Are Smart Microgrids in Your Future? Exploring Challenges and Opportunities for State Public Utility Regulators

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Any inaccuracies, mistakes, or omissions are my responsibility. Comments, corrections, and recommendations for future work are welcome and can be submitted to:

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Executive Summary

Microgrids are poised to play a significant role in the smarter electric grid of the future. Technically, microgrids can serve to coordinate arrays of distribution-scale supply- and demand-side resources, including demand response, load management, electrical and thermal storage, and distributed generators. That coordination can be managed to reduce customer-service costs, increase utility system benefits, or some combination of the two. Microgrids might or might not be the most cost-effective means of producing these benefits, however. In general, microgrid benefit-to-cost ratios are improving as component costs decrease and their performance increases. But microgrid benefits can vary widely depending on their physical location in the utility-system macrogrid and the size and scope of microgrid operations. In some cases, because consumers value the benefits microgrids can provide, consumers are willing and able to pay all or nearly all of the associated costs. In that circumstance, utility-system benefits can be highly cost-effective, irrespective of the benefits and costs to the microgrid's consumers.

But even when and where microgrids can be fully cost-effective, there could be circumstances in which legal and regulatory obstacles, or even just uncertainty about legal and regulatory aspects, could prevent customers and developers from pursuing microgrid operations. This paper envisions possible business models that could be applied to microgrid operations, especially by regulated utility companies. It also begins to identify state policies and regulations that could be posing obstacles or barriers to microgrids. These are both preliminary, tentative efforts intended to promote dialogue among interested parties about changing policies that, inadvertently or not, could be preventing the development of cost-effective microgrids.

This paper relies on a review of literature and interviews with participants in several U.S. microgrid research and demonstration projects to develop a current and near-term future view. The introduction includes microgrid definitions and a brief discussion of near-term and future microgrid markets. From a policymaking standpoint, the salient defining characteristic is the ability of a microgrid to intentionally island, thus continuing service to internal loads, in the event of power problems or outages on the interconnected macrogrid. Microgrid markets are generally characterized by (a) facilities that have a special interest in high-reliability, high-power-quality electricity (such as military bases and data centers); (b) remote loads (such as industrial facilities and mines, village power systems, physical islands, and mobile military operations); and (c) campus environments with relatively large, diverse loads (such as university campuses, office parks, and medical centers). Microgrids are also frequently cited as a possible lower-cost means of bringing electricity and other energy services to the estimated 2 to 3 billion people that presently have very limited or no access to electricity.

Part II summarizes the many benefits researchers associate with microgrids, categorized as benefits for customers, the energy system as a whole, and society at large. Almost a dozen customer benefits are identified, including reliability for energy supply to critical loads, improved power quality, increased energy efficiency, reduced total costs for delivered energy services, improved economies of scale for distributed energy resources, and reduced price volatility. An even greater number of utility system benefits are identified, including enhanced integration of distributed and renewable energy sources and increasing fuel and technology diversity, allowing for low-risk demonstrations of the benefits from wider-scale smarter-grid

implementation, helping to create and maintain self-healing networks, enhancing energy security, reducing investment risk, attracting private investment, reducing transmission- and distribution-system losses, deferring and reducing the needs for future transmission and high-voltage distribution assets, reducing system peak loads, supplying cost-effective ancillary services to the bulk-power system, and improving bulk-power-system reliability. Societal benefits can include reducing emissions, land-use requirements, water consumption, and solid waste production; reducing price volatility and putting downward pressure on fuel prices; increasing economic development and supporting employment; and providing safe-haven facilities during macrogrid power outages.

Part III describes preliminary, conjectural ideas about business models that could be adopted by utilities, energy-service companies, or combinations of the two. An underlying premise for this analysis is that utility regulation plays an important role in all microgrids that are interconnected to a macrogrid and for stand-alone (not grid-connected) microgrids that serve multiple customers. The only unregulated alternative envisioned would be a microgrid providing stand-alone service for a single customer, which essentially describes a privately owned and operated energy system. In that circumstance, the operating assumption can be that the customer is fully responsible, subject only to regulation by the applicable safety, construction, and environmental-code officials.

Business models are described for providing five different kinds of microgrid functions. The five functions generally represent conditions that result in increasing regulatory challenges. These functions include:

1. Utilities accepting interconnections at a single point of common coupling, with switchgear to allow individual customer islanding;
2. Utilities offering intentional islanding as a premium service for specific customers, on a fee-for-service basis;
3. Microgrid services only for critical-needs customers;
4. Microgrid services only for specific grid locations; and
5. Microgrid services for any and all clusters of customers.

Implementing the first concept might require only minimal changes to interconnection rules and standards, to allow intentional islanding in compliance with the new IEEE standard 1547.4. But microgrids are like any option that tends to reduce electricity sales or utility capital investments. Therefore, important questions about regulatory and financial incentives could require, for example, attention to performance-based regulation and decoupling of profits from sales levels. The second, third, and fourth concepts represent various ideas for opening the option of microgrid service to limited groups of utility customers. All three of these concepts would trigger needs for decisions about rates for premium services—whether those rates would be market-based or regulated—and which microgrid services could be provided by utilities, competitive energy suppliers, or both.

The fifth concept envisions opening the option of microgrids to all utility customers. In this approach, points of common coupling (PCC) would be identified throughout a utility's service territory, and each PCC would serve as a gathering point for microgrid supply and demand components and become a node for intentional islanding. Ultimately, the existing distribution system would evolve into a network of microgrids, including nested microgrids.

The array of regulatory challenges identified in this review of possible business models includes:

- Using rates and tariffs to ensure close correspondence between microgrid costs and benefits and associated customer charges and payments;
- Conforming interconnection standards to IEEE 1547.4 intentional-islanding provisions;
- Considering decoupling to mitigate disincentives for reduced sales resulting from high-efficiency end uses, customer demand response, and on-site generation;
- Considering performance-based regulation to adjust utility profits based in part on reliability and power quality;
- Determining whether utilities can own and operate distributed generation and storage facilities, and, if so, whether those facilities can be installed on the customer side of a utility billing meter;
- Determining what products utilities can sell (e.g., electricity, thermal energy);
- Determining what products and services can be offered by utilities, by energy-service companies, or both;
- Determining who can offer demand-response and load-management options;
- Determining rates, terms, and conditions of service for regulated microgrid services;
- Determining customer eligibility for microgrid service, depending on critical needs or locations where microgrids can produce and deliver specific grid-support services;
- Defining what it means to be considered a “public utility” in a manner that allows microgrid services to be supported;
- Determining how and when distributed electricity or thermal energy can be delivered to neighboring customers, and whether regulated or market-based rates—wholesale or retail—will apply to those transactions;
- Making provisions for integrated resource planning to examine microgrids on a fair and consistent basis, as possible alternatives to other generation-, transmission-, and distribution-system enhancements;
- Making provisions for transmission-expansion plans to consider microgrids as a possible lower-cost means of producing non-transmission alternatives;
- Determining the scope of services a non-utility provider can offer to a customer or to multiple customers, without triggering regulation as a public utility;
- Determining how to separate premium from standard services, costs, and revenues, if a premium-service model is used;
- Determining the appropriate role of microgrids in a smarter-grid future, and defining the relationships, if any, between microgrids and smarter-grid implementation; and

- Determining the circumstances that allow private distribution wires to be constructed, and whether private wires can be used in conjunction with a public, regulated utility network.

Though this list is not exhaustive, it does demonstrate some of the many concerns that microgrids can raise.

Part IV presents policy options and recommendations intended to resolve issues, remove uncertainty, and reduce barriers to cost-effective microgrids. The recommendations call for an incremental, evolutionary approach to open up one or more opportunities for demonstration, experimental, or pilot-project microgrids, in order to explore remaining questions, test potential solutions, and develop experience to prove that microgrids can operate safely and reliably. There are four basic recommendations: (1) review and clarify existing policies and develop a roadmap for incremental, sequential policy changes to remove or reduce selected barriers or obstacles; (2) review rate structures for both full- and partial-requirements service to ensure that price signals reflect both distributed energy-resource and utility-system costs and benefits; (3) ensure that distributed-generation interconnection rules enable intentional islanding in compliance with IEEE 1547.4 Standard *Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*; and (4) open at least some opportunities for microgrids—as a premium service for specific customers, on a fee-for-service basis, for critical-needs customers, or for specific grid locations.

Part V offers a brief summary of the major ideas reviewed in this paper.

The Appendix includes brief summaries of some existing U.S. microgrid projects, developed from publicly available information and interviews with leaders involved with several of the projects. Four major observations were gleaned from the project surveys: (1) Few of the projects operate as full-fledged microgrids capable of intentional islanding; (2) technology choices and operations are changing in some of the projects, because of combinations of costs being higher than originally anticipated and some products not being available in the time frames necessary to satisfy grant requirements; (3) the projects have received much utility cooperation and support, such that regulatory and legal obstacles have not been significant issues; and (4) some of the utility cooperation could be motivated by local businesses affiliated with microgrid development and the potential for associated economic development in the utility's service territory.

Table of Contents

Table of Tables

I. Introduction

Smart microgrids are being touted as an efficient, economical means of improving or refining utility service to some electricity consumers. Early installations are proving that microgrids can meet the technical and engineering challenges involved, but based on current knowledge about microgrid costs and benefits there is still uncertainty about microgrids' economic viability.

Microgrid proponents note the following: (a) Several important distributed generation technologies have rapidly declining cost and increasing reliability and efficiency, and are poised to become fully economical; (b) microgrids in the right locations and at the right scales will produce tangible transmission and distribution-system benefits, sufficient to make those microgrids fully cost-effective; (c) smarter-grid investments in distribution-system communications and control systems will make incremental microgrid communications and control costs dwindle; and (d) some customers and energy-service companies are already willing to be early adopters and technology innovators—often because of the customers' needs for the highest reliability and power quality—and will pay practically all the costs of microgrid development, if only they can get utility cooperation and regulatory approvals to proceed.

On the other hand, some observers assert that microgrids might not prove cost-effective because (a) distributed generation presently costs more than central-station power plants when compared on the basis of lifecycle levelized cost of energy, (b) microgrids require substantial incremental investments for communications and controls, and (c) the practice of intentional islanding is not completely failsafe (Carley & Andrews, 2012, p. 108; Gomez & Morcos, 2009). Therefore, some observers conclude that, for the present time at least, microgrids are neither cost effective nor ready for anything more than limited research and demonstration projects. According to this point of view, regulators and policymakers would be well advised to delay microgrid development, at least until such time that distributed generation becomes fully cost-competitive and any remaining technical issues are fully resolved.

Another concern is that microgrid operations that include combustion-based distributed generation could result in localized negative effects, such as noise and air pollution in urban areas (Chicco & Mancarella, 2007, p. 546; Heath, Granvold, et al., 2006). Those issues, though, are most often addressed by siting and zoning officials and environmental regulators, not public utility regulatory commissions.

In any event, there is growing interest in microgrids, and the number of microgrid pilot and demonstration projects is growing worldwide. The major differences in perspective on the part of different customers, utilities, other stakeholders, and regulators are not likely to disappear in the near term; everyone involved has much to learn about the many changes that could result from the widespread deployment of microgrids. For the time being, however, this paper's recommendations are based on seven major observations:

(1) Many microgrids already exist at university, medical, military, and industrial complexes. In restructured markets, these microgrids can be market participants,

supplying valuable ancillary services such as demand response, voltage and VAR support, and day-ahead and real-time generation dispatch.

(2) *Some* microgrids in *some* locations can be fully economical today, even if the benefit–cost data necessary to prove it might not be readily, publicly available. In many cases, extensive efforts will be needed to gather the relevant information about utility system and societal benefits, in order to determine cost-effectiveness.

(3) Costs for many distributed generation technologies are continuing to fall while performance is continuing to improve, many traditional generating facilities and technologies face new environmental regulations that will increase their costs, and additional costs will be faced for reducing grid congestion in specific locations. Therefore, at some point in time and in many specific grid locations, microgrids are likely to be fully economical.

(4) Some customers, energy-service providers, and financial institutions are already willing to assume the risks associated with microgrids. This means some or even most microgrids can be developed with little or no ratepayer contribution to costs. Interested developers need only the opportunity to try.

(5) Policymakers are well advised to make advance preparations for the plausible eventuality of many fully cost-effective microgrids. In fact, some states are already doing this, exploring or beginning to develop policies to enable and support microgrids.

(6) Therefore, near-term efforts are warranted to thoroughly understand regulatory barriers and obstacles to microgrid development. In addition,

(7) Modest efforts are warranted now to continue microgrid research, development, and demonstration.

This paper explores some tentative possibilities for microgrid business models and begins to identify state policies that could be creating obstacles or barriers to microgrids. The goals are to focus attention on pre-existing policies that could inhibit microgrids—what Brown and Salter (2010, p. 3) call "legal and regulatory relics of an earlier era"—and to promote dialogue among interested parties about changing policies that, inadvertently or not, are preventing development and operation of cost-effective microgrids.

A. Defining microgrids

There is no universally accepted definition of a microgrid.[1] Carley and Andrews (2012, pp. 110-111, references omitted) explain:

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[1] See other microgrid (sometimes hyphenated as "micro-grid") definitions and descriptions from Asmus (2010, p. 73); Bialek (2012, p. 3); Basak (2012, p. 5546); Chaouachi, Kamel et al. (2012, p. 1);

> Microgrids are relatively small, low-voltage distribution networks…comprised of small power generators and other distributed systems, including micro-turbines, renewable energy systems, storage, batteries, and load control technologies. Microgrids range in size from large household or housing estate applications to municipal-level applications. Microgrids use load management control to provide power for small electric networks, such as industrial parks, isolated rural communities, or small municipal regions. In the most efficient applications, the combination of different generation sources provides not only electricity but also heating and cooling for local demand using cogeneration technologies. …
>
> Microgrids are designed to be self-controlled, semi-autonomous entities that are interconnected to the central grid via a controlled interface but can easily be isolated to serve as an islanded electricity system. … When it is cost-efficient to do so, microgrids remain hooked to the central electricity system, which enable them to draw additional power, if needed, and ancillary services from the central network, and to export excess power to the grid. Microgrids also are designed as "plug and play" systems, meaning that single distributed generation units can be interconnected at any interface along the grid.

A microgrid could incorporate many technologies, including low- or zero-emissions distributed generation and combined heat and power (CHP) systems, automated demand response and load management, and distributed energy storage. There are different views about how autonomous microgrids can or should be, and the extent to which microgrids will be managed by macrogrid operators (EPRI, 2011), as opposed to being self-managed or autonomous. In either case, researchers expect that microgrids will incorporate smarter-grid monitoring, sensing, communication, and controls and use those technologies to integrate the operations of many supply and demand management components (Asmus & Stimmel, 2012). Smart microgrids will (a) coordinate and manage supplies and demands within their boundaries, and (b) operate as an island, separated from the outside electricity macrogrid and powering internal loads using any combination of distributed generation and electricity storage. Microgrids will often, but not always, have at least some internal generation, often including at least some generation powered by renewable resources. Microgrids that are interconnected with a utility macrogrid are most likely to serve customers using combinations of macrogrid services, energy efficiency, automated demand response and load management, on-site distributed generation, and perhaps energy storage.

From a customer standpoint, microgrids could promise to deliver higher reliability, operating in intentional-island mode during at least short-duration macrogrid outages; and lower total costs for energy services, by most efficiently managing supplies and demands for thermal energy and electricity. From the macrogrid utility's standpoint, a microgrid can appear as a single macrogrid node (called a point of common coupling, or PCC), with its own aggregated supply-and-demand characteristics. As Marnay, Asano, et al. (2008, pp. 69-70) describe it,

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Chicco and Mancarella (2009, p. 543); Hyams et al. (2010, p. 2); Lasseter (2010, p. 1); and Lawrence Berkeley National Laboratory (2012).

> [T]he participants in a microgrid are not customers in the traditional sense; rather, they are a grouping of coordinated sources and sinks that are operating in unison, so they appear to the utility as a single entity, either a net source or net sink.

B. Describing near-term and future microgrid markets

Primary candidate facilities for microgrid operations include "campus environment/ institutional, stationary U.S. military bases, and a wide range of remote/off-grid applications (village power systems, weak grid islands, remote industrial mines, and mobile military bases)" (Asmus & Wheelock, 2012a, p. 104). Microgrids are also being developed to provide high-reliability service during macrogrid outages, especially for facilities providing emergency response and other critically important services (St. John, 2012c). Some researchers also predict that microgrids could spread rapidly as a lower-cost means of bringing electricity to areas not presently served by any macrogrid, or for particular locations within a macrogrid, especially remote areas, where establishing a microgrid can be less expensive compared to replacing existing, aging macrogrid infrastructure (Patterson, 2007, p. 91; Unger, 2012). Primary targets for microgrids operating independently from any area macrogrid include "village power systems, weak grid island systems, industrial remote mine systems, and mobile military microgrids" (Asmus & Wheelock, 2012b, p. 2). This market ultimately represents an estimated 2 to 3 billion people that presently have very limited or no access to electricity. In both cases, considering the developed and as yet under-developed world, there could be vast market opportunities for companies producing microgrid technologies and providing microgrid services.

Microgrids are becoming increasingly practical in both engineering and economic terms. Microgrids are supported by advancements in smarter-grid controls and communications, distributed generation, and energy-storage technologies. Davis (2000, 2002a, 2002b, 2002c, 2002d) concludes, based in part on low natural gas prices, that microgrids with distributed generation are already a least-cost means of providing electricity to most existing electric utility customers. Basic outlines of energy futures dominated by distributed energy resources are described in books by Patterson (1999, 2007) and Lovins and Rocky Mountain Institute (2002). Asmus and Davis (2011, p. 4) state, "[C]urrent trends toward a more distributed energy future appear to make microgrids an inevitable augmentation of today's centralized grid infrastructure."

Many industry participants and observers view microgrids as important tools that can help achieve local, state, and national objectives for providing environmentally clean, highly reliable, and secure energy at reasonable prices. Some customers who are single owners of large properties (e.g., college campuses, military bases, office- and industrial parks) are already engaged in microgrid development and deployment; experiments and demonstration projects are underway, to validate and exhibit microgrid operations. The U.S. Department of Energy (US DOE, 2011b) is supporting several related projects to test and develop microgrid technologies (see Appendix). The U.S. military, largely because of its interest in highly reliable, secure energy systems, has recently embarked on well-publicized efforts to establish microgrids at military bases and develop mobile microgrid technologies for battlefield capabilities (Asmus & Legel, 2011; Pellerin, 2011). And many campus environments are also serving as case studies for smart microgrids, including colleges and universities, hospitals and medical care facilities, and office and industrial parks (Asmus & Davis, 2011).

A growing number of customers are interested in the benefits microgrids can offer (Asmus & Legel, 2011; Asmus & Davis, 2011; SBI Energy, 2012). Cost-effective opportunities for deploying distributed energy resources (DER) arrayed in microgrids sometimes exist, in specific locations on the electric grid, with one of the results being high-reliability energy services at lower costs (compared to the traditional alternatives of central-station power plants using long-distance electricity transmission).

Technological developments and engineering concerns associated with microgrids are not addressed in this paper. Those issues are the subject of multitudes of recent publications, including catalogs of microgrid technologies (Asmus & Stimmel, 2012; Beebe & White, 2010); descriptions of communications and control systems (Balachandran, Bendtsen, et al., 2012; Basak, Saha, et al., 2009; Gustavsson, 2007; Lopez-Rodriguez & Hernandez-Tejera, 2011); implementation standards for interconnections (Basso & DeBlasio, 2012); reports of microgrid demonstrations, case studies, experiments, and pilot projects (Appendix; Basak & Sara, 2009); and simulations and theoretical investigations (Basak & Sara, 2009; Chaouachi, Kamel, et al., 2012; Etamadi, Davison, & Iravani, 2012; Fuchs, Hoffman, et al., 2012; Manfredi, Pagano, & Raimo, 2012; Pourmousavi & Nehrir, 2012).

C. The focus of this paper

This paper focuses narrowly on possible business models for microgrid operations and the related public-policy issues that will need to be addressed if microgrids are going to expand much beyond today’s experimental installations and pilot projects. Because microgrids might affect existing electric utility business models, DER in general and microgrids in particular could act as disruptive technologies (Paglia, 2011, pp. 107-109; Ryan, 2012). With the right attention, though, utilities could possibly reorient business models so that they could support and work in concert with operating microgrids.

This paper’s primary intent is to explore the major regulatory issues raised by microgrid deployment and begin to identify changes to existing regulations, rates, and tariffs that could be required to enable fully functional microgrid operations. At a minimum, this review could, as suggested by Laing, Schwaegerl, et al. (2011, p. 264), “raise academic, industrial, governmental, as well as public awareness to these impeding factors...” and thus encourage dialogue, to assist with removing at least any unnecessary and unintended barriers to microgrid deployment.

The research also explores appropriate roles for various parties in microgrid design, development, and operations, including regulated utility companies (primarily electric, but also to some extent gas, water and wastewater utilities), competitive energy services providers, and consumers. Carley and Andrews (2012, p. 110) explain:

> Microgrids can be owned and operated by traditional electric utilities or by independent power producers. Independent ownership may be established on a for-profit basis and held to basic rate regulations, or may alternatively serve in a not-for-profit capacity.

The paper explores microgrid facilities and operations developed and managed by (a) regulated utilities; (b) combinations of regulated utilities and competitive energy-service providers; and (3) competitive energy-service providers alone, operating with an absolute minimum of regulated-utility involvement. Electricity markets are the major focus for this work, but relevant details are also included about markets for producing and distributing thermal energy, both to individual consumers and through district energy systems (e.g., for space and water heating, space cooling, and industrial or commercial thermal process energy). The paper provides practical recommendations for state public utility regulators, identifying generic changes to rules and regulations that could be needed to enable cost-effective, reliable, and secure microgrid operations.

Utilities investing in smarter-grid technologies are among the initial enablers of microgrid functions and operations, and some of the promised smarter-grid consumer benefits could ultimately depend on the availability and implementation of microgrid functions. Thus, this subject is especially important for commissions that are evaluating utility smarter-grid deployment plans. As smarter-grid investments proceed, there are important questions to be asked and answered. For example: Will facilities installed now remain cost-effective as new technologies are introduced, and will they enable microgrid functions to be implemented at the lowest total system cost?

Brown and Salter (2010, pp. 30) delineate a set of “rights” for “consumer empowerment,” which they propose smart-grid deployment should deliver. The proposed rights include:

- to choose to have central dispatch of customer-premises equipment (e.g., appliance control) subject to agreed-upon protocols with appropriate pricing;
- to install equipment, either individually or collectively with other customers, to improve electric service quality (e.g., microgrids), as long as the installation has no adverse effects on the rest of the system;
- to have net metering and dynamic market pricing for distributed generation; … and,
- to choose and invest in the desired level of power quality.

Still, guiding a transition to a 21st-century electric utility industry infrastructure that includes multiple interconnected microgrids will not always be smooth, straightforward, or simple. One reason is that state public utility laws and regulations, some put into place more than half a century ago, could present obstacles to microgrid deployment under various utility and third-party business models (see Bronin, 2010; Brown & Salter, 2010).

This paper addresses the following important questions:

- How do existing market structures (especially vertically integrated monopolies and monopoly wires companies with competitive generation-services companies) affect microgrid deployment? Are policy changes to support microgrid deployment warranted? If yes, what microgrid policies make sense for each major type of electric utility market structure in the U.S.?

- In states that have restructured, what is the appropriate wires-company role in microgrid development? Should the wires company be a microgrid enabler, partner, developer, or owner? What policies could help ensure that wires companies will (a) not block (b) welcome, or (c) actively support microgrid development? What policies will best harmonize competitive service offerings with microgrid functions?

For regulatory policy, five major questions are:

(1) Which customers, if any, are eligible to participate in microgrids?

(2) Which energy-service providers and utilities are eligible to develop microgrids?

(3) Which entities are allowed to manage microgrid supplies and demands, and are there any prohibitions against autonomous microgrid management?

(4) When and how are distributed generators allowed to deliver power to customers in intentional island mode?

(5) Can service to an intentional island include more than a single customer?

In most circumstances, answers to these questions will determine whether microgrid service can be provided—to whom, by whom, and under what circumstances. The answers can restrict the possibilities for microgrid development. As some researchers have noted (e.g., Bronin, 2010, p. 566; Gordijn & Akkermans, 2007; Hyams et al., 2010, p. 31) uncertainty alone can obstruct or prevent microgrid development. Gordijn and Akkermans (2007, p. 1188) observe that the "commercial viability of new business models" requires both "regulatory certainty" and "a stable regulatory framework." Hyams et al. (2010, p. 23) caution, "In many cases, the mere threat of… litigation ... could stop a project." McGuireWoods (2011, p. 1) note the complexity of the presently existing regulatory and legal system, explaining that it sometimes "mandates a zigzag path to successful development," with added costs due to the resources and time needed to ascertain exactly what rules and regulations apply and then obtain all required approvals. Hyams et al. (2010, p. 1) explain:

> Microgrid systems… are rapidly overcoming technological barriers… [but] energy market regulations and policy lag behind… creating uncertainty and inhibiting investment… . We currently face a situation where, although the theoretical advantages of microgrids are well understood and the technological capabilities exist, barriers to their installation seem to be so widely presumed that few capable actors have begun to develop plans or strategies to test them, much less develop actual systems.

D. Research methods used and organization of the paper

The research was conducted by literature survey and structured telephone interviews. Interviews were conducted with key personnel representing developers and project managers who are working on about a dozen microgrid projects in the U.S. The projects include nine that are funded in part by the U.S. DOE, using ARRA grants. Other projects were identified through the literature review and by referrals from personal contacts. The interviews are summarized in Appendix.

Part II of this paper summarizes the many benefits researchers associate with microgrids, which variously accrue to microgrid customers, the energy system as a whole, and society at large. Part II also draws from the interviews and review of literature to make preliminary observations about the readiness of proven microgrid capabilities to produce the anticipated benefits. Reviewing the expected benefits supports the proposition that microgrid obstacles and barriers deserve policymaker attention.

Part III describes a set of plausible, preliminary business models for microgrids, which could be adopted by utilities, energy-service companies, or combinations of the two. This portion of the paper is conjectural, based on ideas gleaned from the review of literature.

Part IV provides a set of policy options and recommendations intended to resolve issues, remove uncertainty, and reduce barriers to cost-effective microgrids. The recommendations call for an incremental, evolutionary approach to open up one or more opportunities for at least demonstration, experimental, or pilot-project microgrids, in order to explore remaining questions, test potential solutions, and develop experience to prove that microgrids can operate safely and reliably.

Part V presents a brief summary of the major ideas reviewed in this paper.

II. Identifying the Benefits that Microgrids Could Provide

A. Introduction

Proponents attribute to microgrids many expected benefits for energy consumers, to energy systems, and to society as a whole. Those benefits are summarized in Table 1 for consumers, Table 2 for the electricity system, and Table 3 for society as a whole. A few important caveats are warranted, however, when reviewing these extensive lists.

One caution is that benefits attributed to microgrids result from the multiple DERs included in a microgrid. Thus, at least some of the same benefits can be obtained by implementing specific distributed resources, whether or not microgrid service is enabled. Prominent examples include at least some portion of demand response, load management, energy efficiency, and distributed generation. Hyams et al. (2010, p. 7) point out, "[M]icrogrids will provide benefits associated with the particular DER applications and energy distribution design and control schemes deployed."

Nevertheless, some researchers do hypothesize that the total positive results from combinations of distributed resources will increase, conceivably even maximize, when consumers and energy-service companies with proper financial incentives provide microgrid services (Boait, 2009, pp. 5-7; Brown & Salter, 2010, pp. 26-27; Carley & Andrews, 2012, p. 108; Considine & Cox, 2009; Marnay, Asano, et al., 2008; Marnay & Venkataramanan, 2006; Patterson, 2007, p. 81). These hypotheses are based on (a) the added attention consumers might pay to their energy uses and choices; (b) the sophisticated, automatic controls that microgrids could enable; and (c) viable business models for energy-service companies that presumably will bundle all available microgrid components (e.g., efficiency, load management, automated demand response, DG, and thermal and electric storage) to achieve the greatest economic rewards for consumers and the companies themselves.

A second and related caveat is that the expected benefits will depend on assumptions about the capabilities assumed for microgrids and microgrid consumers' energy-use behaviors, and the changes in those behaviors. For example, the benefits from aggregating multiple loads will depend on the sizes and numbers of participating customers, and some microgrid benefits will depend on consumer willingness to shift loads, purchase and install high-efficiency end-use equipment, and cooperate with actions determined by microgrid controls. This is one reason why the predominant markets for microgrids are in campus environments—military bases, universities, and the like—where a single property owner or operator controls these variables.

Another item of note is that the multiple benefits accrue to multiple beneficiaries. From an engineering and economic standpoint, it might be possible to show that a particular microgrid is fully economical, but if no single party can monetize enough of those benefits, it could be impossible to develop and operate the microgrid. Hyams et al. (2010, p. 7) explain:

> While many [microgrid] benefits flow directly to system owners or hosts—energy cost savings and improved reliability, for example—other benefits are more diffuse and frequently may not be captured by system owners (e.g., the value of reduced CO2 emissions or electric distribution system deferrals).

Also notice, as Hyams et al. (2010, p. 8) observe,

> These categories are fluid in the sense that certain benefits commonly spill over into multiple categories. For example, reduced line losses simultaneously deliver both economic and environmental benefits and reduced power interruptions can provide both economic (e.g., uninterrupted productivity) and security/safety benefits.

Also, a microgrid's projected benefits depend on its specific location, capabilities, and power capacity. The ability to defer and reduce needs for future transmission and high-voltage distribution assets is location specific, depending on a host of qualities of the existing electric grid. Also critically important for determining grid benefits is the size of microgrids, in terms of the total load served, total distributed generation and storage available, and compared to total distribution system capacity and loads in the particular grid location. In the simplest terms, if microgrids are not in locations where the grid faces needs for expansion or replacement, or if the quantity of power reliably displaced is small, then avoided costs for grid investments will not be realized. In addition, fulfilling a microgrid's potential to defer or avoid grid investments could require contractual or physical assurance that loads will not exceed established levels.

B. Consumer benefits

As shown in Table 1, some of the important consumer benefits involve increased reliability and improved power quality. Hyams et al. (2010, p. 5, footnotes omitted) explain:

> Unreliable and low quality power is expensive; it costs the U.S. an estimated $80-150 billion annually in lost productivity and damaged goods. Even momentary interruptions are costly for certain customers at more than $11,000 per event for medium and large commercial customers… . A majority of this cost is borne by commercial electricity customers, which nationally assume approximately 72% of the economic costs of interruptions.

Many times, cost comparisons between central-station power plants and distributed electricity options use levelized lifecycle cost-of-energy calculations (Banks, Carl, et al., 2011, pp. 21-26). However, even when modelers attempt to include the associated avoided transmission and distribution costs, the added value that certain customers place on increased reliability is seldom modeled; it is highly variable, depending on the specific customer and end uses involved (Sullivan & Schellenberg, 2010; US DOE, 2011a). A large majority of all reliability and power quality problems do occur in the distribution system, however (Chowdhury & Koval, 2009), and they can be more easily and less expensively addressed using microgrid technology (Hyams et al., 2010, p. 3; Zerriffi, Dowlatabadi, et al., 2002). Some researchers believe that it would be prohibitively expensive to achieve end-user needs for very high reliability and power quality, relying only on the existing electric-system infrastructure using central-station power plants and long-distance, high-voltage transmission (Carvallo & Cooper, 2011, pp. 11, 15-16; Patterson, 2007, p. 103).

Table 1: Consumer Benefits that Microgrids Might Provide

- Increases reliability and reduces the number and duration of outages
- Ensures highest-reliability energy supply to critical loads
- Provides improved power quality, controlled at the local level
- Increases energy efficiency, including applications of CHP
- Promotes and increases customer participation in energy efficiency, demand management and load leveling
- Lowers total costs for delivered energy services, including reduced purchases of fuel for on-site thermal energy demand and providing opportunities for operating flexibility depending on the variable prices of heating fuels and electricity
- Aggregates multiple loads to help optimize the use of DER and achieve improved economies of scale
- Promotes community energy self-reliance and allows for community decision making about energy supply
- Increases retail competition and consumer choice
- Reduces price volatility
- Facilitates and simplifies sales of excess electricity to the macrogrid

Sources: Banks, Carl, et al., 2011; Basak, Sahaet, et al., 2009; Bialek, 2012; Boiat, 2009; Carley & Andrews, 2012; Chicco & Mancarella, 2009; Hyams et al., 2010; Manfredi, Pagano, & Raimo, 2012; Pollitt, 2009; and Stanton, 2011.

Other potential consumer benefits also depend on how and when the consumer uses energy and on the end-use changes modelers presume during microgrid operations. Those prominently include the potential for energy-efficiency improvements, the ability to utilize CHP, the total load served and operational plans for distributed generation, and opportunities for demand response.

Special cautions are warranted when thinking about CHP. One important concern is whether electric utilities have or can easily obtain authority to invest in and earn a rate of return on CHP systems (Chittum & Sullivan, 2012). A second concern is the extent to which CHP provides utility system benefits. CHP is typically dispatched to meet the host facility’s thermal and electrical needs. That restricts operating flexibility, and the host’s needs might not coincide with utility-system needs. Detailed analysis is needed to determine CHP utility-system benefits for distribution, transmission, and generation. Another concern is that many, if not most, studies of the technical and economic potential for CHP installations assume ideal candidates, most prominently industrial facilities with large thermal loads. Such studies typically begin by sizing prospective CHP installations based on thermal load, and then model how best to use the electricity generated (see, e.g., Chittum & Sullivan, 2012). As witnessed by the relatively slow growth in industrial CHP installations in the U.S., however, there are many difficulties with industrial candidate sites. Often the ratio of industrial needs for thermal and electrical energy does not match the technical capabilities of CHP equipment, and anticipated revenues from off-site sales at wholesale prices are any combination of too uncertain or too low to support the financial case for CHP installation. In addition, industrial decision makers often hesitate to make capital investments that necessitate any disruption in production, or with expected simple-payback times any longer than just a few years (Abadie, Ortiz, et al., 2012; Blass, Corbett, et al., 2011; Brun and Gereffi, 2011). Thus, better opportunities could exist for CHP and even micro-CHP (Boait, 2009, pp. 11-13; Williams, 2012) in institutional, commercial, and residential facilities. Modeling for CHP technical and economic potential should explore options for providing both heating and cooling energy, and consider multiple options for system sizing to meet either a portion or all of thermal and electrical needs.

C. System benefits

Table 2 lists many benefits that microgrids could conceivably produce for the electric system as a whole. Again, though, many of these benefits derive from the DER included in microgrids and depend on the specific location and size of microgrids being considered, along with the assumed microgrid performance in reducing and limiting consumer demand. It is also important to realize that traditional utility planning studies have not always recognized and considered such localized system benefits (Lovins & Rocky Mountain Institute, 2002; Marnay, Asano, et al., 2008, p. 72).

It is also important to understand that these potential grid benefits will not always translate into increased utility revenues or earnings. Whether grid benefits directly or indirectly support utility profitability depends on the utility’s role (in providing generation, transmission, distribution, and customer services) and regulatory incentives. Integrated resource planning is the tool of choice for identifying future investment options, but it has seldom been applied at the granular, localized level necessary to evaluate microgrids. The Maine Public Utility Commission is presently investigating possible means for including localized resource planning for both the transmission and distribution systems (Stanton, 2012). California municipal utilities are establishing tariffs for distributed renewable energy generators (not more than 3MW) that are “strategically located and interconnected to the electrical transmission and distribution grid in a manner that optimizes the deliverability of electricity generated at the facility to load centers.” Under this law (California, 2012), a California local, publicly owned utility that purchases the output from qualifying generators shall ensure that its tariff “reflects the value of every kilowatt-hour of electricity generated on a time-of-delivery basis, and shall consider avoided costs for distribution and transmission system upgrades, whether the facility generates electricity in a manner that offsets peak demand on the distribution circuit, and all current and anticipated environmental and greenhouse gases reduction compliance costs.”

Some of the benefits included in Table 2 highlight the potential importance of microgrids in achieving goals attributed to the future smarter grid. Some researchers see this potential as a central role for microgrids (Hyams et al., 2010, pp. 6-7; Manfredi, Pagano, & Raimo, 2012, p. 1148). They expect that microgrids will greatly facilitate a utility’s ability to integrate distributed generation and variable-output renewable energy, and will act as initial proving grounds for demand-response, energy-efficiency, and load-management programming. From this point of view, it will be much easier for the utility to manage or monitor performance objectives at a few PCCs than to grapple with the alternative of managing many more individual devices and consumer choices at the level of each individual consumer meter, submeter, or appliance.

Table 2: Electricity System Benefits that Microgrids Might Provide

- Enhances integration of distributed and renewable energy sources, handling sensitive loads and the variability of renewables locally
- Provides an initial step toward full realization of the future smarter grid
- Serves as low-risk demonstrations of the benefits of a national smarter grid
- Creates and maintains self-healing networks
- Increases flexibility in construction and operation by providing multiple additional infrastructure options
- Increases fuel- and generating-technology diversity
- Enhances energy security
- Reduces investment risk and enhances flexibility of investments, producing option value for long-term-planning purposes
- Attracts private investment, helping to spur innovation in energy products and services
- Encourages third-party investment in the local grid and power supply
- Reduces system-transmission and distribution-system losses
- Defers and reduces needs for future transmission and high-voltage distribution assets
- Reduces system peak loads, promoting demand-side management and load leveling and providing congestion relief
- Increases customer price-response capability, helping to lower system peak prices
- Supplies cost-effective ancillary services to the bulk-power system
- Resolves voltage regulation or overload issues
- Improves bulk-power-system reliability by enabling multiple loads to be disconnected in response to challenging grid conditions

Sources: Banks, Carl, et al., 2011; Bialek, 2012; Carley & Andrews, 2012; Chicco & Mancarella, 2009; Hyams et al., 2010; Manfredi, Pagano, & Raimo, 2012; Nichols, Stevens, et al., 2006; Stanton, 2011; Thomas, Kroposki, et al., 2007; Zerriffi, Dowlatabadi, et al., 2002.

D. Societal benefits

Table 3 summarizes potential benefits that microgrids could provide for society as a whole. These represent mostly intangible and difficult-to-monetize benefits. As with several of the benefits already discussed, most of these depend on the locations and sizes of loads served by microgrids. For example, the ability to reduce land-use requirements depends on ample microgrid installations to displace a transmission or distribution corridor. Also, proponents foresee enough microgrid installations, associated with higher energy efficiency and more distributed zero- or low-emissions generation, to significantly reduce emissions. Some researchers postulate the need to reduce fossil-fuel emissions, rapidly and profoundly, as a response to concerns about global climate change (e.g., Driesen, 2009; Marchant, 2009, p. 832; Pollitt, 2009, p. 2), and others explicitly propose microgrids as a partial solution integral to addressing that eventuality (Carley & Andrews, 2012, pp. 98, 106; Williams et al., 2012).

Table 3: Societal Benefits that Microgrids Might Provide

- Reduces emissions of both criteria pollutants and greenhouse gases
- Reduces total land-use requirements for energy systems
- Reduces water consumption and solid-waste production
- Increases efficiency and consumer participation in electricity markets, leading to reduced price volatility and downward pressure on fuel prices
- Promotes community energy independence and allows for community involvement in electricity supply
- Increases economic development and supports employment
- Provides safe haven facilities during macrogrid power outages

Sources: Banks, Carl, et al., 2011; Bialek, 2012; Bronin, 2010; Carley & Andrews, 2012; Chicco & Mancarella, 2009; Driesen, 2009; Hyams et al., 2010; Marchant, 2009; Stanton, 2011; Williams, DeBenedictis, et al., 2012.

One of the societal benefits is the idea of using microgrids to serve safe-haven facilities. The Connecticut Public Utilities Regulatory Authority has initiated the process of responding to state legislation (Connecticut, 2012a), which defines microgrids and directs the state to "establish a microgrid grant and loan pilot program to support local distributed energy generation for critical facilities." The U.S. military has embarked on efforts to incorporate microgrids at bases around the country, to provide high-reliability energy services and protection against security threats (Asmus & Legel, 2011).

III. Envisioning Plausible Business Models for Microgrids

A. Introduction

Researchers and practitioners frequently identify the lack of viable business models that would motivate utilities to encourage microgrids as a primary factor impeding microgrid development. There is, however, a growing literature about business models for microgrids, including potential roles for regulated vertically integrated monopoly utilities and wires-only companies (e.g., Asmus, 2010; Bolton & Foxon, 2010; Geiger, 2012; Gordijn & Akkermans, 2007; Hyams et al., 2010; Krovvidi, 2010; Mancarella, 2012; Pollitt, 2009; Poudineh & Jamasb, 2012; Somlal, 2010).

In addition, many researchers are exploring and proposing business models for both regulated utilities and competitive energy-service companies to provide specific microgrid-service components, including distributed solar (Jung, Asgeirsson, et al., 2011; Unger, 2012); electric vehicles (Jung, Asgeirsson, et al., 2011; Whitefoot, 2012); electricity storage (Dehamna & Adamson, 2012; De Ridder, Hommelberg, & Peeters, 2009; Grünewald, Cockerill, et al., in press); remote, off-grid, stand-alone, and mini-grid installations (Krithika & Palit, 2011; Unger, 2012; Worldbank, 2008); and aggregating customers for demand response (Considine & Cox, 2009; Matusiak, Pamula, et al., 2011).

Asmus (2010, p. 77) examines business models for microgrids and describes three operating principles, explaining that microgrids will be designed to (1) provide high reliability for critically important loads; (2) "maximize economic opportunity by selling excess energy services to the larger grid;" or (3) "operate on the transmission side of the substation—aggregating, optimizing and then dispatching… ." In any of the business models presented here, the viability of the second and third principles depends on the combination of the microgrid's capabilities and the rates and tariffs that determine payments for providing macrogrid services.

Key questions about microgrid business models include:

- How might a utility company serve its shareholders' best interests by either encouraging or directly investing in microgrids?
- Which microgrid design, development, and operations roles can or should utility companies fulfill?
- Which roles can or should be fulfilled by competitive service providers?

Here, some salient features of plausible business models are explored, to see how microgrids might be deployed by utilities, energy-service companies, or combinations of the two. In this context, both vertically integrated monopoly and competitive industry structures are considered. These tentative ideas about business models begin by contemplating the simplest, most straightforward example of a regulated utility company providing microgrid services to a single customer at a single facility, with all microgrid services provided "inside the fence" and "behind the meter." From that starting point, multiple scenarios are explored, representing increasingly complex regulatory challenges, until reaching the most extreme case of microgrid services offered to multiple customers by multiple service providers, both regulated and unregulated, with services to multiple facilities, with microgrid equipment both inside and outside the fence and on both sides of the individual customer utility meters.

The preliminary concepts guiding this analysis are presented in Table 4. That table presents, in five rows, basic descriptions of microgrid functions representing increasing regulatory complexity. For each function, observations are presented of associated basic utility motivations and regulatory questions.

Although the logic does not always hold for every circumstance depicted in Table 4, the regulatory questions can generally be understood to be additive. That is, as the microgrid functions increase in complexity (progressing in Table 4 from each row to the next), all the regulatory questions presented in previous rows remain relevant, and the questions in the new row are added.

A preliminary premise for this analysis is that microgrid installations always include some role to be filled by a regulated utility company. Ample regulatory oversight is required to ensure the fulfillment of four essential principles: (1) All installed equipment shall meet or exceed all applicable minimum performance and safety standards, (2) all utility equipment shall be properly maintained, (3) customer benefits will be maximized, and (4) rates for providing microgrid services shall be just and reasonable. (In this context, the concept of a "regulated utility company" is used in the broadest sense of the term. The responsible regulatory agency could be a state regulatory authority, but it could also be a municipal board or commission, or a member-designated board in the case of a cooperative utility company.) Traditionally, an important distinction has been drawn between the minimum safety and performance standards for customer-installed equipment versus public utility equipment. Standards for privately owned equipment are the purview of public code authorities (for example, for construction, electrical, mechanical, and plumbing codes), fire safety officials, and the like, while standards for facilities serving the public fall under some form of public utility regulation. All of the situations described here presume some role for a regulated utility company that provides public utility equipment (e.g., wires, meters, and utility-network power-management equipment).

For any grid-connected microgrid, this means, at a minimum, that a regulated utility company will own and operate the distribution wires connecting individual customers to the grid, the billing meter (or at least a guaranteed right to access the billing meter to retrieve billing-determinants data), the point of common coupling between the microgrid and macrogrid, and switchgear capable of protecting the utility's system and macrogrid customers' equipment from electrical faults. In some cases, the utility specifies the type of protection equipment the microgrid operator shall install, but that equipment is not utility owned or operated. In all cases, regulators should consider whether and how to protect customers from neglect or abandonment of systems that provide essential energy services, which is usually represented by a utility's obligation to serve.

Table 4: Microgrid Functions, Utility Motivations, and Associated Regulatory Questions

Microgrid Functions	Utility Motivations	Regulatory Questions
1. Utilities accept interconnections at a single point of common coupling, with switchgear to allow individual customer islanding	• Ensure safe & reliable operations • Microgrid services are offered as smarter-grid investments for any individual customer who pays the entire cost as provided in approved interconnection standards and procedures	• Do interconnection standards conform with IEEE 1547.4 intentional islanding provisions? • Is decoupling needed to mitigate disincentives for reduced sales resulting from high-efficiency end-uses, customer demand response, and on-site generation? • Is performance-based regulation needed to adjust utility profits based on measures of reliability and power quality?
2. Utilities offer intentional islanding as a premium service for specific customers, on a fee-for-service basis	• A utility offers a bundle of services, including distributed generation (DG) and distributed storage (DS), with the ability to earn an authorized rate of return on the investments	• Can a utility own and operate DG and DS equipment? • What products can the utility sell (electricity, thermal energy)? • Who can offer demand-response and load-management options? • What will be the rates, terms, and conditions of service?
3. Microgrid services are only for critical-needs customers	• A utility offers service only to critical-needs customers (such as medical care, public safety, first responders, and emergency shelters)	• What will define the specific customers who are entitled to receive this service? • How will costs be allocated?
4. Microgrid services are only for specific grid locations	• A utility provides for distributed resources where they are a least-cost option for producing specific system benefits	• Will local IRP be used to justify distributed resource investments? • Will feebates help focus private investments on producing the most system benefits?
5. Microgrid services for any and all clusters of customers	• A utility provides high-quality service, engendering customer loyalty	• Will intentional islanding of grid segments become a de facto standard of service quality?

A regulatory role is also necessary for stand-alone (not grid-connected) microgrids that serve multiple end-use customers. Again, the operating principle is to ensure fulfillment of the three essential principles: (1) All installed equipment shall meet or exceed all applicable minimum performance and safety standards; (2) all utility equipment shall be properly maintained; and (3) rates for providing microgrid services shall be just and reasonable. The premise is that a microgrid serving multiple end-use customers is essentially a small public utility system, which needs to be regulated.

An unregulated alternative could be stand-alone service for a stand-alone industrial facility, like a mining operation or paper-making mill. In that circumstance, where there is essentially a privately owned and operated energy system, the operating assumption can be that the customer is fully responsible, subject to regulation by the applicable code officials. Even then, however, state laws typically determine exactly what it means to be a single utility customer and which energy services can be self-provided, will be unregulated, or will be regulated. States usually handle this determination with laws that explicitly define how many customers a distributed energy system can serve before triggering public utility regulation. The answer to this question varies by state—from as few as zero in five states, depending on the details of the financial transaction between developer and end-use customer (DSIRE, 2012d; see also Kollins, Speer, &Cory, 2010); to "more than one," depending on customer class in Michigan (MCL 460.10a(12)); to as many tenants as a landlord can serve on property owned by the landlord in Ohio (Ohio Power Co., 2012; Public Utilities Commission of Ohio, 1992; Supreme Court of Ohio, 2006); to "contiguous" users served by an on-site generation facility in New Jersey (New Jersey, 2010); and "multiple users" in New York (New York State Public Service Commission, 2007).

B. Business Model 1: The utility role is limited to managing interconnections

This business modeling assessment begins with the simplest case (summarized in Table 4, Row 1), in which a microgrid serves an individual, partial-requirements customer interconnected with the utility grid. This situation is essentially the same as the situation for any customer that has an interconnected distributed generator, a back-up generator, or an electricity storage facility such as an uninterruptible power supply (UPS). The essence of microgrid service in this circumstance is the capability of intentional islanding, with automatic and seamless switching between parallel and islanded operations. It is essentially only the automatic and seamless switching between grid-connected and islanded conditions that distinguishes this microgrid operation from the way that any customer might presently use an uninterruptible power supply or backup generator, with a switch to isolate the customer from the utility grid in the event of a macrogrid outage and a time delay while a backup generator is started.

As described in Table 4, Row 1, a utility's role could be restricted to oversight and approval of the grid interconnection, with the individual customers and their agents providing all of the microgrid functions and services. This path to microgrid development appears to be the most likely at the present time and in many jurisdictions, given so much uncertainty about the regulatory environment and any existing laws or rules that appear to block the other business models described in the rest of Table 4.

As Wesoff (2012) reports, though, some companies with microgrid-capable technologies design business plans to side-step the utility regulatory system altogether, delivering their products and services directly to end-use consumers, behind the meter. At present, most microgrid approaches involve single-customer, behind-the-meter, and net metering approaches, which trigger minimal if any needs for regulatory approvals. But, observers note:

- interconnection rules do not necessarily clarify a customer's right to operate generation in intentional island mode (Laing, Schwaegerl, et al., 2011, pp. 268-69);

- not all microgrid benefits accrue to end-use customers, so the full complement of utility and social benefits might not be achieved using this development model;

- net metering, under current practices, might result in cost-shifting from participating to non-participating customers for distribution and possibly also generation equipment;

- few individual customers possess adequate demand to benefit from economies of scale in distributed generation and ample load diversity and opportunities for demand response and load management, and some combination of these factors can be prerequisites for making microgrids fully economical (Zerriffi, Dowlatabadi, et al., 2002); and

- optimized distributed generation often produces excess electricity or thermal energy that will be wasted if it cannot be delivered to neighboring customers.

In this first business model, the customer's responsibility to the utility system would be determined by commission-approved interconnection standards and procedures and rates and tariffs for partial-requirements customers. Those customer responsibilities and associated costs are typically minimal for the smallest generators and increase in discrete steps as generator size increases (see Interstate Renewable Energy Council, 2009).

Pollitt (2009, p. 22) observes:

> If a world of micro-grids and energy-service companies (and actively managed distribution networks) is to emerge, it will have to do so in a way which challenges the current business model of distribution network operators. No doubt innovative [utilities] will be able to adapt to such a world, but all will have to face the threat of intensifying competition for the provision of network services and/or further unbundling and erosion of their natural monopoly.

Microgrids, like any technology or programming option that tends to reduce electricity sales or utility capital investments, raise important questions about regulatory and financial incentives. As Brown and Salter (2010, pp. 6-7) suggest,

> There are… powerful regulatory disincentives for utilities to invest in smart grid technology. … [T]raditional cost of service ratemaking discourages investments that result in reduced power sales… [and] incumbent utilities will generally not wish to open themselves up to competition that may threaten their business model or customer base.

Financial incentives and disincentives for incumbent utilities are long-standing regulatory concerns, but microgrid services—with the promise of maximizing customer end-use efficiency, demand response, and provision of distributed generation—can definitely bring them into focus. Brown and Salter (2010, p. 25) point out:

> [T]o the extent that [smarter-grid] technology is used to set up microgrids, utilities are likely to see competitive threats that they would strongly prefer to avert. Even where proposed microgrids are not meant to be competitive but rather to be merely supplemental to the utility to add an additional level [of] power quality, local utilities are still likely to see a competitive threat to be avoided, unless of course they retain full control. That could have the effect of limiting the full scope of smart grid benefits otherwise available to customers. … [I]f the utility's ratemaking incentives do not encourage more efficient use of energy and more effective load management, customers in monopoly environments are likely to see less of the demand-side and reliability enhancing benefits afforded by smart meters and control mechanisms. Thus, having utilities deploy smart grid without realigning their tariff incentives runs the very real risk of failing to capture many of the demand-side benefits of deploying the technology.

Szatow, Quezada, et al. (2012) liken DER to an "invasive species" that could significantly shake up the status quo for incumbent utilities. Szatow and Quezada caution that "perverse incentives" currently discourage generators, wires companies, and retailers from striving to maximize total energy services efficiency. Further, they note that policies and regulatory mechanisms intended to address this problem face major challenges because of "systemic inertia… if the scale of change required threatens viability of incumbent systems."

As Boait explains (2009, p. 6), "It would be preferable if business models for energy supply could flourish based on economic incentives… inherently aligned to policy goals… ." But it could be that some combination of performance-based regulation (PBR) and decoupling of utility revenues (and thereby profits) from sales levels will be necessary in order to create a viable business model that will be sufficient to overcome a utility's initial resistance to microgrids (see: Banks & Carl, 2011, pp. 47-48; Boonin, 2008; Joskow, 2011; Ter-Martirosyan & Kwoka, 2010; Thomas, Kroposki, et al., 2007, p. 5). Both decoupling, which removes a utility's disincentive toward sales and throughput reductions, and PBR, focusing on achieving specific power quality and reliability goals, could be required to provide ample incentives, combinations of carrots and sticks, to overcome inherent utility resistance. As Ter-Martirosyan and Kwoka (2010) report, empirical evidence from experience at U.S. electric distribution companies suggests that PBR should incorporate explicit service quality standards. In addition, utility cost recovery for smarter-grid investments could be tied, at some appropriate point in time, to some requirements for providing at least limited microgrid services.

Jurisdictions with integrated resource planning (IRP) requirements could explore opportunities for cost-effective microgrid development. But, even if explicit microgrid assessment requirements are incorporated into IRP procedures, it could still prove difficult to encourage a utility to accurately and thoroughly investigate microgrid options, if the utility is unfamiliar with microgrids or unmotivated to identify solutions that could result in lost sales or reduced capital expenditures. One possible approach for overcoming this obstacle could be to invite microgrid proponents and prospectors to produce and supply the location- and customer-specific options for IRP consideration, similar to the approach being discussed for pilot-testing in Maine (Stanton, 2012).

Utilities always face competition for customer attraction and retention. There is always the possibility of competition for new customers, whose location decisions might be influenced by utility service offerings. For example, Jones Lang LaSalle (2012) observes employment and economic gains in cities that are leaders in smarter-grid innovations. Some existing commercial or industrial customers, if they are less than fully satisfied with a particular utility's offerings, might move operations (or simply shift operations or production) from one utility service territory to another. The reverse is equally true: A firm might include positive utility service offerings as one criterion affecting its location decisions. This is termed "benchmark competition" (Kwoka, 2006), which means that customers compare utility services and prices but cannot literally switch service from one retail distribution company to another at a particular location. Instead, theory holds that benchmark competition among utility service territories serves as a competitive threat and thus helps to discipline monopoly utilities to keep rates and services in line with their competitors. For customers seeking the highest-reliability electricity service, a utility could offer microgrid service as a load-retention or load-building strategy. This could be a competitive advantage and a first-mover advantage for utilities. In particular, there could be opportunities for data processing firms and server farms to locate facilities where utilities offer the highest reliability service (see Glanz, 2012).

Another type of first-mover advantage can accrue to states and utilities that are home to distributed energy and smarter-grid component manufacturing companies. Already, some of the case studies reviewed for the Appendix and favorable distributed-resources policies in many states demonstrate some favoritism toward in-state businesses. The operative theory is that helping to develop internal markets (in-state or in-utility-service-territory) for the products and services that local businesses provide will help grow the economy and thus utility sales. However, proving such cause-and-effect relationships and measuring the results is a contentious and complex endeavor (Swenson, 2012; Wei, Patadia, & Kammen, 2010).

C. Business Model 2: Utility offers premium services, on a fee-for-service basis

Table 4, Row 2 describes an incremental step in microgrid business models, where the utility role expands to include providing customers with microgrid services, on a fee-for-service basis. This business model offers opportunities for utilities to make capital investments and earn a return on them. Marchant (2009, pp. 845-846) encourages policymakers to rely on consumer pull rather than technology push, and this business model does just that. As Pollitt (2009, p. 14) observes, microgrid service could help cultivate a new kind of direct "facilities-based competition in the supply of energy services, with…contestability in local markets… ." If a market for microgrids does start growing, an incumbent utility could decide to seek a role as a microgrid developer.

Gordijn and Akkermans (2007) use a micro-computer business-networking simulator called *BusMod* (e3value, 2007) to explore the effects on different business models of variations in: (a) distributed generation costs and performance, including the costs of actively managing distributed generation resources; (b) interconnection costs; (c) market rates for energy, power, and ancillary services; (d) customer time-of-use and demand shifting; and (e) regulatory and tax policies. These researchers find (2007, p. 1179) that workable business models will necessitate revenues "from the *complete bundle* of services offered: electricity supply, aggregation, scheduling and metering" [emphasis in original]. In particular, Gordijn and Akkermans (2007,

p. 1188) explore business opportunities for commercial greenhouse and gardening businesses, which they find to be good candidates for combined heat and power (CHP) applications. They conclude that “a well-designed bundle of services” can be profitably employed “in active management of distribution networks.”

Microgrid service could be offered to those customers that are willing to pay for it, in much the same way that utilities presently provide other equipment or services dedicated to serve an individual customer’s needs, such as capacitor banks for improving power factor problems or redundant feeds to improve reliability. As Hyams et al. (2010, p. 7) note:

> [M]icrogrids provide a way to deliver high quality and highly reliable energy services to end users that are willing to pay for it without “gold plating” the electricity grid by providing this level of service universally.

This business model will inevitably raise some questions about regulatory policy, as shown in Table 4. One threshold question is whether a utility may own and operate distributed generation and electricity storage equipment. In addition, the answer might depend on whether that equipment is located on the utility or customer side of the meter. In jurisdictions with competitive service providers, utilities might be barred from owning and operating generating facilities. A second question is raised if CHP equipment is included in a microgrid. Can an electric utility own and operate equipment that provides thermal energy, and if so, how will the rates, terms, and conditions of service be determined? Are the answers the same or different for providing steam, hot water, and chilled water, or for hot or chilled air? Put in a slightly different way, these same questions also need to be asked and answered for any non-utility provider of distributed generation, electricity storage, and CHP equipment: Can a non-utility provider offer these services to a customer or multiple customers? What kinds of service would trigger regulation as a public utility?

In addition, the full range of products and services that could be utilized in providing microgrid services would need to be evaluated, to determine which ones can be provided by regulated utilities, by competitive energy services providers, or both. Again, depending on market structure, regulated utilities might or might not be authorized to provide demand response, load management, energy efficiency, and other related services. The regulatory distinction between standard and premium services is critical. Premium services do not necessarily require benefit-cost justification, like standard services, but separating premium from standard costs and revenues could prove difficult.

If a utility were to offer customers microgrid services as a premium energy management service, then the commission would have to decide whether to allow market-based pricing or have the commission determine the associated rates, terms, and conditions of service. Either way, from a sales and marketing standpoint, prospective consumers would have to perceive the value associated with the bundle of services as being worth the price of premium services. A threshold question for regulators would be whether the unbundled services should be offered to all similarly situated customers, or if offering particular services only to microgrid customers can be justified. For a premium service where customers bear the costs, there is little justification for limiting customer eligibility. But cost-effective opportunities for microgrid deployment are not evenly distributed among all utility customers or in all portions of a utility grid, but appear first where certain circumstances prevail. Opportunities for cost-effective deployment, as discussed in Part II, depend on characteristics of both the local area electric grid and the customer or customers that could be served by a microgrid. The end results and total benefits could be diminished if customers participate without regard to locational, system benefits.

D. Business Model 3: Microgrids are only for critical-needs customers

This model is a modest variation of Models 1 and 2. With this approach, microgrid service might be restricted, at least for the time being, to designated customers with special, public-interest needs for high reliability power. Microgrid services could be considered for any and all facilities that are designated for homeland security purposes as critical infrastructure or critical energy infrastructure. This could include, for example, facilities used by first responders; hospitals, medical care, and assisted living facilities; transportation and communications systems; and facilities used by the public during times of emergencies. For example: Connecticut (2012a) has already begun to identify the kinds of critical facilities that might be afforded opportunities for microgrid development; the U.S. military is investing in microgrids for many of its bases and for portable, "battlefield" energy systems (Asmus and Wheelock, 2012a; Pellerin, 2011; Appendix); and, the Santa Rita Jail microgrid project (see Appendix) provides services to the jail facility and sheriff's offices.

The regulatory questions associated with this business model are the same as those listed for Models 1 and 2, but include two additional concerns. The first is how to define "critical needs" and how to determine the specific customers who are eligible to receive this type of service. Then, a different kind of cost allocation might be reasonable under these circumstances, because of the nature of services provided by this special group of customers. A commission could consider allocating some utility costs to all customers, based on the premise that all customers will benefit from the improved services afforded to critical-needs service providers. Alternatively, as in Model 1, customers could cover all of the costs, or non-utility sources of public funding could be used. That is the approach planned for the new Connecticut program, which uses state bond revenues (Connecticut, 2012b, §9(b)(2)).

Another example of special regulatory treatment could apply to utilities agreeing to work with the U.S. military to establish microgrids for military bases. The issue is whether a military base should be considered to be a single customer with multiple facilities on a single large land parcel, or if it is more appropriate to consider the base as a collection of multiple utility customers (some residential, some commercial, some qualifying for special critical-needs categories). A similar case can be made for many college and university campuses, many of which have self-generation facilities and the capability of operating as an intentional island in the event of macrogrid outages. At first glance, it does seem that many utility companies are willing to cooperate with military bases that want to establish microgrids, while the same utility companies might not readily offer microgrid service to any other community of similar size and with similarly diverse loads. Another plausible determinant of utility cooperation in microgrid development, however, could be the existence of any large loads served exclusively from a dedicated substation or high-voltage distribution transformer. It could be something of a historical accident that many military bases, and other substantial campuses under the control of sole ownership, are served from dedicated substations, which can make it much easier from an infrastructure and engineering standpoint to establish a single PCC and make it safe for intentional islanding service. From a regulatory standpoint, as it might apply to Models 1, 2, and 3, this ultimately raises the question of what defines a single utility customer, and whether single or multiple customers have the right to request or establish their own microgrid service.

E. Business Model 4: Microgrids are only for specific grid locations

This idea is also a modest variation of Models 1 and 2. The impetus for this approach would be to establish microgrids in those specific locations where they can be justified because they will produce utility-system benefits in excess of utility costs. This implies justification based on a localized IRP or, as contemplated in Maine (Stanton, 2012), a microgrid option designed as an alternative to a planned transmission or high-voltage distribution investment.

The basic concept in this approach would be to identify microgrid development zones and then restrict microgrid development to those zones, at least for the time being. This is an example of Marchant's recommendation (2009, pp. 851-853) to tailor policies to local conditions. Some researchers have recommended that brownfield sites serve as special distributed resource- development zones (Adelaja, Shaw, et al., 2010; Edwards, 2009). Some states are also establishing special energy-improvement districts; that concept could be amended to include provisions for microgrid service (e.g., Connecticut, 2007, §21 et seq.; New Mexico, 2009; Paglia, 2011). Another approach, recommended by Chittum and Sullivan (2012), would be to establish special zones around the areas where existing power plants are slated for closure.

For any ongoing program of this type, feebate systems are one possible approach. Feebates are a means of focusing prospector attention on delivering DER in specific grid locations (see Boonin, 2008; Tomain, 2009). With a feebate approach, the grid would be divided into regions, such as at the substation level; then a variable fee or rebate would be established for each region, based on the results of localized IRP. A rebate, probably per MW of capacity, would be offered to distributed resources for locating and operating in areas most in need of actions to relieve grid congestion or defer or avoid future investments. Similarly, fees would be charged to distributed resources locating and operating in areas not in need of capacity relief and not anticipating future distribution system investment. In order to make this kind of program revenue-neutral, ample fees need to be collected to cover the rebates.

Using any of these approaches could provide a means for allowing microgrid services to be extended to multiple utility customers, but only on a restricted basis. That idea of opening microgrid services to multiple utility customers as opposed to limiting microgrids only to single customers or campuses owned by a single entity is the subject of Business Model 5.

F. Business Model 5: Microgrid services are offered to any and all customers

This business model would open the possibility of microgrid service for any and all utility customers. Whether to allow microgrids that include multiple customers related only by grid location is perhaps the ultimate regulatory question in this context. That same issue of serving multiple unrelated customers could also be faced in Business Models 2, 3, and 4, but it is presented separately in Business Model 5 because it raises such important regulatory issues.

Realistically, most states' public utility laws, rules, and regulations make this approach difficult. Franchises for the use of local rights of way and restrictions on the use of existing utility infrastructure are two rather likely, primary obstacles. As reviewed for Virginia in the McGuireWoods survey (2011), states' energy-market rules and public utility regulations can present a gauntlet for microgrid developers.

This business model could be based primarily on regulated utility service. That implies microgrids as an integral aspect of smarter-grid functions, driven by benefit-cost analysis. Microgrids would likely help to increase many categories of smarter-grid benefits, notably those associated with enhanced service reliability, reductions in fossil fuel use and emissions, and producing option value for utility planning and investments. Microgrids also could be integral to the vision of the smarter grid as a self-healing network. With this business model in play, a distribution utility would gradually develop PCCs throughout its service territory, and each PCC would serve as a kind of gathering point for microgrid supply and demand management components and become a node for intentional islanding. This is an extension of Business Model 2, with the utility motivated by the opportunity to earn a return on investment plus the ability to cost-effectively meet or exceed existing performance standards. But in this model, the utility would be more proactive in planning for the distribution grid to operate in sections, in intentional island mode. Ultimately, the existing distribution system would evolve into a network of microgrids, including nested microgrids.

Alternatively, competitive energy-services providers could take the lead in microgrid development. They would market a bundle of products and services to customers and work with the distribution company to determine where one or more PCCs could function to isolate sections of the grid during any macrogrid disturbances. This approach would necessitate either a clear legal or regulatory path to aggregating customers for such service, or a willingness on the part of the distribution company to work with competitive suppliers to establish the appropriate PCCs.

Either approach potentially raises some important questions about customer choices and the sale of electricity from distributed generators to multiple end-use customers.

An important customer-choice question is whether and how customers would opt in or opt out from microgrid service in their area. Except for landlord-tenant circumstances, where a landlord would opt in and then tenants would receive microgrid services under a rental agreement, microgrid development models almost always are based on an opt-in model. Utility or competitive service rates will presumably reflect the cost savings achievable through a bundle of microgrid services, and customers opting in will obtain the benefits of cost savings based on their energy-use patterns. With this model, service during a macrogrid outage could be extended to non-participating customers, if those customers would be included for islanding within an area isolated by a PCC. Otherwise, non-participating customers would not have any material effect on this kind of microgrid, except to the extent they would dilute the ability of the microgrid to dampen demand or serve loads when islanding. Presumably, the rates for non-participant service would be the same during either islanded or grid-connected conditions.

The sale of electricity by a distributed generator to multiple customers is likely to be treated as a wholesale transaction for the generator and a retail transaction for end-use customers. Utility ownership of distributed generation, under commission rate-of-return regulation, has the same result: The utility produces electricity at wholesale and sells it to end-use consumers at retail, under regulated rates. Depending on market structure, the transactions would be through a utility or competitive energy provider. A handful of states have already established aggregated, community, neighborhood, or virtual net-metering programs that allow solar electricity generators to produce and deliver energy, with credits at the full retail rate for participating customers. Similar transactions could be contemplated by microgrid developers, but this approach would be a major departure from traditional ratemaking methods if each participating end user could avoid paying a regulated rate for their use of the distribution network.

A plausible workaround would be for distributed generation to be delivered to multiple customers on the customer side of the utility meter, using private wires. This is different from connecting a set of private wires to the grid at a single PCC and serving multiple connected loads solely through the private wires. Instead, with this approach, customers would receive utility service through the utility grid and separate private service through a duplicative, private wire. (See Banks, Carl, et al., 2011, pp. 51-52; Boait, 2009, pp. 2-3). This approach, however, would result in duplicating distribution infrastructure, could run counter to existing franchise provisions, and might be prohibited by terms and conditions of regulated utility service.

G. Summary

This conjectural review of possible business models demonstrates some of the ways that microgrid service could be more or less disruptive to the existing electric utility industry. The next section of this paper turns attention to options and recommendations for public utility commission action on microgrid policy, with the intent of guiding as smooth a transition as is practical for achieving the potential benefits of microgrids.

IV. Options and Recommendations for State Microgrid Policy

A. Introduction

Carley and Andrews (2012, p. 99) describe the U.S. electricity sector as a “regime” and project microgrids as a possible agent for regime change. As Carley and Andrews (2012, pp. 103-104) relate, however, the “continued inertia” of the present utility regulatory environment and industry structure is “not inevitable.” They explain, “Such regimes do evolve and even transform in response to changes both in market forces and in technological innovation, as well as other influences such as policy changes.” This part of the paper explores options for microgrid policy evolution, to provide options and recommendations for state commission action.

As revealed in the interviews conducted for this paper (in the Appendix), microgrids are in the early stages of commercialization. Before microgrids can become widely available, multiple parties need to work together to resolve many important technical, engineering, economic, financial, education and marketing, and policy concerns. Laing, Schwaegerl, et al. (2011, p. 265) call for continuing dialogue among the interested parties. They observe that current microgrid case studies are showing promising results but are not sufficient by themselves to prove the “universal business case.” Additional R&D is needed, they say, “to ensure microgrid technology is truly ready for market under all kinds of… conditions.” Because there are still so many unanswered questions about microgrids, a preamble to any supplemental policy actions is for commissions to support continuing research, development, and demonstration efforts, to learn more about microgrids and develop better understanding.

Some of the important concerns and problems identified through microgrid case studies and interviews (see Appendix) include establishing best practices for (a) consistent methodologies for determining and measuring microgrid benefits; (b) engaging customers; (c) cybersecurity methods and protocols; (d) interoperability standards; and (e) microgrid communications and control systems, including for autonomous operations. Some of the policy concerns identified include how best to (a) implement dynamic pricing; (b) refine interconnection policies; (c) adjust retail rate designs and refine rates for partial-requirements service; (d) establish policies for utility investments in DER; (e) develop retail-market participation rules; (f) provide utilities with appropriate regulatory incentives; (g) coordinate microgrid policies with other policies intended to promote DG, electric vehicles, and other distributed resources; and (h) achieve consistent regulatory policies across multiple utility service territories, including multi-state, regional, and conceivably national policies. Thus, it appears that what is needed are policies flexible enough to allow experiments, demonstrations, and pilot projects to continue and expand, and adjustable enough to accept changes, over time, as more is learned.

One tool needed to support microgrid prospecting is comprehensive modeling capabilities for quantifying microgrid costs and benefits (Koonin & Gopstein, 2011; Thomas, Kroposki, et al., 2007; Williams, DeBenedictis, et al., 2012, p. 53). Models are needed for both the utility system as a whole—for energy supply, demand, and utility economics—and microeconomic analysis for individual participating customers (Chicco & Mancarella, 2009, pp. 545-546; Hoffman & Russo, 2011, pp. 6-7; St. John, 2012a).

Distributed resources, customer-response options, and non-utility-owned equipment add much complexity to traditional utility distribution system modeling (Falaghi, Singh, et al., 2011). But computer simulation models with ample capabilities are being developed, especially with the idea of being able to analyze the detailed information from new smarter-grid infrastructure about the time and location of distributed energy use and production (e.g., Electrical Distribution Design, Inc., 2012; St. John, 2012a, 2012b). In addition, prospecting for primary microgrid locations can be greatly facilitated through the use of publicly available geographic information systems capable of exploring many relevant resources and existing infrastructure, at both large and small scale (e.g., EISPC, 2012). Frías, Gómez, et al. (2007) report an analysis for several European Union (EU) distribution companies of the effects on utility profits of large percentages of DG. For the eight rural and eight urban systems modeled, DG represents anywhere from about 10% to as much as about 90% of total generation, and the resulting changes in profits from the influx of DG range from +9% to -40%, with lost profits reported for 10 of the 16 utilities studied. As distributed resources play a larger role in utility systems, the impacts on utility revenues and earnings will vary substantially depending on the existing market design and tariff structure. Increasing importance will be associated with the ability to model utility costs and revenues based on different rate and tariff structures. The complex, detailed modeling required for distribution-system integrated-resource planning and utility profitability can best be addressed using a comprehensive, "mirror world" (Gelernter, 1991) simulation model. But smarter-grid AMI deployment will make available the detailed data about the time and location of energy use and production, to support the required, comprehensive assessments.

For individual microgrid microeconomics, Chicco and Mancarella (2009, pp. 544-545) review more than a dozen published reports about analytic tools for modeling the performance and economics of, and optimizing the complex assortments of, supply and demand resources that could be dispatched in a microgrid. Also, a public-domain microeconomic analysis computer model is readily available (LBNL, 2012), which includes the ability to explore effects due to changes in technology costs and operations, financing options, fuel prices, and utility rates.

Furthermore, the Perfect Power Institute (2012) is in the process of developing consensus-based criteria and metrics for evaluating microgrids on the basis of consumer engagement, operational efficiency, reliability, and environmental and energy efficiency.

Table 5 lists major microgrid components and functions and related regulatory and policy concerns, and Table 6 provides a brief summary list of policy options for state utility commission consideration. Those policy options are discussed in the following sections.

Table 5 is intended to assist state regulators with completing a thorough review of existing policies, along the lines of the Hyams et al. (2010) and McGuireWoods (2010) documents. Hyams et al. (2010) completed a thorough review for New York, and McGuireWoods (2010) performed a related review for Virginia. As the Hyams et al. and McGuireWoods policy reviews demonstrate, determining the laws, rules, and regulations that apply to microgrids is a fairly complex undertaking. The primary purposes for this review are to identify barriers and obstacles and clarify existing microgrid development options.

Table 5: Microgrid Components and Functions and Related Regulatory and Policy Issues and Concerns

Microgrid Components and Functions	**Ownership and Operations Options**	**Regulatory and Policy Issues and Concerns**
Distribution wires up to and at the point of common coupling	• Utility, except for off-grid, private utility systems which could be customer, landlord, or third-party owned.	• Interconnection standards and procedures • Under what circumstances will off-grid private systems be regulated as public utilities? • What is a private system's obligation to serve, if any?
Distribution wires (and pipes?) inside the microgrid	• Utility • Customer • Landlord or third-party	• Does the microgrid serve a single customer or campus owned by a single entity, or multiple customers on multiple land parcels? • Are any private wires allowed? • Does the installation of wires (or pipes) need any public right of way, franchise, or CPCN?
Individual meters or submeters inside the microgrid	• Utility • Customer • Landlord or third-party	• Do master-metering or sales-for-resale policies apply? • Do distributed generators or storage require separate meters?
Distributed generation & electricity storage	• Utility • Customer • Landlord or third-party	• What rates, wholesale and retail, apply to generation and storage for (a) self-service power; (b) net metering; and (c) some, mostly, or entirely wholesale delivery? • Are the rules and ownership options the same for electricity and thermal-energy distribution? • Are the thermal-energy-distribution rules the same for steam, hot and chilled water, and air? • Is multiple ownership allowed?
Microgrid controls & communications systems	• Utility • Customer • Landlord or third-party	• Who is authorized to own the switchgear at the PCC, and how are costs allocated between the microgrid customer(s) and utility? • What entities can offer load management and demand-response programming? • Who determines the operating protocols for the microgrid? • Under what circumstances, if any, shall microgrid controls be governed by the utility (or independent system operator)?

Source: Adapted from Hyams et al., 2010, pp. 22-67.

Table 6: Recommendations for State Microgrid Policies

(1) Review and clarify existing policies
(2) Review rate structures for both full- and partial-requirements service
(3) Open Business Model 1 through implementing interconnection rules that enable and ensure compliance with IEEE 1547.4 Standard *Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*
(4) Open any versions of Business Models 2, 3, and 4.

Thus far, there are few published, comprehensive reviews of these issues. Morgan and Zerriffi (2002) surveyed eight states, and subsequently King (2006a, 2006b) surveyed 27 states, to gather at least preliminary insights about microgrid policies. Brown and Salter (2010) surveyed 11 states to collect basic information about smarter-grid policies, but did not explicitly review regulations affecting microgrids.

As Table 5 suggests, state regulations affecting microgrid operations are likely to include (a) interconnection standards and procedures; (b) definitions of "public utilities"; (c) franchises or other rules governing the use of public rights of way; (d) CPCN requirements; (e) master-metering and sales-for-resale tariffs; (f) self-service power and net-metering rules; (g) PURPA or other wholesale-market sales rules; and (h) regulations governing thermal energy distribution.

The treatment of microgrids under one or more of these provisions is likely to depend on (a) the entity that is the service provider; (b) the specific services provided; and (c) the type(s) and number(s) of customers being served. Carley and Andrews (2012, p. 117) observe that existing regulations could be partly a matter of historical accident, resulting in unintended consequences for microgrids. But, they note, it is more likely that the existing regime was originally designed to ensure monopoly status and prevent the independent provision of electricity service to customers in the franchised territory already being served by a regulated utility. Marnay, Asano, et al. (2008) report that microgrids are likely to "encroach on multiple areas of existing regulation not conceived with [microgrids] in mind… ." Thus, in most states the status quo will include at least some "legal restrictions… requiring that all commerce in electricity occur only through the macrogrid rather than through independent or semi-independent community scale microgrids." Carley and Andrews (2012, p. 117) elaborate:

> There are legitimate concerns and difficult issues embedded in these barriers, including how reliability of service is to be assured, who is ultimately responsible for assuring it, and what are fair prices both for distributed generators to receive for off- or on-peak electricity generated and to pay for their share of the fixed costs of any grid in which they participate. But there are examples of a broader range of possible answers to these questions than have yet been widely discussed and evaluated by most state utility commissions or legislators, and these deserve fuller and more widespread consideration.

B. Recommendation 1: Review and clarify existing policies

This first recommendation for commission action is to direct a review of current rules and regulations and expose all parties to a broader range of possible options and expanded discussion and evaluation. Three major objectives for this activity can include: (1) clarifying policies and removing uncertainty about microgrid participation for customers, developers, and utilities; (2) understanding the relationships between microgrid policy and other policies intended to support DER; and (3) developing at least preliminary ideas for incremental, sequential policy changes to remove or reduce selected barriers and obstacles.

Clarifying policies and removing uncertainty will provide all interested parties with the best current understanding of options, if any, for microgrid development. Because most existing laws, rules, and regulations were enacted prior to the availability of microgrid technologies, it is not likely that any clear definition exists or that anyone fully understands how the possible business models are affected. It could be that opportunities exist for microgrids in specific situations, and knowing how those situations are defined will help prospectors know their options. Even if a review determines that no options presently exist for full microgrid service delivery, that is hardly different from the status quo, in which uncertainty is slowing progress, with companies consciously constraining microgrid service offerings to avoid interacting with utilities and potentially difficult regulations. Removing uncertainty is a prerequisite to the "long-term commercial viability of new business models" (Gordijn & Akkermans, 2007, p. 1188).

Establishing basic microgrid policy can be necessary but not sufficient for opening commercial opportunities. Understanding existing (and proposed) incentives, subsidies, and mandates is important, too. As Holt, Exeter, and Sustainable Energy Associates (2011, pp. 32-48) observe, even when some policies explicitly support DER, supplemental policies are usually required to help start markets for systems that have to overcome "unique hurdles." Other policies need to be reviewed to consider how they will mesh with microgrid policies, include interconnection standards and procedures, franchise and CPCN requirements, net metering, and clean-energy portfolio standards.[2] Utility rate structures should also be reviewed as part of this process, as discussed in Recommendation 2 below. In addition, many states and the federal government might already have non-regulatory, ancillary policies providing support for potential microgrid resources, including grants, loans, rebates, performance-based incentives, favorable tax policies (especially for real and personal property taxes), and tax incentives (Banks, Carl, et al., 2011, pp. 35-72). State and local siting, zoning, and permitting and environmental regulations can also have major impacts on the ability to develop some distributed resources and thus should be reviewed, too.

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[2] Some existing state portfolio standards provide extra credit for distributed generation, or explicitly require some portion of capacity to be produced using distributed generation. These states include Arizona, Colorado, New Mexico, New York, and Washington (Banks, Carl, et al., 2011, p. 46). As well, some state clean-energy portfolios include thermal energy produced from renewable resources and high-efficiency CHP. These include Arizona, Delaware, Massachusetts, Michigan, Ohio, New Hampshire, Washington, and Wisconsin, but specific rules for implementing these provisions remain to be developed in some states (DSIRE, 2011, 2012a, 2012c; King & Parks, 2012).

Once the inventory of current policies is thoroughly understood and the current atmosphere for microgrid development is clarified, the third objective could be addressed. That is to consider policy approaches that could be taken to remove or reduce selected barriers and obstacles. Of course, policymakers must decide if and when changes should be made. Having a roadmap for the relevant policy changes similar to the one that Hyams et al. (2010, pp. 101-107) produced for New York State could prove helpful to all interested parties, even if there is no immediate interest in making those changes. In addition, if implementing Recommendations 3 and 4 requires any policy changes, they can be described and considered sooner rather than later.

C. Recommendation 2: Review rate structures

Rate structures for both full- and partial-requirements service should be reviewed, to ensure that price signals reflect, as accurately as practical, DER utility-system costs and benefits.

Thomas, Kroposki, et al. (2007, p. 4) recommend

> …price signals that: reflect the costs and benefits to the system of DER; accurately reflect the time and geographic properties that affect costs; and account for the benefits (such as reliability, diversity, avoided generation, transmission and distribution costs) that are conferred to the [utility grid] by DER systems.

Thomas, Kroposki, et al. (2007, p. 4) also note the need for rates that reward demand-side management and "reduced rates for non-firm standby service," noting that several states already offer reduced standby charges for "DER customers that can provide physical assurance that the system will not exceed a specified load during peak periods."

Boait (2009, pp. 14-15) discusses preliminary concepts for "unbundling" electric distribution rates, so that distribution charges would most accurately reflect the loads that microgrid customers impose on, and services they use from, the distribution network. Some of the concepts include distribution charges differentiated by load and distance, by the peak load compared to average load on particular distribution circuits, and by nodal use charges that reflect distribution-system locational marginal prices (similar to locational marginal pricing, which already exists for some transmission tariffs).

Similarly, Frías, Gómez, et al. (2007, 2008) recommend four policy changes to realign regulatory practices with the goal of increasing the deployment of cost-effective distributed resources: (1) implementing incentive regulation based on price or revenue caps; (2) allowing distribution companies to earn incremental profits, resulting from efficiency gains (due to their efficient integration of distributed resources); (3) implementing differentiated system-use charges and payments based on service voltage level, time of use, and ancillary services provision; and (4) revising planning criteria to include the potential benefit of deferring or reducing network investments.

Some of these goals for ratemaking, however, represent major changes from the long-standing preference for average rates, not differentiated by location and with limited, if any, adjustments based on time-of-use. Therefore, commissions might prefer to approach such changes with experimental rates and then eventually with a series of incremental changes. If so, microgrid customers could be ideal subjects for voluntary experimental rates, to help demonstrate the value of differentiated rates for both consumers and the system as a whole.

D. Recommendation 3: Open Business Model 1

This recommendation would open the possibility of intentional islanding for individual customers. Hyams et al. (2010, p. 23) assert:

> Customers who install DG ought to have the right to operate that DG in island mode, as long as they can do it safely and without endangering the utility grid. To block it means preventing one of the potential benefits of DG service.

Adopting this recommendation simply means implementing interconnection rules that enable intentional islanding and ensure compliance with IEEE (2011) Standard 1547.4, *Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems.* Now that an international standard for intentional islanding systems exists, it should be possible to open a path for the approval of compliant systems.

E. Recommendation 4: Open some opportunities for Business Models 2, 3, or 4

The gist of this final recommendation is for commissions to enable one or more microgrid demonstrations, experimental installations, or pilot programs, based on any of the Business Models 2, 3, and 4.

As discussed at the beginning of this part of the report, there is still much to learn and prove about microgrids. Laing, Schwaegerl, et al. (2011, p. 207) highlight the serious challenges that remain. Joint efforts from multiple stakeholders will be necessary to resolve existing issues and concerns, they say, and to create an atmosphere where commercialization can readily occur. They call for “more challenging” microgrid experiments that will provide “a closer match of harsh reality” for robustly testing interconnections, all operating modes (that is, both importing and exporting energy when grid connected, and operating in intentional island mode), and protection schemes. They also identify the need to establish mechanisms to ensure that the economic benefits of microgrids will be equitably distributed among the participating developers, customers, energy suppliers, and distribution utilities.

Commissions can ensure progress toward the end game of a utility system that includes safe, reliable, and efficient microgrid service by opening one or more of these opportunities, at least on a limited basis.

V. Summary

As Grünewald, Cockerill, et al. (in press) observe, new technologies and services can result in pressure for regime change in current markets and institutions. Microgrid service represents this kind of potentially disruptive technology.

That there is growing interest in microgrids is indisputable. So is the fact that microgrid development raises issues that can be addressed only by state public utility commissions.

The current status of microgrids in the U.S. is that a small number of case studies are starting to provide preliminary proof that microgrids can provide many important benefits for customers, the electric grid, and society as a whole. Though many important benefits from microgrids are possible, those benefits are conditional, depending on the specific combinations of components included, the capabilities embodied in controls and management protocols, grid locations, and size in terms of electric capacity. In many ways, state public utility regulations will ultimately determine the details about whether, how, and where microgrids can be built, what customers they can serve, what services they can provide, and thus what benefits microgrids can produce.

At present, the policy arena for microgrids is uncertain in most jurisdictions; that uncertainty has a chilling effect on both companies interested in providing and customers interested in obtaining microgrid services. As a starting point for addressing microgrids, current policies will need to be reviewed and clarified. Once the current policy environment is clearly understood, then all interested parties can begin to identify possible future policy changes to enable one or more business models for microgrid development.

The three major policy approaches this paper recommends are that commissions (1) provide leadership for the process of reviewing and clarifying present rules and regulations; (2) review rate structures for full- and partial-requirements service customers to align them as much as practical with the costs and benefits of DER; and then (3) take modest, incremental steps to begin opening one or more opportunities for microgrids, at least for additional demonstrations, experiments, or pilot projects

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Appendix:
Informal Review of Microgrid Case Studies

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Appendix:
Informal Review of Microgrid Case Studies

U.S. microgrid projects were identified through a review of literature and by reference from the U.S. Department of Energy (DOE). U.S. DOE references included nine projects funded through the Department's Renewable and Distributed Systems Integration (RDSI) program and others funded through the American Recovery Act (ARRA) Smart Grid Infrastructure Grants (SGIG) program.[3] DOE held a peer review workshop in June 2012, which included reports from several of the identified projects.[4]

An informal telephone interview survey questionnaire was designed to gather basic information about each project. Table A-1 shows the telephone survey questionnaire content.

Table A-1: Contents of Telephone Survey Questionnaire

Basic Project Information	• Project name, location • Contact person(s) and contact information • Utilities serving project (electric and natural gas) • Utility regulatory agency for project • Basic market structure for electric utilities in this location (vertically integrated or competitive) • Project size (e.g., numbers and types/classes of electric and natural gas customers or meters served, average and peak demand in MW) • Resources in the project (e.g., numbers and types of DG, electricity storage, thermal storage, demand response, load management, other) • Intentional islanding capability (yes/no)? If yes, how long can the microgrid operate in island mode?
Policy Environment	• Are particular policies supporting microgrid development? • Are some policies making microgrid development more difficult? • Do you have recommendations for policy changes for the future?
Other (Open Ended)	• Is there anything else you would like to share with us that we have not yet discussed?

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[3] Basic information about RDSI and SGIG projects is available in the U.S. DOE *Smart Grid Research & Development Multi-Year Program Plan 2010-2014 – September 2011 Update* (pp. 6-7, 40-43) at http://www.doe.gov/sites/prod/files/SG_MYPP_final_2011-09262011.pdf. SGIG projects are listed at http://www.smartgrid.gov/recovery_act/project_information. SGIG projects are included in this survey only if they are explicitly described in the SGIG database as being microgrid projects.

[4] See http://events.energetics.com/SmartGridPeerReview2012/index.html. Presentations are indexed under "Agenda" on that web page.

Prior to telephone interviews, publicly available reports about the projects were scanned to gather relevant information. During the phone interviews, basic information was confirmed and specific clarifying questions were added, depending on information gleaned from the review of public documents. In one instance (Borrego Springs) no telephone interview was completed, so that summary is drawn only from the publicly available reports.

The projects included in this survey are briefly identified in Table A-2.

Table A-2: Microgrid Projects Included in This Survey

Project Name	Location	Referral Source
ATK Aerospace Systems	Magna, Utah	SGIG[1]
Borrego Springs	San Diego, California	SGIG
CERTS[2] Microgrids	Multiple Locations	Literature Search
Consolidated Edison Smart Grid Demonstration Project	New York City	SGIG
FortZED (Zero Energy District)	Fort Collins, Colorado	SGIG
Maui Smart Grid	Maui, Hawaii	RDSI,[3] SGIG
Mesa del Sol	Albuquerque, New Mexico	Personal Interview, Literature Search
NextEnergy Microgrid	Detroit, Michigan	Literature Search
Santa Rita Jail	Alameda County, California	SGIG
U.S. Department of Defense Projects	Multiple Locations	SGIG, DOD, Literature Search
Villa Trieste Homes	Las Vegas, Nevada	SGIG
West Virginia Super Circuit	Morgantown, West Virginia	RDSI, Literature Search

[1] SGIG means the U.S. Department of Energy Smart Grid Investment Grant program, funded under the American Recovery and Reinvestment Act (ARRA). See http://www.doe.gov/oe/technology-development/smart-grid/recovery-act-smart-grid-investment-grants.

[2] CERTS is the Consortium for Electric Reliability Technology Solutions. See http://certs.lbl.gov/.

[3] RDSI means the U.S. Department of Energy Renewable and Distributed Systems Integration Program. See http://www.doe.gov/articles/doe-selects-projects-50-million-federal-funding-modernize-nations-electricity-grid.

General Observations from the Project Surveys

Four major observations were gleaned from the project surveys, including: (1) few of the projects operate as full-fledged microgrids, capable of intentional islanding; (2) technology choices and operations are changing in some of the projects, because of combinations of costs being higher than originally anticipated and some products not being available in the time frames necessary to satisfy grant requirements; (3) the projects have received much utility cooperation and support, such that regulatory and legal obstacles have not been significant issues; and (4) some of the utility cooperation could be motivated by local businesses affiliated with microgrid development and the related potential for economic development in the utility's service territory.

The following pages include brief reports of each project surveyed.

- **ATK Aerospace Systems, Promontory, Utah**

Interview respondent	Roger Weir, Plant Engineer/Energy Manager ATK Aerospace Systems PO Box 98, M/S G2UT Magna, UT 84044 Phone: 801-251-2063 Email: roger.weir@atk.com
Utilities serving microgrid	Electric: PacifiCorp/Rocky Mountain Power Gas: Questar Gas
Regulatory agency	Public Utilities Commission of Utah
Electricity market structure	Vertically integrated monopoly utilities

ATK Aerospace systems is a manufacturing company that specializes in production for the military and NASA. ATK's Magna, Utah, manufacturing facility covers about 20,000 acres and includes between 500 and 600 buildings. Current employment at this site is around 1,500 people. This project is demonstrating the integration of renewable energy generation, energy storage, and automated demand response. The total cost of the project is estimated at $1.8 million, which is shared between the U.S. Department of Energy and the project participants.

Total load at the ATK facilities is about 15-20 MW, with over 75% load factor. Prior to this project, ATK already had a total of 10MW of on-site stand-by diesel generators with transfer switches, so that the factories could continue operating in the event of a macrogrid outage. Presently, ATK's facilities are interconnected so that there will never be any back-feeding of electricity into the utility grid. The technologies included in this project affect only a small portion of the facilities' total demand.

When the project is complete, it will include 100 kW of wind generation, 100 kW of waste heat generation, and 1,200 kWh of chemical-battery electrical storage. In the planning process, other electricity storage options have been considered, including compressed air, small pumped hydro, and flywheels. Those technologies are not part of the current plans, however. In some cases, decisions about which technologies to deploy were made because of challenges in meeting the timelines required by grant funding. At present, the waste-heat equipment is being fabricated and remains to be installed. The waste-heat generating equipment uses heat recovery from flue gas. The automated controls are expected to reduce the facility's electric demand by 3.4%. Battery storage will allow charging using low-cost energy and available power from the wind and waste-heat generators, and then dispatch during peak periods when the electricity has the highest value.

Mr. Weir believes that microgrid development can be important to ATK because of the company's interest in high-technology and new developments. ATK wants to reduce and better manage its peak electricity demands, because electricity demand charges are becoming a higher-cost element of ATK's total operations.

Mr. Weir reports challenges with the interconnection procedures. Current indications are that an interconnection agreement might not be required, though, because the system will never export energy onto the outside grid. The utility is currently reviewing ATK's protective relay configuration to determine if it is adequate.

Web links:

- http://events.energetics.com/SmartGridPeerReview2012/pdfs/24_Integrated_Automated_DG_Technologies_Demonstration.pdf
- http://www.sgiclearinghouse.org/ProjectList?q=node/1572&lb=1
- http://www.energy.utah.gov/government/docs/forum/march2010/ATK%20UEF%2003%2025%2010.pdf
- http://der.lbl.gov/sites/der.lbl.gov/files/weir.pdf

- **Borrego Springs, San Diego, California**

Interview respondent	No interview conducted
Other contact(s)	Vic Romero, Director of Asset Management and Smart Grid Projects Sempra Energy 8326 Century Park Ct San Diego, CA 92123 Thomas Bialek, PhD., P.E. Chief Engineer, Smart Grid Sempra Energy Phone: 858-654-8795 E-mail: tbialek@semprautilities.com
Utilities serving microgrid	San Diego Gas & Electric
Regulatory agency	California Public Utilities Commission
Electricity market structure	Restructured market with competitive generation service

Borrego Springs is a small San Diego County community located almost 90 miles northeast of San Diego. The Borrego Springs Microgrid is a three-year demonstration project, by San Diego Gas and Electric (SDG&E). SDG&E is steadily working toward a smarter-grid, and this project is part of its overall strategy. The microgrid is seen by SDG&E as a smarter-grid service delivery model and as a means of incorporating alternative energy generators (e.g., wind, solar, storage, etc.) and improving reliability. The utility believes the microgrid demonstration project will help SDG&E "address standards, integration, and interoperability challenges… ."

Borrego Springs was selected because it is a progressive community that already has many rooftop solar PV systems installed. It is also an isolated area fed by a single radial sub-transmission line, with the potential to become more energy self-sufficient and to have a more reliable energy supply through this project. In addition, the Borrego Springs community is served by the Borrego Springs Substation, which is integrated into the microgrid. The project is exploring microgrid islanding of a circuit, with the potential for the entire substation area. The project's goals also include reducing peak load on the macrogrid by 15%, using the microgrid to integrate distributed generation and energy storage, and improving substation area reliability. The project will demonstrate self-healing networks, by integrating feeder automation system technologies (FAST) into microgrid operations.

The Borrego Springs microgrid will grow to approximately four MW in size and integrate multiple DER technologies, energy storage, FAST, and outage management systems with advanced controls and communication systems. The following will be included: two 1.8 MW Caterpillar diesel generators owned by SDG&E; 31 units totaling about 700 kW of rooftop solar already deployed by customers; one 500 kW, 1,500 kWh battery at Borrego Substation; three 25 kW, 50 kWh community energy storage batteries; and six 4 kW, 8 kWh home energy storage units. There will be 125 residential customers with home area network (HAN) systems installed, participating in testing how pricing signals alter their usage.

Unlike some other microgrid case studies in which the local utility is primarily a technical partner, this project was spearheaded by SDG&E. The utility sought out and received RDSI funding of $7.5 million, awarded in 2010. The project also received $2.8 million from the California Energy Commission (CEC) as well as matching funds from SDG&E and partners. The CEC funding is part of its Public Interest Energy Research (PIER) Program which funds "energy-related research, development, and demonstration for research not adequately provided by competitive and regulated markets."

California has a suite of policies that are motivating utilities to develop innovations, such as microgrids. SDG&E has an overall plan to transition toward a smarter grid by 2020 with significant 2015 and 2020 milestones. This transition is motivated by public policies and consumer choice. SDG&E reports that its customers are "currently adopting technologies such as rooftop solar and electric vehicles at rates higher than anywhere else in the nation," and have "consistently shown support for more renewable generation projects, technologies and legislation" (SDG&E Smart Grid Deployment Plan).

While policies such as California's Renewable Portfolio Standards helped to spur on the Borrego Springs Microgrid, according to Thomas Bialek, the project also faces policy challenges involving: local permitting, developing standards for all equipment and communications protocols, cyber and physical security, and customer participation.

Web links:

- http://events.energetics.com/SmartGridPeerReview2012/pdfs/30_SDGE_Borrego_Springs_Microgrid.pdf
- www.sdge.com/smartgrid/
- http://www.sdge.com/sites/default/files/documents/smartgriddeploymentplan.pdf
- http://www.sdge.com/sites/default/files/documents/1138900767/SDGE_Annual_Report_Smart_Grid_Deployment.pdf?nid=3774
- http://energy.gov/sites/prod/files/EAC%20Presentation%20%20SGD%26E's%20Microgrid%20Activities%2010%202011%20Bialek.pdf
- http://www.recovery.gov/Transparency/RecipientReportedData/pages/RecipientProjectSummary508.aspx?AwardIdSur=119147
- http://www.energy.ca.gov/2012publications/CEC-500-2012-003/CEC-500-2012-003-CMD.pdf
- http://www.smartgridlibrary.com/2012/02/27/sdge-takes-on-microgrid-challenges/
- http://www.pikeresearch.com/blog/articles/california-microgrids-rescos-to-the-rescue
- http://www.sgiclearinghouse.org/node/1477
- http://www.sgiclearinghouse.org/node/1489

- **CERTS Microgrids, Multiple Locations**

Interview respondent	Robert H. Lasseter, Professor Emeritus Department of Electrical and Computer Engineering Power Systems Engineering Research Center (PSERC) University of Wisconsin – Madison 2559A Engineering Hall 1415 Engineering Drive Madison, WI 53706-1691 Tel: 608/262-0186 E-mail: lasseter@engr.wisc.edu

A CERTS microgrid is one that meets standards and operates using principles set by the Consortium for Electric Reliability Technology Solutions (see http://certs.lbl.gov/). That group has about 40 different sponsoring organizations, including the U.S. Department of Energy, NARUC, NASEO, state energy offices, utility companies, several electricity reliability councils, and more. CERTS microgrids are designed to meet all of the utility's needs for grid reliability and power quality at the PCC, not for each individual distributed energy resource. CERTS proponents believe it will be more cost-effective to cluster the distributed resources and have them operate so that there is only one interface with the utility, the PCC, which then has to meet all of the interface requirements needed to ensure safety and reliability for the utility system. The CERTS protocols favor localized sensors and controls that can work autonomously to adjust as needed to maintain power quality and reliability, without the need for a fast coordination controller between DER units.

There are multiple locations in the U.S. where CERTS microgrids are being tested. Some are projects at military bases, one is at Sacramento Municipal Utility District's headquarters building, another is at a pier in Manhattan, and the Santa Rita jail project applies the CERTS algorithms in its operations. Professor Lasseter's experience is in working with American Electric Power on a CERTS microgrid demonstration project in Ohio.

In this experience, microgrids can be instrumental in helping utilities to best manage the integration of variable output generation, such as wind and solar. Microgrids can coordinate the use of standby generation, storage, demand response, and load management to smooth out variations in distributed power flow, especially from solar PV. Microgrid resources can be coordinated and controlled, so that they help make the utility system more robust. Prof. Lasseter expresses confidence that having the IEEE standard for intentional islanding, 1547.4, will be very helpful in resolving any disputes about microgrid operations.

Prof. Lasseter recognizes the importance of policies to address the potential effects of utility lost revenues. He speculates that part of the answer might be to allow utility companies to own and operate DG and use microgrids to provide system resources, just like the transmission system is used. The hope would be to optimize resources and make the distribution system more reliable and efficient, and less costly.

Another policy concern Prof. Lasseter identifies is with ratemaking. He believes much value can be provided to customers if rates are changed to reflect the time and locational value of energy—both for energy used and for energy produced and delivered to the grid.

Web links:

- http://certs.lbl.gov
- The Development and Application of a Distribution Class LMP Index (M-25)
  http://www.pserc.wisc.edu/research/project_summaries/m25.aspx.
- Setting-less Protection Methods (T-49G)
  http://www.pserc.wisc.edu/research/project_summaries/T-49G.aspx

- **Consolidated Edison Smart Grid Demonstration Project, New York City.**

Interview respondent	Andre Wellington Consolidated Edison of New York 4 Irving Place -1875S New York, NY 10009 Phone: (212) 460-2227 Email: wellingtona@coned.com
Other contact(s)	Thomas George Project Manager National Energy Technology Laboratory 3610 Collins Ferry Road Morgantown, WV 26507-0880 Phone: (304)285-4825 Email: Tom.George@netl.doe.gov
Utilities serving microgrid	Consolidated Edison of New York
Regulatory agency	New York State Public Service Commission
Electricity market structure	Restructured market with competitive electricity suppliers

Partners in this estimated $92 million smart grid demonstration project include Consolidated Edison Company, U.S. DOE, and several sub-awardees. The centerpiece of this project is a “visualization platform” that will eventually integrate into one place all of the utility’s systems for measuring real-time feeder load and equipment load along with different demand-side management (DSM) resources. This is a mapping platform that shows operators the status of different grid resources, using different colors to depict different operating status conditions. It also has the ability to display different DSM resources and their real time curtailment status and performance.

The major purpose for this project is to develop and demonstrate technologies required for integrating customer-owned distributed generation resources and demand-response into the electrical distribution system operations. The utility is actively demonstrating the integration of customer data into this system, including interval metering data, demand-response technologies, solar PV systems, and other distributed generation resources. Some of the resources will be controllable by the utility and others will provide data that is useful for planning purposes. It will incorporate automated demand-response protocols for load-shedding and the control of customer-owned and operated distributed generation. The project is also being conducted in conjunction with an estimated $18.6 million interoperability project, which includes an automated demand-response application for targeted distributed resources and a thermal storage facility. The thermal storage plant will be used for rapid demand response and for peak shifting in response to electricity market prices. Twenty MW of distributed diesel generator resources on 24 customer sites are being aggregated.

In this project, there are presently no plans for intentional islanding operation; thus, it is not a microgrid project. Some of the participating customer sites are able to reduce their load significantly, but they will still take some power from the grid. The Consolidated Edison system is comprised largely of underground networks, where primary voltage distribution feeders serve a mesh network of secondary feeders. Redundancy is already designed into secondary distribution network, which is planned and designed to manage two simultaneous contingencies (n minus 2 redundancy). The expectation is that the redundancy reduces system outages and therefore decreases the need for intentional islanding.

A policy issue of concern to this project revolves around the future of demand-response pricing and programs. The utility's visualization platform system will eventually provide vast amounts of useful data for determining the location, potential effect and performance of demand response resources. Determining the economic value and true market potential of demand response will be a precursor to designing future demand response programs. The utility expects its system management platform will demonstrate capabilities for integrating different types and quantities of resources. Eventually, this could lead to more efficient geographically-targeted demand response curtailments, from specific groups of customers, to help solve specific grid contingencies. As more experience is gained through use of the visualization platform, and more research is conducted on the local market potential of emerging demand response technologies, the utility will have the ability to operate its distribution system more efficiently and might, in time, adjust its demand response program offerings.

Web links:

- http://www.coned.com/publicissues/smartgrid.asp
- http://events.energetics.com/SmartGridPeerReview2012/pdfs/26_Interoperability_of_Demand_Response_Resources_in_New_York.pdf
- http://www.coned.com/publicissues/PDF/ESLRP%20Assessment%20Documents%20December%202010%20Final.pdf

- **FortZED (Zero Energy District), Fort Collins, Colorado**

Interview respondents	Bill Becker, Director of Business Development Spirae Phone: 970-484-8259 ext.122 E-mail: bbecker@spirae.com Oliver Pacific, Spirae Phone: 970-484-8259 ext.115 E-mail: opacific@spirae.com
Other contact(s)	Dennis Sumner, Senior Electrical Engineer RDSI Project Manager City of Fort Collins Utilities Email: dsumner@fcgov.com
Utilities serving microgrid	Electric: Fort Collins Utilities Gas: Xcel Bulk electricity supplier: Platte River Power Authority
Regulatory agency	Public Utilities Commission of the State of Colorado Fort Collins Municipal Utilities Board
Electricity market structure	Vertically integrated monopoly utilities

The Fort Collins, Colorado, microgrid is one part of a larger project known as FortZED (Fort Collins Zero Energy District). FortZED is a public-private partnership that is attempting to create a net-zero-energy district in Fort Collins. A net-zero-energy district will generate enough thermal and electrical energy to meet its own needs, and would export any excess energy.

The project began with the FortZED Jumpstart Project, partially funded by the US DOE's RDSI program, which tested the microgrid and its associated distributed generation and concluded successfully in July 2012. This project was designed to provide the foundation for future phases of FortZED by advancing the expertise, technologies and infrastructure necessary to implement the zero-energy district. The project's objectives are to reduce peak load through demand response and through the integration of a significant amount of renewable energy. The microgrid integrates a large amount of distributed energy resources. It has already managed to reduce peak electricity demand in the FortZED district by 20%.

The budget for the project from Fiscal Year 2009 through 2012 was just over $11 million, with about $6.3 million inRDSI grant funding and the community partners contributing the additional $4.7 million. Lead agencies are the City of Fort Collins and Fort Collins Utilities. The project also includes: Colorado Clean Energy Cluster; Colorado Energy Office; Fort Collins Community Foundation; Fort Collins Downtown Development Authority; Fort Collins' UniverCity Connections District; and FortZED District. Spirae is the project technical lead, and technical partners include Advanced Energy Industries, Brendle Group, Eaton Corporation, and Woodward. Research and Development partners also include Colorado State University (CSU) Engineering Department and its InteGrid Lab (co-owned by CSU and Spirae).

Eventually, about 11% of Fort Collins Utilities' electricity customers will be in FortZED. Together their peak demand is about 46MW. For now, five partner sites are integrated into the RDSI microgrid: City of Fort Collins Operations; New Belgium Brewing Company; InteGrid Lab at Colorado State University's Engines & Energy Conversion Lab; Larimer County Facilities; and Colorado State University (CSU) Facilities Management. The microgrid is set up to integrate these facilities' distributed generation, thermal storage, and load-shedding capabilities, presently comprising nearly 5 MW. The project includes diesel, natural gas and biogas generators, steam turbine waste-heat generators, solar photovoltaics, and load shedding by thermal storage, by HVAC equipment, and for plug-in electric vehicles. At this time, there is no intentional islanding capability in this microgrid, but it could be added in the future.

The Fort Collins microgrid goes beyond many other microgrid demonstration projects, by involving multiple properties and owners. No policy barriers have been presented to this project, because it is a pilot and has the local utility as a partner. Fort Collins Utilities has four major goals that are served by the FortZed project: reducing energy bills; delaying investment in new generation; cleaning the air and reducing greenhouse gas emissions; and continuing to provide high reliability and competitive rates.

At the present time, Mr. Becker believes that finding a suitable business model is a much greater barrier than any technology issues, and business models are difficult to construct in the regulated world that is not particularly receptive toward innovative business strategies. He feels that pilot projects are doable, but to implement projects in more general contexts having a workable business model will be essential. Mr. Becker notes that the FortZed project, as a technology proof-of-concept effort, does not raise any specific regulatory issues. He expects a future characterized by trial and error in finding suitable business models, with some successes and some failures.

Web links:

- http://events.energetics.com/SmartGridPeerReview2012/pdfs/25_Demonstration_of_a_Coordinated_and_Integrated_System.pdf
- http://events.energetics.com/rdsi2008/pdfs/presentations/wednesday-part1/5%20Freeman.pdf
- http://www.spirae.com/images/uploads/general/RDSI_PR_mss_Sep6update.pdf

- **Maui Smart Grid, Maui, Hawaii**

Interview respondent	James "Jay" Griffin, PhD Hawaii Natural Energy Institute (HNEI) University of Hawaii at Manoa 1680 East-West Rd, Post 109 Honolulu, HI 96822 Phone: 808-956-0495 E-mail: griffin4@hawaii.edu
Utilities serving microgrid	Hawaiian Electrical Company (HECO) Maui Electric Company (MECO)
Regulatory agency	Hawaii Public Utilities Commission
Electricity market structure	Vertically integrated monopoly utilities

As the most oil-dependent state in the U.S., Hawaii relies on imported oil to generate most of its electricity, making the islands vulnerable to supply shortages and price fluctuations. Electricity costs nearly three times more in Hawaii than on the mainland, which motivates the state to seek ways to integrate more renewables into its energy supply. Maui is a good candidate for renewable generation with an abundance of sunshine as well as consistent winds and ocean currents. The combination of abundant renewable resources and high energy costs has led to significant growth in new wind and solar projects on Maui and shortly this island's grid will have one of the highest penetrations of wind and solar in the U.S.. Of the island's distributed generation, 99% is solar photovoltaic (PV), and its use is growing exponentially. Because Hawaii's electricity prices are tied to the price of oil, net-metered solar PV generation there is typically worth up to 35-40¢/kWh.

The rapid growth of intermittent renewable energy sources presents several challenges for operators managing Maui's grid and a key issue is maintaining enough spinning reserve to offset variability of renewable resources. The Maui Electric Company (MECO) traditionally has used its conventional generating units to maintain reserves but this generation is primarily fueled by diesel and costly to operate at today's oil prices. By using conventional generation for reserves, MECO is also sometimes required to curtail output from renewable energy sources. A key focus of the Maui Smart Grid Project is to assess how aggregating distributed energy resources, such as distributed energy storage and demand response, can help MECO address important transmission- and distribution-level issues on the grid. The project is funded by the U.S. Department of Energy (DOE) as part of the American Recovery and Reinvestment Act (ARRA) under the Renewable and Distributed Systems Integration (RDSI) program. It is being undertaken by MECO and the Hawaii Natural Energy Institute (HNEI) at the University of Hawaii. RDSI program funding was awarded to the project in late 2008. The total project cost amounts to about $14.4 million, with almost half provided by the DOE grant.

The Maui Smart Grid Project does not include a microgrid. Separate circuits at a particular substation are involved, but at the present time they are not capable of operating in intentional-island mode. The project is still relevant, however, because it is developing a deeper understanding of how best to manage distributed loads and generating sources.

The project involved upgrades to MECO's grid infrastructure as well as the installation of smart meters and a home area network to communicate with in-home displays and appliances in the homes of volunteer participants. The technologies can help volunteers manage their energy use and reduce energy consumption during peak periods. The home-based technologies portion of the project is located in the Maui Meadows neighborhood in South Maui. Customers who opted in were give a smart meter and access to a website with data on their energy usage, allowing them to better monitor and control their energy consumption. The project team will be finishing up installations and plans to have these systems installed and operating by the end of 2012.

The project's objectives are to: reduce distribution circuit loading and transmission congestion; help consumers better manage energy use; improve service quality; use more as-available renewable energy resources (wind and solar PV); and demonstrate flexible, expandable, distribution system architecture that is compatible with legacy systems.

The Hawaii Natural Energy Institute (HNEI) at the University of Hawaii at Manoa has been actively involved in two additional, related projects, which consist of:

- A $37 million project by the New Energy and Industrial Technology Development Organization (NEDO), a Japanese governmental organization with a mission to foster research and development of technology related to alternative energy, energy efficiency, and industrial production. U.S. and Japanese governments signed an agreement to cooperate on clean energy technologies research and development. This project will be testing Hitachi-supplied equipment on the island of Maui, with Hitachi as the lead entity running the project. The project is installing an island network of fast vehicle charging stations and expects to learn what ancillary services the vehicle charging systems can provide. One key service could be helping to manage variations in wind and solar power output. The demonstration project involves managing voltage and capacity issues at a neighborhood level.

- A project of the SEGIS (Solar Energy Grid Integration Systems) program involving advanced inverters integrated with the smarter grid. The key technology partners are Silver Spring Networks and Fronius. These companies are collaborating to address issues with distributed PV, EV charging, and large-scale integration with renewables. HNEI is also the lead organization on this project.

The Maui Smart Grid Project involves aggregating energy storage, controllable loads, DG, customer-feedback, and energy efficiency resources. The project incorporates a home area network (HAN), a distribution management system (DMS), a 1 MWh battery storage energy system. The total project is for a roughly 200 MW electricity grid system, which already includes approximately 72 MW of wind and over 15 MW of solar PV generation.

The Hawaiian Islands, like many islands around the world, are vulnerable to energy supply problems because they are not part of a national grid and their fossil-fuel supply lines are long. Because of the high costs of energy and dependence on imported oil, Hawaii's legislature established the Hawaii Clean Energy Initiative in 2008, in cooperation with the U.S. DOE. This plan calls for increasing renewable electricity generation from the current 10%, to 40% by 2030. In addition, it calls for energy efficiency and conservation to reduce total energy use by 30%. Hawaii's experiences in building resilient local energy systems could produce knowledge that can be applied in many populated islands and other remote locations around the world.

A significant number of smart grid and alternative energy projects being undertaken on Hawaii right now. For example, the grids in the separate islands of Lanai and Molokai are effectively microgrids. There is a lot of related work being undertaken on Hawaii, particularly on military bases. For example, there is a microgrid demonstration at the Wheeler Army Airfield on Oahu. There are also other facilities interested in developing microgrids, to be able to operate critical loads in island mode. Right now there is no standard process for intentional-islanding operations, but there is interest on the part of customers because it could increase the reliability and security of their power supply. There is also a great deal of interest in how to change rate structures so that there will be incentives for customers to provide ancillary services to the utility.

One potential obstacle is interconnection procedures, which still require significant time for applicants to obtain approvals.

Web links:

- www.mauismartgrid.com
- http://events.energetics.com/SmartGridPeerReview2012/pdfs/23_University_of_Hawaii_Renewable_and_Distributed_Systems.pdf
- http://www.hawaiicleanenergyinitiative.org/about/
- http://www.nedo.go.jp/english/introducing_profile.html
- http://www.sgiclearinghouse.org/node/1477

- **Mesa del Sol, Albuquerque, New Mexico**

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Utilities serving microgrid	Public Service New Mexico New Mexico Gas Company
Regulatory agency	New Mexico Public Regulatory Commission
Electricity market structure	Vertically integrated monopolies.

Mesa del Sol is a planned community on the outskirts of Albuquerque, New Mexico. It is a mixed-use development on a 20-square-mile parcel, and is being billed as an “ultra-sustainable” community. The Mesa del Sol installations include a high energy-efficiency standard for all buildings, redundant power supply and transmission systems, underground distribution system, advanced metering infrastructure, demand-response capabilities, automation and communication systems to isolate faults, and for the residential buildings solar-ready components, distributed generation and energy storage. The microgrid system features an 80-kW fuel cell operating alongside a 50-kW solar PV system, a 240-kW natural gas-powered generator, and a 160 kW/hr battery storage system. Project partners include Japan’s New Energy and Industrial Technology Development Organization (NEDO) which is investing a total of $22 million in the system, Public Service New Mexico’s Prosperity Energy Storage Project, Sandia National Laboratories, the University of New Mexico, and nine major Japanese companies.

Mesa del Sol is demonstrating cyber-security for commercial microgrid applications and a system using “all-sky monitoring” for estimating and predicting solar power output, to improve microgrid controls in a system that includes a large amount of solar photovoltaics.

Web links:

- http://events.energetics.com/SmartGridPeerReview2012/pdfs/3_Energy_Surety_Microgrids.pdf
- http://www.galvinpower.org/transforming-grid/perfect-power-systems/prototypes/perfect-power-mesa-del-sol/introduction
- http://www.galvinpower.org/transforming-grid/perfect-power-systems/prototypes/perfect-power-mesa-del-sol/report
- http://www.smartgrid.epri.com/doc/16_SG%20Post%20Workshop_Albuquerque%20uGrid_Shimz.pdf
- http://www.bizjournals.com/albuquerque/news/2012/05/17/mesa-del-sol-unveils-aperture-center.html?page=all

- **NextEnergy Microgrid Pavilion, Detroit, Michigan**

Interview respondent	Roland Kibler Director, Generation, Storage & Fuels Programs Office: 313-833-0100 ext. 104 Mobile: 734-474-9139 rolandk@nextenergy.org
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Utilities serving microgrid	Detroit Edison and Michigan Consolidated Gas, both DTE Energy Companies
Regulatory agency	Michigan Public Service Commission
Electricity market structure	Generation & distribution utilities, separated from transmission utilities, with up to 10% of each utility's peak load eligible for service from competitive suppliers.

NextEnergy is a non-profit entity initially funded by the State of Michigan. Its mission is "to accelerate energy security, economic competitiveness, and environmental responsibility through the growth of advanced-energy technologies, businesses, and industries." To fulfill that mission, the NextEnergy Center was established in Detroit, adjacent to Wayne State University in Detroit's "Tech Town" neighborhood. The NextEnergy Center includes NextEnergy offices, a conference and education center, and some business incubator space.

At the NextEnergy Center is the NextEnergy Microgrid Pavilion, which serves as a test facility for microgrid technologies, integrated with the Detroit Edison grid. The main features of this microgrid include programmable, bidirectional A/C and D/C power controllers. The fest facilities are designed to accommodate different technologies over time, as needs change. The systems are designed to emulate variations of power flow and disturbances on the grid, interfaces with distributed generation and facility loads, and controls for voltage and frequency. The system is designed so that the microgrid can vary from providing about 1MW of power to NextEnergy facilities all the way to having NextEnergy facilities exporting about 1MW back to the grid. The system is being used to test and verify renewable energy integration and optimization, and vehicle to grid (V2G) commercial applications.

The NextEnergy Center includes 30 kW of solar panels on the roof and a 380-volt direct-current (DC) power-distribution system in the building used mainly for lighting. At various times, the Microgrid Pavilion has been used for testing fuel cells, internal combustion generators, Sterling engines, and solar PV. Also, Detroit Edison has put a portable diesel generator at this location, which can provide power when dispatched by the utility.

Presently, the Pavilion is being outfitted with an electric vehicle charging station, which can provide bidirectional energy flow for level I and level II AC vehicle charging, with up to 19 kW of power flow in each direction. Through various programs over the last seven years, NextEnergy has developed the physical infrastructure and personnel to provide a broad range of testing and demonstration capabilities for the vehicle-to-grid (V2G) interface. Available on-site testing and validation equipment includes seven Level I AC chargers; ten Level II AC chargers; two Level I DC chargers; 19 total uni-directional charging stations; three total bi-directional charging stations; and two locations for inductive charging.

This microgrid has been installed and operated as a test facility, outside of Detroit Edison's normal policies. Thus, no regulatory barriers were encountered. NextEnergy recognizes Detroit Edison's interest could be heightened due to the economic development potential in the utility's service territory, especially related to electric vehicles, V2G, and battery manufacturing being developed in southeast Michigan.

Mr. Kibler reports that NextEnergy is interested in electricity storage policies, including tariffs that can work for facilities at the scale of 1MW or smaller.

Web links:

- http://nextenergy.org/facilities/testing-a-validation-platforms
- http://www.nextenergy.org/newsandevents/todayatnextenergy
- http://www.nextenergy.org/newsandevents/news-a-events
- http://www.prnewswire.com/news-releases/dte-energy-technologies-signs-contract-to-develop-microgrid-at-nextenergy-site-73101317.html
- http://css.snre.umich.edu/project/technology-assessment-and-evaluation-nextenergy-zone-microgrid-system
- http://www.elp.com/index/display/article-display/336307/articles/electric-light-power/volume-86/issue-4/sections/renewables/fuel-cell-microgrids-in-the-real-world.html

- **Santa Rita Jail Project, Alameda County, California**

Interview respondent	Matt Muniz Energy Program Manager General Services Agency Alameda County Phone: 510-208-9518 E-mail: matt.muniz@acgov.org
Utilities serving microgrid	Pacific Gas & Electric
Regulatory agency	California Public Utilities Commission
Electricity market structure	Competitive generation service.

The Santa Rita Jail microgrid is owned and operated by Alameda County, powering its extensive jail campus. The jail is the County's largest facility, occupying one million square feet and consisting of 18 housing units with capacity for 4,000 inmates. The facility has a full kitchen serving 12,000 meals a day and a laundry processing about 3,000 pounds of laundry a day. It also has an infirmary and Sheriff's Department offices. Despite the sizable scale of the jail campus, the microgrid serves only a single energy customer on a single property, which is often the case with microgrid demonstration projects. Thus, the added complexities of serving multiple energy users and crossing property boundaries are not present in this case study.

The facility's heating and cooling capacity comes from a central plant with natural-gas-fired hot-water boilers and electricity-driven chillers. This gas is delivered by PG&E but purchased as a commodity through the Department of General Services, as part of the State of California Natural Gas Buying Program. The electricity the jail receives from PG&E's distribution grid is delivered to the campus via a single point of common (PCC) coupling and then distributed to the jail's seven substations. The jail receives electricity at 21kV, which is then stepped down to 12 kV and distributed. The facility is treated as an industrial customer by PG&E, receiving electricity at one of PG&E's lowest-price tariffs.

A jail cannot do without electricity, so a microgrid demonstration project makes sense in such a critical setting. Before the microgrid, the jail would go dark for up to 8 to 10 seconds during a power outage while emergency backup generators were started. Now, it should be able to seamlessly island from the grid without a single flicker of the lights. Prior to the microgrid, during a power outage, the jail relied on its back-up generators for power, so reliability was definitely a motivator of this project. The county's primary motivator for installing the microgrid, however, was a desire to save on its operating costs.

The microgrid project was initiated by Chevron Energy Solutions four years ago in response to a DOE research grant. Chevron asked the county to partner on the application for up to $7 million. The county had an existing relationship with Chevron Energy Services who had already built the jail facility's fuel cell generators. The resulting microgrid system has been operational since March 2012. Because of technical start-up challenges, it has been functioning for only a few months.

The total project cost was $11.7 million with battery storage being the biggest cost. The county did not want to risk any of its own funds on this project because nobody had done a microgrid at this scale before and there was new, unproven technology in play. The DOE Grant provided $6.5 million, and the county came up with matching funds, including a $2.5 million Renewable Energy Secured Communities grant from the California Energy Commission (CEC), a $2 million self-generation incentive program for advanced energy storage from PG&E, and about $300,000 from Chevron Energy Services for five 2.3 kW micro wind turbines.

It is still unclear how much savings the county will gain each year as a result of this project. Right now, the county estimates a savings of about $100,000 per year from a combination of the new system and its ability to reduce its peak electrical demand and engage in demand response. The county will be operating its microgrid with the objectives of reducing peak demand during summer and limiting maximum demand throughout the year.

Santa Rita Jail's system is a CERTS microgrid, with battery storage and islanding capability. It includes a grid-disturbance static disconnect switch at the PCC. The system has not yet had to island in a true emergency, but tests have been successful. The microgrid uses onsite distributed generation from its solar power systems, fuel cell, and wind turbines and imports any additional energy needed from PG&E. The system can provide demand response in response to a utility request.

The microgrid has battery energy storage that can be charged affordably during off-peak hours and then utilized to reduce demand during expensive on-peak hours. In an outage, the microgrid will automatically switch to island mode. The batteries will be discharged to provide electricity for the jail's loads. Once the batteries are completely discharged, the backup generators would be run at full capacity to run the jail and recharge the batteries.

Before the microgrid project, the county had already installed distributed generation capacity, beginning in 1994, and completed several energy efficiency projects. These included a lighting retrofit, HVAC central-plant efficiency improvements, installing a 1.2 MW rooftop PV system, and a 1 MW molten-carbonate fuel cell cogeneration plant. The microgrid was developed to integrate all these generators and give them the ability to island. Additional distributed generation and storage were added as part of the microgrid project. This was partially due to a California grant requirement for the project to include three renewable energy sources. Newly added DG and storage includes five 2.3 kW wind turbines, 4 MWh of battery storage, and 275 kW of tracking solar PV systems. A concentrating solar thermal system to provide hot water is expected to be operational by the end of 2012.

Over time, with the combination of efficiency and distributed generation, the jail has reduced significantly the electricity it needs to obtain from the grid. Energy usage is reduced by 60% compared to the early 1990s. For instance, in 1992 the facility had a peak demand of 3.4 MW of macrogrid energy during peak times (generally noon to 6 pm), but it currently uses only about 500-600 kW on peak. Right now, the fuel cell generates about 50% of the power needs, solar generates about 15%, and the rest is supplied by PG&E.

The new batteries will reduce the jail's peak usage even further. Right now, the batteries are charged with inexpensive power from the macrogrid in the middle of the night and then that power can be utilized during peak times. As the facility's on-site renewable-energy generation capacity is increased, surplus energy can help keep the batteries charged without relying on the macrogrid as much. At certain times of the year during peak hours, when solar is at its greatest output, the facility can generate 100% of its load by a combination of solar and fuel cells without even relying on the batteries. That tends to occur in May and October when solar is generating well, yet weather is relatively cool and thus there are no chiller loads.

Once the solar thermal project is working, the jail will be able to generate about 40% of its domestic hot water need, displacing about 45,000 therms of natural gas per year.

Before the microgrid, PG&E would not allow the Santa Rita Jail facility to export into the macrogrid. They had a reverse-power relay at the PCC, which could trip the fuel-cell generators and result in outages for the whole jail. Now that the microgrid is operational, they have been able to remove the reverse-power relay. The county is not considered a market participant yet, so any energy exports are being delivered to the utility for free, at this point.

The County's Energy Program Manager, Matt Muniz, did not experience any significant regulatory hurdles or barriers to this project. Because this is a single property and single owner, and with the electric utility cooperating with the project, the relative ease of implementing this project might not be entirely comparable to other microgrid projects that may arise in California in the future. Still, it is a relevant proof of concept for microgrid technologies, interconnection, and operations.

The local electric utility, Pacific Gas and Electric, has been a willing partner to this project from the beginning. PG&E and the Jail have an interconnection agreement for the microgrid and its associated distributed generation. According to Mr. Muniz, one of the main benefits to PG&E from this project is increased battery storage on its network; having a distributed network of battery storage will make the grid more stable. In the event of an outage, there is more stored energy capacity within the service district, which takes some pressure off the utility during a crisis. PG&E also benefits from seeing more battery technology vetted, contributing to a general improvement in battery storage technology over time.

Another potential benefit to the utility is the reduction of summer peak demand on the grid. Santa Rita Jail's microgrid is one less load for PG&E to contend with during peak hours, when the utility has to spin up its most expensive generators to satisfy demand that can spike high enough to produce brownouts. On the flip side, Mr. Muniz also sees this as an opportunity for Pacific Gas and Electric to sell more low-cost, middle-of-night energy service, as the Jail will be purchasing power off-peak to charge the microgrid's batteries. The utility has excess capacity sitting idle during off-peak hours, and selling it for battery charging is desirable to them. Overall, Mr. Muniz reports, PG&E has been forward-thinking about customer-owned renewables being interconnected with the grid.

From a national-policy standpoint, there is a general concern that small operators of distributed generation and especially microgrids could be treated like small utilities when it comes to rules, permitting, and other regulations. This could be problematic in some states where such rules and regulations could be barriers for very small players that are not equipped to deal with them. Interestingly, Alameda County is not concerned about this issue—in fact, it is quite the opposite. They are looking into having the California ISO consider them to be a small utility. They feel there might actually be some benefits to this scenario, including more funding opportunities.

Web links:

- http://www.sgiclearinghouse.org/node/1653
- http://der.lbl.gov/microgrids-lbnl/santa-rita-jail
- http://www.acgov.org/smartgrid.htm
- http://e2rg.com/microgrid-2012/Santa_Rita_Jail_Alegria.pdf
- http://blogs.scientificamerican.com/plugged-in/2012/06/19/california-jail-transforms-into-modern-microgrid/
- http://www.nrel.gov/esi/pdfs/wkshp_1012_example_commercial_microgrid.pdf

- **U.S. Department of Defense Facilities, Military Bases in Multiple Locations**

Interview respondent	Mike Hightower Sandia National Laboratories 1515 Eubank SE, MS 1108 Albuquerque, NM 87123 Phone: 505-844-5499 Fax: 505-844-0968 Cell: 505-850-8630 Email: mmhight@sandia.gov

The U.S. Department of Defense (DOD) is engaged in advanced microgrid development for several military bases and for mobile military options when troops and equipment are deployed in remote locations. DOD facilities are generally interested in secure, high-reliability power for meeting critical mission needs. Because of the interest in security, some of the details about DOD facility microgrids are not publicly available.

One DOD project is called SPIDERS, for Smart Power Infrastructure Demonstration for Energy Reliability and Security. SPIDERS is a three-phase, $30 million, multi-federal-agency project to provide secure control of on-site generation at several DOD bases. The lead design agency is Sandia National Laboratories. The SPIDERS project is particularly focused on demonstrating how smart, cyber-secure advanced microgrids, operating in either islanded or grid-tied configurations, can cost-effectively enhance energy security and reliability by integrating existing back-up diesel generators with variable-output, on-site renewable energy sources like wind and solar.

Mr. Hightower believes that advanced military microgrids represent new opportunities for utility companies. One reason is because military bases are often served from dedicated substations, and the military either owns or has privatized the distribution systems on bases. In some circumstances, Mr. Hightower sees utilities being more willing to work on advanced microgrid solutions with military bases, relative to their other customer facilities, because the bases (a) represent large and steady loads, (b) offer opportunities for fewer PCCs and more opportunity for load management, (c) have opportunities for larger renewable energy generation spread over available large geographic areas, (d) already have experience with backup generation and energy reliability issues, and (e) utilize military cyber-security expertise for secure energy information and management. Another reason is that large distributed and renewable generation resources integrated on military installations can be used to help reduce congestion on existing transmission lines that are approaching load limits, thus avoiding new transmission-line development costs.

Mr. Hightower reports that utility concerns can accompany advanced microgrid deployment. Many states have regulatory policies adopted to support the regulatory paradigm associated with central-station electricity generation, and do not yet effectively address the potential benefits of large scale penetration of DG. He reports that few jurisdictions have thought through how advanced microgrids that could operate as both grid-tied and islanded can improve energy-system performance and reliability for utilities and customers. Among several of the issues that need to be addressed, Mr. Hightower cites current standby-rate policies and how to address the treatment of utility lost revenues with large-scale distributed generation being controlled by a military base.

On the positive side, Mr. Hightower notes that some utilities are already finding opportunities where distributed generation and microgrids can help meet utility needs. For example, he notes that advanced microgrid installations with integrated distributed and renewable generation can obviate the need for upgrading transmission lines that are nearing capacity overload, and that some utilities can utilize the integrated distributed generation to help offset the need for high-cost peaking generation, help meet specific reliability criteria, and support rapid recovery after power outages.

Web links:

- http://events.energetics.com/SmartGridPeerReview2012/pdfs/3_Energy_Surety_Microgrids.pdf
- https://share.sandia.gov/news/resources/news_releases/spiders/
- http://www.ieee.org/organizations/pes/meetings/gm2012/slides/pesgm2012p-001604.pdf
- http://www.army.mil/article/60709/
- http://www.militarysmartgrids.com/
- http://www.ect.coop/power-supply/transmission-distribution/grid-week-2012-military-bases-providing-power/49104
- http://www.serdp.org/Program-Areas/Energy-and-Water/Energy/Microgrids-and-Storage/
- http://www.serdp.org/content/download/15304/175087/version/3/file/MIT-LL-DoD-Microgrid-Study

- **Villa Trieste Homes, Las Vegas, Nevada**

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Utilities serving microgrid	Nevada Energy Southwest Gas
Regulatory agency	Public Utilities Commission of Nevada (PUC-NV)
Electricity market structure	Vertically integrated monopolies

Villa Trieste is a new 185-unit housing development in northwest Las Vegas. The homes are being built to LEED platinum energy-efficiency standards. All homes will have integrated, roughly 2 kW, grid-tied solar PV units. The project also includes advanced metering, demand-response capabilities, and distributed battery-electric storage. The main objective for this project is to demonstrate summer peak-demand reductions. The builder, Pulte Homes, says the advanced construction methods used in Villa Trieste will reduce electric and gas bills by more than 60% compared to standard-built houses. This partnership includes $7 in U.S. DOE funding plus Nevada Energy rebates through its Cool Share, Energy Plus, and Zero Energy Home programs.

Initially, the project was to include a large battery-storage facility at a substation, capable of supplying energy temporarily to a particular distribution feeder. Because of the high cost and technical and logistical issues involved, the project ended up forgoing the large battery storage system, at least for now. Instead, it uses small battery banks in several individual homes. These are 8kWh batteries that can provide about 2.5 kW of peak power for about three to four hours. The batteries will be under utility control, and their main function will be for peak shaving.

Because of this change in the project, the Villa Trieste project is not a full-fledged microgrid; it does not include the capability for intentional islanding.

Eventually, the Villa Trieste project is expected to make available to customers instantaneous power prices and cost incentives for demand reductions. Nevada Energy has applied for and is awaiting PUC-NV approval for a dynamic pricing program to enable this capability.

Web links:

- http://events.energetics.com/SmartGridPeerReview2012/pdfs/27_Dramatic_Residential_Demand_Reduction_in_the_Desert_Southwest.pdf
- http://www.ecohomemagazine.com/green-building/pultes-villa-trieste-development-sets-new-standard-for-sustainability.aspx
- http://www.usgbc.org/ShowFile.aspx?DocumentID=6957

- **West Virginia Super Circuit Project, Morgantown, West Virginia**

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Utilities serving microgrid	First Energy (electric)
Regulatory agency	Public Service Commission of West Virginia
Electricity market structure	Vertically integrated monopolies

Project participants include the US DOE Office of Electricity Delivery and Energy Reliability, FirstEnergy, Science Applications International Corporation (SAIC), Intergraph, North Carolina State University, and the Advanced Power & Electricity Research Center (APERC) of West Virginia University.

The West Virginia Super Circuit (WVSC) project changed substantially between its initial conceptual plans and implementation. Initial plans called for microgrid capabilities to be incorporated into a distribution circuit serving about 2,400 AMI meters. Instead of working with so many residential customers, however, the project is now focused on two adjacent commercial buildings in one industrial park. Part of the reason for the change was that the initial budget did not include the reporting and auditing that is required for ARRA grants. Another reason is that experience with demand-response programs in other utility service territories has shown rather high residential customer drop-out rates, and the WVSC project will need long-term cooperation on the part of the participating customers for demand response and load management.

A major goal of this project, as with other DOE-funded projects, is to demonstrate the ability to reduce peak power needs by 15% or more. This project is also developing and testing hardware and software systems for fault prediction, location, isolation, restoration.

The WVSC microgrid load includes two commercial buildings with a combined load of about 200 kW for two tenants, one in each building. Resources in the microgrid will include about 160kW of natural gas internal combustion engine generators, about 40 kW of solar photovoltaics, and energy storage capable of providing about 24 kW for a two-hour period. A FirstEnergy-controlled PCC with an automatic switch will isolate the two buildings for intentional islanding. FirstEnergy expects that all equipment will be installed and operational by about mid-year 2013.

The project partners have identified some policy challenges facing microgrids. One is that a majority of benefits will accrue to consumers and society at large, rather than utilities; utilities will face a majority of the costs while a majority of the benefits accrue to others. Thus, regulatory changes could be needed to encourage utilities to fully embrace all of the associated project components. (Feliachi et al., 2011). A second obstacle is that West Virginia utility rates are not yet time-differentiated and utility buy-back rates do not necessarily account for the time-value of energy delivered. Customers installing distributed generation will strive to recover their investments through avoided purchases and through the sale of excess electricity, but that is more difficult in areas with lower average utility rates. West Virginia does have a net metering program with a broad range of eligible technologies, including combined heat and power or cogeneration, in sizes up to 2 MW for industrial and 500 kW for commercial customers (DSIRE, 2012). West Virginia customers could access the time-differentiated PJM wholesale market, but its bidding rules require a 3MW minimum. Mr. Mayfield looks for buy-back rates that will make electricity sales more lucrative during peak times and in emergencies. For example, he notes that some utilities already offer peak-pricing rates, encouraging customers to turn off unneeded equipment during high-cost periods, and suggests that a symmetrical buy-back rate would reward customers for producing and delivering electricity when it is most needed, too.

Web Links:

- http://www.sgiclearinghouse.org/node/2272
- http://journal.esrgroups.org/jes/papers/jes7_1_10.pdf (Feliachi et al., 2011)
- http://ns.umc.edu.dz/vf/images/proceeding/ali_feliachi%20-%20alger%20dec%202011.pdf
- http://events.energetics.com/rdsi2008/pdfs/presentations/wednesday-part1/2%20Mayfield%20WVSC.pdf
- http://der.lbl.gov/sites/der.lbl.gov/files/sandiego_inan.pdf
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- http://www.smartenergylabs.com/projects/demonstration-projects/allegheny-power-2013-west-virginia-super-circuit/allegheny-power-2013-west-virginia-super-circuit
- http://www.netl.doe.gov/energy-analyses/pubs/WV_SGIP_Final_Report_rev1_complete.pdf
- http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=WV03R&re=0&ee=0 (DSIRE, 2012)