger units realizing some economies of scale (lower per kW costs). For the subject analysis, we assume an average cost for portable generators of about $1,250 per kW.

In addition, connecting a generator – either fixed or portable – to a facility requires a significant amount of preparation, involving wiring and switches as well as safeguards to ensure against inadvertently back feeding into the grid. For portable applications, sites can be designated and wiring and connection points prepared in advanced (which saves a significant amount of time in powering up the facility) or can be connected at the time of the outage (which takes several hours of work and requires that a qualified electrician are available and dispatched to the site).[10] In either case, the cost of connecting the portable generator to the load can be significant and could match the cost of the equipment itself.[11] For purposes of this analysis, we estimate the overall cost of generation equipment plus its installation infrastructure and fuel sufficient to support a few days of generation to be roughly twice the cost of generation equipment alone, or about $2,500 per kW. Comparatively, this cost is fairly expensive when compared to the cost of installed capacity that is supplied over the grid – but power from portable generators isn't proposed as a replacement to grid power and its cost might well be justified as emergency power.[12]

The resulting cost to acquire a fleet of mobile generators with capacity sufficient to meet the 2.7 MW of capacity summarized in Figure 2 would, then, be about $6.8 million.[13] Assuming that these assets are acquired by the electric utility, and further assuming typical utility ownership and capital structure for their fixed cost recovery, this investment would translate into a revenue requirement from the town's electric customers of about $816,000 per year.[14] On a rate-effect basis, this is roughly 0.07 cents per total delivered kWh (*i.e.,* prorated across the entire year's volume, and excluding the costs of the backup fuel burned, which might be another 4 to 8 cents per kWh depending on efficiency and fuel type. The fuel cost is minuscule given that the mobile generators only operate on a small number of days). Equivalently, this is about $8 in capacity carrying charges per year for an average residential customer.

By contrast, earlier, we showed that customers typically pay

9. Portable generators of larger scale are available, although these tend to be permanently affixed as back-up power facilities. Such larger units also might require special permitting that smaller scale portable generators (of less than roughly 50 kW) don't.
10. Designating in advance the sites of critical services that may receive back-up power is efficient in that facilities can be powered-up quite quickly. However, this requires selecting sites in advance and completing connection preparations which may never be utilized.
11. For example, in *CPUC Self-Generation Incentive Program: Cost Effectiveness of Distributed Generation Technologies*, a report prepared by Itron for PG&E, February 9, 2011: the installed cost for a fixed microturbine used for DG was $3,150 per kW, of which roughly $950 per kW represented the cost of the microturbine from the manufacturer and $2,200 per kW covering the cost to install the system. The cost to connect a portable generator to load would be less (because it doesn't involve costs for site preparation, pouring a concrete base and piping and wiring) but nonetheless substantial.
12. We assume that most or all of these DG units will be fueled by diesel or gasoline some may be able to take advantage of their proximity to natural gas infrastructure. The cost of fuel in this application – *i.e.,* using the portable generators for very short periods of time over the course of the year – would constitute a small percentage of the project's capital cost.
13. Fully implementing this program will involve other costs, notably fuel and connections, including tapping into natural gas lines and connecting to facilities. We consider some but not all of these costs in the assumed cost per kW for mobile DG units. We don't include in the analysis, the cost of fuel, which varies depending upon usage. Ideally, these generators would be fueled with natural gas; in practice, location might require that they're fueled with gasoline or diesel.
14. The roughly $6.8 million total cost amortized at a carrying charge of 12 percent yields an annual cost of roughly $816,000. This annual amortized cost is spread over annual demand of 1,150 GWh, yielding 0.07 cents per kWh.

almost four times this much, or about 0.3 cents per kWh for power generation reserves,[15] which would be about $30 per year for the average residential customer living in the city in our example. The low voltage insurance of 0.07 cents per kWh to keep critical services available during a prolonged outage is considerably less than the high voltage insurance of 0.3 cents per kWh, which insures against relatively rare overall generation service disruptions.

Is It Worth It?

Based on the discussion above, the cost per normal service, delivered kWh of low voltage insurance is about one-third of the corresponding cost of insuring against a loss of generating capacity – and the probability of losing power at critical facilities is considerably higher than the chance of losing sufficient generating capacity to cover peak loads. Thus, on the surface, this appears to be a modest cost to ensure that the citizens have access to critical services during prolonged power outages. However, $8 per year is sizable enough to raise concern among ratepayers, and value isn't always assessed by such comparable analyses.

Estimates of the value to customers of receiving uninterrupted electricity are measured through surveys that query about a customer's willingness to pay in order to avoid a loss of service. These surveys are translated into what is dubbed the value of lost load, or VOLL, as a function of the duration of disruption. Typically, VOLLs are much higher than the average cost (and rate per kWh) of delivered power. For residential customers, VOLLs range from $2.10 per event for a momentary power outage to $10.60 for an outage that last eight hours. This translates into a value of from $0.90 to $16.80 per unserved kWh,[16] which is almost 100 times higher than normal service rates. By these accounts, residential customers would be more than willing to pay much more than $8 per year to avoid a loss of power to themselves for, say, 48 hours. However, the above VOLLs reflect the values that customers place upon not losing power personally – not the value they would place on avoiding loss of power to social service providers. (Accordingly, we refer to this type of VOLL willingness to pay as P-VOLL, for personal VOLL.)

Little, if any, research has been conducted concerning what customers would be willing to pay for power restoration or outage prevention services that aren't directly for their own consumption needs. It's likely that the loss of power to providers of critical services would not be as acute a concern (to an individual consumer) as would loss of power to one's home. That is, unless and until an outage becomes widespread and protracted. Then, consumers would likely place a material value on preserving power and access to the facilities that provide critical services. The relevant benchmark for a social VOLL (or, S-VOLL) is the dollar value of what citizens would be willing to pay after a few days of outage, to prevent a few more days of outage to those services.

The annual cost of the mobile DG program discussed above ($816,000) if used to provide power up 2.7 MW of critical services during a single 48-hour outage would have an implied cost of about $7 per unserved kWh.[17] That's within the $0.90 to $16.80 per unserved kWh range for P-VOLLs cited above, although we expect that there will be at least two key differences between P-VOLLs and S-VOLLs.

By contrast, customers now typically pay 0.3 cents per kWh (about $30/year) for power generation reserves.

The first concerns the relationship between VOLL and outage duration. The research concerning P-VOLLs indicates that customers are willing to spend more in total (though less per kWh) to avoid longer outage events (*i.e.,* events that span eight hours) compared to what they are willing to spend to avoid shortage outages events (*e.g.,* momentary outages). We expect that S-VOLLs will exhibit a similar pattern – but customers would probably not place any value on losing access to critical services during short lived outages. Instead, S-VOLLs would begin to be realized as the duration of outages increase – which is the reason underlying our choice of a 48 hour outage in the example above. Most studies concerning P-VOLLs cover outages ranging from momentary or very short durations through eight or perhaps as long as 24 hours. S-VOLLs, on the other hand, would probably not register among customers until outage duration exceeded 48 or more hours or more.

The second difference between P-VOLLs and S-VOLLs concerns who must be willing to pay to avoid an outage. P-VOLLs reflect the dollar value that an individual customer would be willing to pay to avoid experiencing a power outage. The S-VOLL estimated above, however, reflects the value that an entire community would need to pay to avoid losing access to critical services. Thus, S-VOLL of roughly $7 per unserved kWh can be spread over the entire scope of residential, commercial and industrial customers instead of being incurred by a single customer.

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15. Our analysis estimated the cost from acquiring mobile DG assets under the assumption that the electric utility would own these assets. However, that need not be the case. Mobile DG assets may instead be owned by municipalities or other public entities and financed with tax-exempt borrowing – which could be justified by the fact that more than just electric customers would benefit from the social services.
16. Sullivan, M., Mercurio, M., and Schellenberg, J. (2009), *Estimated Value of Service Reliability for Electric Utility Customers in the United States,* Lawrence Berkeley National Laboratory. See Table E-5: "Estimated Average Electric Customer Interruption Costs US 2008$ Anytime By Duration and Customer Type."
17. That is, $816,000 / 116,640 kWh (2700 kW x 48 hours x 90 percent load factor).

Our analysis suggests that implementing a mobile DG program has merit, in part because its costs would be widely shared. However, it's still an insurance policy with an annual payment of about $8 for each residential customer. Deciding whether to take out an insurance policy should be based on the likelihood of a sufficiently damaging event occurring. In a year where a severe weather event hits, the $8 payment would likely be considered to be money well spent (based on the VOLL indicated above).

Imagine the victims of Superstorm Sandy, wishing they could have spent $8 each last year to maintain access to gasoline and groceries. But what if there's no storm or outage?

To answer that question, assume that the risk of a severe storm that would result in a prolonged power outage is roughly one in 20 (*i.e.,* a 5 percent chance of such a storm per year – roughly what the MIT study mentioned above is the rough frequency of what were supposed to be one-in-a-hundred year events). Then, the $8 per year premium paid by each residential customer – year in and year out – translates into needing a willingness to pay about $160 (cumulatively over time), per expected event. This is more material, but to the authors, it also doesn't seem implausible, given that it could be paid in installments that are much more modest. Of course, the same math can be constructed for the high voltage generation insurance that customers already pay, and it would involve a much higher payment per rare event, again spread over many years of non-events. There, regulators have determined that it's an insurance policy worth paying for.

The decision concerning whether to pursue a mobile DG resiliency program inevitably will require a range of inputs, notably from local interest group as well as from customers and regulators, each of which will likely have a range of opinions concerning value and design of a mobile backup program. Empirical research concerning S-VOLLs might well help in resolving the ensuing policy debate.

Local Government Involvement

A mobile DG program could be cost-effective, but there are many important questions about how such a program would be sized and conducted, as well as who would decide those matters. The costs included in our stylized analysis are based on providing mobile DG support to only a portion of the critical services located within the utility's service area. Constraining the number of facilities that will be supported during a prolonged outage serves to contain the cost, but it also could require selecting some gas stations and schools while excluding others (though it's also possible that not all would be out of service in any given storm, so sometimes all could be served). Although this selection decision can be made rationally – for example, designing an algorithm to minimize travel distances among residences to critical facilities – the result might inevitably offend some constituents. Thus, planning a mobile DG program is bigger than a utility decision, and requires the involvement of municipal or regional planning agencies – or both – to make sure social and political factors as well as coordination with other relief initiatives are appropriately considered.

Equally important is the way that mobile assets are acquired, maintained, secured, and utilized. As insurance, mobile DG assets could have very low utilization – hopefully so, as they are utilized only during prolonged outages. Mobile DG assets can be leveraged through a sharing arrangement among utilities (or municipalities) similar to the mutual assistance agreements in place among electric utilities. There, a utility experiencing an outage calls upon the work crews and inventories from unaffected utilities. This has the effect of increasing the size of the workforce and spare parts on hand on an as-needed basis, which is far less expensive than each utility sizing staff and inventory for a worst-case scenario. Likewise, each utility (or municipality) can acquire and hold a reduced portfolio of mobile DG assets (relative to its stand-alone needs) and pool them together with others. In this way, each utility needs to hold fewer mobile DG assets but has the option to call upon other assets when needed. Making this work will involve developing standards and sharing procedures, similar to the way that the EEI developed the Mutual Assistance Network for transmission and distribution utilities.

Imagine victims of Superstorm Sandy – wishing they could've spent $8 last year to maintain access to gasoline and groceries.

A final implementation issue concerns cost recovery. Mobile DG assets provide insurance against the inconveniences and social hardships associated with prolonged outages in general. However, the specific locations of such outages are indeterminate; they could occur within pockets of a utility's service area or across its entirety. Thus, costs are incurred on behalf of all of the residents within a utility's service area, while benefits could be realized by some or possibly even none of those residents, depending on whether and where a prolonged outage is realized. That is, all residents are beneficiaries of the DG supply insurance but they might (or might not) all be in a position to need a pay-out from the policy if disaster strikes. The benefits also don't accrue in proportion to the amount of electric service that ratepayers in the area would normally consume, so there might well be a case for covering these resiliency reserves as taxpayer-funded assets that are simply managed and coordinated by the local utilities.

Are There Better Technologies?

There's no question that backup diesel generation represents a fairly low-end technology. Could we be missing some other, higher-end solution?

First of all, it's likely that utilities increasingly will experience more frequent extreme weather events than has been the case in the past. Second, it's unlikely that smart grid solutions will remedy all of the service disruption caused by breaks in electric distribution lines. Third, it's simply economically infeasible to harden utility assets such that they're made immune to severe ice, heavy snow, and wind. Our solution – using portable generators in a mobile DG program – could fill a gap in more sophisticated resiliency plans that rely on smart meters, system intelligence and broadband communications.

Analysis suggests that the cost of such a program is likely to be considerably less than the cost to ratepayers for maintaining generating reserve requirements (that is, the current high voltage generation insurance policy) that's already in place. Of perhaps greater importance is the likelihood that the need for critical-service low-voltage backup could arise more often than the need to call on high-voltage generating reserves. Nevertheless, the cost of initiating such a program will likely be substantial enough that regulatory commission consent would be required. Extrapolating from the analysis above, the cost of a mobile DG program for a utility serving 1 million customers could be as much as $20 million per year – though this probably could be lowered substantially if similar assets and costs could be shared among neighboring utilities.[18]

In short, while understanding relative costs provides important context, ultimately it's all about the value that such a program brings to customers. Granted, customer willingness to pay to maintain electric supply for certain commonly used social services is, as yet, an untested metric. All the same, our analysis suggests that outage costs (the value of lost load) need not be very high for benefits to exceed costs.

18. The actual cost would depend on many factors, including the population density of the service territory and the number of critical facilities serving the population. The above analysis was conducted for a city with a population of 100,000 included in 40,000 households, which is also the number of residential electric customers. One million residential customers are roughly 25 times the residential customers included in the illustrative analysis.