The regulatory environment for interconnected electric power micro-grids: insights from state regulatory officials

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Abstract:
Targeted use of distributed energy resources (DERs) can have considerable benefit for customer-generators as well as legacy utilities and their customers. The micro-grid concept is an extension of traditional DER applications that in some contexts can yield greater benefits at lower per-unit costs. Despite the expected benefits, micro-grids suffer from underadoption and underinvestment, partly because of an uncertain regulatory environment in which micro-grids are perceived neither as traditional utilities nor conventional DERs. Results from a survey of regulatory officials across the country support this argument. Only 17 of 27 participating states indicated that the installation and operation of a micro-grid is probably or definitely legal, and then only under certain circumstances and subject to varying stipulations. Among those 17 states, only 4 indicated that existing laws for the interconnection and operation of DERs would apply to micro-grid systems. No states have clear guidance for the regulatory oversight of micro-grid systems once they are installed, and most respondents indicated that such oversight would be conducted on a case-by-case basis. This paper discusses the survey and relevant insights, and concludes with a summary of recommendations for regulatory changes that could reduce uncertainty and facilitate micro-grid market development.

Keywords: micro-grid, distributed generation, distributed energy resources, regulation, legislation

1. Introduction

Distributed energy resources (DERs) have become the focus of considerable inquiry in the U.S. and around the world. There is a growing body of research that indicates that DERs are not only a reasonable investment for certain types of customers (particularly those that value high reliability and flexibility), but could also provide net benefits to the area's legacy utility and its customers while improving energy use efficiency and environmental quality (IEA 2002; Bailey, Creighton et al. 2003; Pepermans, Driesen et al. 2005; Stovall, Hadley et al. 2005)

Capturing the full range of benefits that DERs can provide depends heavily on their design and implementation. Generally, the economic and environmental quality benefits associated with DERs require the use of cogeneration or trigeneration applications that utilize "waste heat" to displace natural gas combustion for space and water heating (Meyers and Hu 2001; Strachan and Dowlatabadi 2002; Gulli 2004). The provision of high reliability may depend on the integration of DERs with energy management systems and complementary technologies such as uninterruptible power supplies, automated controls, etc. (Willis and Scott 2000). The benefits to utilities, including ancillary services and obviated T&D improvements, depend on the location of the DERs on the system and require advanced controls and integration with the utility system (Lasseter, Abbas et al. 2002).

The cost-effectiveness of DERs can also depend on the size and type of installation, due to economies of scale. The economies of scale for DERs result from two phenomena: 1) reduced installed equipment costs and increased operating efficiency of large generating equipment, and 2) improved asset utilization from more flat, predictable demand profiles. These phenomena are supported by theory (Willis and Scott 2000) and empirical study (Strachan 2000).

In order to best capture the full potential of DERs, a new system architecture known as the micro-grid[1] has been developed. A micro-grid uses distributed generation with cogeneration to provide electricity and heat to multiple customers connected on a local network. The micro-grid is interconnected with the local utility through a single point of common coupling, operates in parallel with that system, and in advanced applications is capable of automatically and instantaneously responding to stimuli from the area utility to either disconnect or provide support during disturbances. Generation and demand on a micro-grid are integrated in a manner that allows customers to shed or otherwise manage loads in such a way as to optimize the performance, cost, and reliability of the micro-grid system during grid disturbances (Kueck, Staunton et al. 2003).

While the micro-grid architecture is designed to build on and maximize the value of DERs, it is sufficiently different from traditional DER applications that the regulatory environment is still clouded in considerable uncertainty. Despite considerable progress by state governments, independent system operators, and even federal regulators to facilitate the development and adoption of traditional DER applications, most regulatory officials are still unfamiliar with the micro-grid concept and uncertain about how ongoing policy developments relate to this new architecture.

This paper builds upon previous work (Morgan and Zerriffi 2002) to explore the legality of micro-grids. In their publication, Morgan and Zerriffi concluded (on the basis of a survey of 8 then-current and former state regulators associated with the EPRI Advisory Board) that regulatory barriers exist that can inhibit the installation of micro-grids, and that it is generally not legal to install or operate an independent electric power micro-grid.

Efforts to clarify and resolve some of the regulatory barriers (King and Morgan 2003) revealed that the regulatory environment for micro-grids is more nuanced and complex than previously thought. Regulators across the country have different notions of what a micro-grid is and how it might operate, and their opinions may depend on how the micro-grid concept is framed. When framed as a small independent power producer, a micro-grid may yield a different reaction than when it is framed as a large distributed generator, or placed in the context of energy services or demand management. Section 2 outlines various applications of the micro-grid concept and their differences. Providing this taxonomy is necessary in order to remove the preconceptions and misunderstandings that exist about micro-grids, especially in the regulatory community.

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[1] The micro-grid concept is more thoroughly explored in publications by the Consortium for Electric Reliability Technology Solutions (CERTS), available on-line at http://certs.lbl.gov/CERTS_P_DER.html .

In Fall 2004, a more extensive survey of state regulators was conducted to better understand the regulatory environment for micro-grids. Regulatory officials, including Commissioners, Directors and General Counsel, from every state were contacted (almost 250 individuals) and the result was at least one response from 27 different states (see Appendix). The survey sought to more fully explore the nature of the regulatory uncertainties that exist, and provide respondents with a better context within which to think about micro-grids. The survey method and resulting insights are discussed in Section 3. Section 4 provides a summary of recommendations for regulatory changes.

2. Micro-grid Ownership Models

Most of the findings in this paper have been simplified to focus attention on the issues that have been identified as most relevant to policy-makers. For this reason, micro-grids are treated as a single concept. However, many regulators observed either explicitly or implicitly that all micro-grid applications are not the same in the eyes of the law. Moreover, the differences among micro-grids that matter most to regulators are not (as is often assumed) in the technical details of the micro-grid installation and operation, but rather in the micro-grid ownership and business practices – that is, in how they make money.

When asking questions about the regulatory environment for micro-grids, regulators generally have a single, predominant conceptual ownership or business model in mind as they answer. When this model is challenged and new models are explored, nuances appear and the regulatory environment becomes even more muddled – but possibly more open.

I propose the existence of five different models that can be used to categorize micro-grids by their ownership and business practices. The use of such models should help reduce confusion and facilitate policy discussion and development. The five models are:

1) **Utility model –** the distribution utility owns and manages the micro-grid to reduce customer costs and provide high reliability power to specific customers on the system.
2) **Landlord model –** a single landlord installs a micro-grid on-site and provides power and/or heat to tenants under a contractual lease agreement.
3) **Co-op model –** multiple individuals or firms cooperatively own and manage a micro-grid to serve their own electric and/or heating needs. Customers voluntarily join the micro-grid and are served under contract.
4) **Customer-generator model –** a single individual or firm owns and manages the system, serving the electric and/or heating needs of itself and its neighbors. Neighbors voluntarily join the micro-grid and are served under contract.
5) **District heating model –** an independent firm owns and manages the micro-grid and sells power and heat to multiple customers. Customers voluntarily join the micro-grid and are served under contract.

Depending on the state in which a micro-grid is located, these models may be considered very different by regulators. Generally, the Utility and Landlord models are viewed most favorably by regulators and the District Heating model is viewed least favorably. These opinions are often supported by regulatory law, and they reflect the risks (real and perceived) that different types of systems pose to legacy utilities and their customers.

Another distinction that can be made among different micro-grids is the way in which they interconnect with the local utility. Micro-grid interconnection can be classified as one of three types: islanded; interconnected at distribution voltages; and interconnected at transmission voltages. In this context, an islanded micro-grid refers to the creation of a system that is never interconnected with the area grid. A permanently islanded micro-grid would be granted much greater flexibility by state regulators and might not even be subject to regulation in some states. This case is fairly uninteresting and is not discussed further in this paper.

The distinction between distribution and transmission voltage interconnection does warrant some discussion. From a regulatory standpoint, interconnection at high voltages does not necessarily result in different rules; however, it does generally indicate participation in the wholesale market. Participation in wholesale markets would result in new regulatory components, particularly those introduced by system operators (e.g. PJM, MISO) and federal regulators (e.g. FERC). The rules and regulations imposed by system operators and federal regulators are not within the scope of this paper, but both FERC and many ISOs have taken steps to develop and adopt standardized interconnection rules and procedures.[2]

The remainder of this paper focuses on the regulatory environment for micro-grids that are interconnected with the local distribution utility at distribution voltages. This focus reflects the available expertise of the regulatory officials who participated, and the expectation that most interconnected micro-grids will have neither the interest nor the technical capabilities to participate in the wholesale market.

3. The regulatory environment for micro-grids

3.1 Survey methodology

In September and October 2004, nearly 250 members or senior staff representing every state Public Utilities Commission or Public Service Board were contacted by e-mail or phone requesting that they participate in an on-line survey. Follow-up contacts were made in states where no one had yet agreed to participate.

The survey consisted of 4 informational questions and 20 questions related to the regulatory environment for micro-grids. Most of these questions were open-ended, and respondents were asked to answer questions as they relate to their home state, and base their answers on specific regulatory rules or laws when possible. Respondents were given some background about the micro-grid concept and some context for the survey. Respondents were asked to consider micro-grids that are between 500 kW and 20 MW in size, utilize various generation sources (including natural gas engines and micro-turbines), and operate as a “collection of interconnected electric power sources that provide power and heat to multiple customers near the point of consumption.”

[2] Representatives at FERC and system operators were not contacted for this survey. However, many state regulators did mention federal and regional rules when discussing the legality of micro-grids at transmission voltages.

Survey questions fell into three categories: the legality of micro-grids; interactions between micro-grids and utilities; and regulatory oversight of micro-grids and micro-grid firms. Questions about the legality of micro-grids focused on the relevance of size, ownership and management, and interconnection voltage levels. Questions about customer-utility interactions focused on service territories, interconnection procedures, technical interconnection requirements, and tariffs. Questions about regulatory oversight focused on whether and how the State should oversee micro-grid operation, micro-grid interactions with customers (e.g. billing, dispute resolution), and provision of information to the State.

The survey was reviewed and approved by Carnegie Mellon University's Institutional Review Board prior to the release of the survey. The survey period lasted nearly 5 months, and the result was 33 responses from 27 different states (including the District of Columbia).

3.2 Legality of Micro-grids

Whether a firm or group of customers has the legal right to build and operate a micro-grid depends primarily on one issue: whether a micro-grid is defined as a public utility. If a micro-grid is interpreted as a public utility it stands little chance of being permitted to operate, especially within the service territory of another public utility.[3] Even in these cases, the administrative and financial burden of being designated a public utility is likely to be prohibitive for micro-grid owners.

If a micro-grid can avoid *public utility* status, there are areas of the country where it has the right to operate. Respondents from seventeen of the twenty-seven participating states gave the opinion that a micro-grid owner definitely or probably has the right to install and operate. Respondents from five states indicated that micro-grids are illegal, and this opinion usually followed the assertion that any micro-grid would necessarily be considered a public utility. Respondents from five states indicated that the legality is unclear. A state-by-state breakdown of these results is provided in Table A2 in the Appendix.

In states where micro-grid owners might have a legal right to install and operate, there are still various limitations on the structure of the micro-grid and the nature of its business. Three stipulations were most commonly cited for systems that want to operate with non-utility status:

1) The micro-grid owner(s)/operator(s) must be the primary consumer(s) of the electricity.
2) Micro-grid customers must be on or contiguous to the site where power is generated.[4]
3) A micro-grid may serve only a limited number of customers.[5]

At least one of these stipulations is applicable in every state, although some states have more restrictive language than others. In almost every case these stipulations allow a micro-grid to be

[3] In some states there are exceptions for cooperative or a municipal utilities. For example, in MN a municipal utility can exist within another utility service territory, but the original serving utility must be compensated.
[4] The definition of "contiguous" varies. For example, in GA and NJ a group of customers are not considered contiguous if they are separated by an easement, public thoroughfare (road, etc), or utility-owned right-of-way.
[5] For example, IA sets an upper limit of 5 customers, AK has a limit of 10, and MN has a limit of 25.

owned and operated under the Utility model or Landlord model. The stipulations become more important and more restrictive for micro-grids developed in the Co-op model, the Customer-generator model, and the District Heating model because there are multiple customers located on separate parcels of land. Micro-grids developed in the District Heating model are most likely to be judged a public utility because the owner/operator may consume little or none of the power on the system.[6]

According to respondents, neither the interconnection voltage nor the size (generation capacity) are considered to be an important determinant of the legal rights of a micro-grid to operate. Many respondents recognized that a micro-grid would face additional rules or regulations from FERC or regional system operators (PJM, MISO, etc.) if it interconnected at transmission voltages. Two respondents also judged that interconnection at transmission voltages could increase the likelihood that a micro-grid was considered a public utility, but it was unclear.

3.3 Uncertainty as a barrier to micro-grid development

Despite the fact that micro-grids might have a legal right to exist in many states, there are still many barriers to micro-grid development that stem from regulatory ambiguity. A prospective micro-grid faces considerable uncertainty with regard to where and how it can be built and operated under the existing regulatory environment. This uncertainty poses a large financial risk for entrepreneurs; such risks can swamp an investment decision and lead to chronic underinvestment for even highly cost-effective applications.

There is consensus among regulatory officials that the current regulatory environment for micro-grids is at best murky. The survey of regulatory officials explored three sources of uncertainty for micro-grid projects: the existence and relevance of utility service territories; utility services and tariffs; and interconnection procedures and technical requirements. The paragraphs that follow explore the nature of these uncertainties. In Section 6, I discuss steps that regulatory authorities can take to clarify the regulatory status for electric power micro-grids.

<u>Service territories</u>
Distribution utilities have traditionally been granted monopoly power to provide service to customers within pre-defined service territories. These territories were created to sustain what was considered a natural monopoly designed to avoid redundant wires crossing a city or town. Service territories reduced the utility's financial risks by guaranteeing a customer base through which capital investments could be recovered, and gave customers assurance that they would receive electric service.

Service territories exist in some form in every state that participated in this study. Some states have pockets where multiple distribution companies can compete, but this is rare. The existence of unique service territories was the primary reason given for why micro-grids might not be legal. Even in states where micro-grids have a legal right to operate, utilities are likely to oppose them and use service territories as a justification for blocking development. Such opposition is manifested in legal challenges, which can take years to settle and yield considerable costs and risks to those proposing to install a system.

[6] This opinion was given by respondents in AL, IA, IL, NJ, NY, OH, OR, SD, TX, VT, WA, and WY.

One example is the 1997 proposal by Pennsylvania Enterprises, Inc. (PEI) to build a micro-grid, or ‘power park’ at an industrial park site in Archbald, PA. The local utility, PPL, argued before the PA PUC that the PEI Power Park constituted a public utility and should not be allowed to provide services to customers in the PPL service territory. In September 1998 the PUC issued a declaratory order that PEI Power Park was not a public utility, and could proceed.[7] Ground was broken on the project in November 1998 and PEI already had customer commitments. However, PPL continued to oppose the project. Under continuing legal threats by PPL in civil court, and the fear of ruining their relationship with the local utility (from which PEI had to purchase standby and supplemental power), PEI abandoned its plans to directly supply electricity to its customers.[8]

Utility tariffs

In recent years many public utilities have developed tariff arrangements to meet the needs of customer-generators that employ traditional distributed generation. In some states these tariffs are required by the regulatory authority. In states where it is not mandatory, there are utilities that have developed them voluntarily.

State Public Code may require utilities to develop tariffs but often it does not dictate how (e.g. rates, applications) or to whom tariffs should apply. In cases such as this, or in states where utilities voluntarily develop customer-generator tariffs, the utilities have wide latitude over the tariff design and its applicability. The resulting tariff structures give the utility maximum flexibility, enabling them to refuse service to customers on fairly loose grounds. Such flexibility undermines the general rights of DER customers by making the applicability relatively arbitrary, and creates an uncertain regulatory environment for prospective DER customers.

The uncertainty discussed above is compounded by the question of whether customer-generator tariff arrangements are even applicable to micro-grids. According to survey responses, most states (25 of the 27 participating states) have tariff arrangements (mandatory or voluntary) for customer-generators. Among regulators in these states, less than half gave the opinion that the tariff arrangements would definitely or probably apply to micro-grids.

In cases where utilities have great flexibility in the application of these tariffs, the utilities may be the ultimate judge of whether such customer-generator tariffs apply to micro-grids. In cases like this, a utility is unlikely to grant favorable tariffs to micro-grids that directly compete with the utility for customers.

Interconnection procedures and technical requirements

An economically viable micro-grid must be interconnected with the area electric grid and allowed to purchase and possibly sell electricity. Utilities have been reluctant to let distributed energy resources interconnect with the grid, citing safety and system stability concerns. While these concerns are sometimes justified, system operators and regulatory authorities have found

[7] A petition for a declaratory order was filed by PG Energy, Inc., then-owners of PEI Power Corporation, at docket 00981405. The Pennsylvania PUC issued its order on September 3, 1998.

[8] This account is based on phone discussions with employees of PEI Power Corporation in June 2004, and news releases published between 1996 and 1999 on the PRNewsWire.

ways to alleviate these concerns by formalizing the interconnection process in a manner that fairly places responsibilities and burdens of proof on both customer-generators and the utility.

When designed correctly, these procedures lay out the timeline and responsibilities for both parties, as well as contingencies if either party fails to meet its obligations. They provide customer-generators with the assurance that if they meet certain pre-defined standards they will be able to interconnect within a reasonable amount of time. They provide utilities with the assurance that customer-generators will not have an adverse impact on their system or their customers.

Recent national and regional developments in this area include IEEE P1547, FERC's proposed Standardization of Small Generator Interconnection Agreements and Procedures, and PJM's ongoing work on small generation interconnection standards. On the state level, the National Association of Regulatory Utility Commissioners (NARUC) published model interconnection procedures in October 2003, and survey results suggest that most states have interconnection procedures and technical requirements in some form that apply to distributed energy resources (see Table 1). The Texas Distributed Generation Interconnection Manual is a particularly good model for clear, standardized interconnection procedures.

Despite progress in most states on the technical and procedural requirements for traditional distributed energy resources, it is not clear that this translates into regulatory clarity for micro-grids. Among 24 states that reportedly have some interconnection procedures for DERs, respondents from 13 states believe these procedures would definitely or probably apply to micro-grids; 6 states indicated that these procedures would definitely or probably not apply to micro-grids; and 5 states indicated that it was unclear. Among respondents from the 19 states that have technical interconnection requirements, 11 respondents believed that such requirements would definitely or probably extend to micro-grids in their states; 4 indicated that they would probably not extend to micro-grids; and 4 were unsure.

Responses from regulatory officials paint a muddy picture for parties interested in constructing an interconnected micro-grid. Interconnection procedures and technical requirements are often not designed well or not easily enforceable. In an effort to limit the risk to utility customers and line-workers, utilities are sometimes given the power to increase the rigor and cost of interconnection studies – generally at the expense of the customer-generator. This places all of the burden of proof on the customer-generator and can result in overly stringent and/or overly expensive interconnection requirements. (Alderfer, Eldridge et al. 2000)

It is the responsibility of regulators to ensure that interconnection procedures and technical interconnection requirements are designed and enforced in a manner that is fair and reasonable for both parties. If implemented in a balanced manner, many of the model standards that have been developed by NARUC, PJM, etc. seem to accomplish this successfully.

Table 1 demonstrates that although states are generally making progress in addressing the barriers to DER development, there is still substantial uncertainty for micro-grids. Even this picture is incomplete. Among the 27 states involved in the study, *only 4 states* – Georgia, Missouri, Pennsylvania, and Minnesota – indicated that 1) micro-grids may be legal under some circumstances; 2) there are existing tariff arrangements, interconnection procedures, and technical interconnection requirements for traditional DERs; and 3) all of these stipulations would definitely or probably apply to micro-grids.

3.4 Regulatory Oversight

Before regulators allow micro-grids to be installed and operated, most want some assurance that micro-grids will have a positive impact on society, and that they will not be able to operate in a regulatory loophole that enables them to mistreat their customers or sidestep environmental laws and participation in social programs. These assurances traditionally come in the form of regulatory controls. In the case of owner-customer interactions, they may also be provided by contractual agreements. This section addresses whether and to what extent micro-grids are or could be subject to regulatory oversight.

<u>Micro-grid customer interactions</u>
One of the roles of the regulatory community is to ensure that the public is protected against unreasonable rates, bad service, and negligence that results in safety or human health risks. It is a matter of interpretation whether this responsibility applies to customers that willingly agree to the provision of electricity and heat from an independent micro-grid. Although some regulators have expressed concern over the manner in which micro-grid firms might provide service to its customers, it is unclear how this relationship is defined in regulatory law.

A micro-grid, by definition, involves multiple customers and essential services for electricity and heating. When one also considers that customers may not fully understand the technical aspects or risks associated with energy quality and reliability, it is clear that the State has an interest in providing guidance, if not legal requirements, for how a micro-grid is managed and operated. The dynamic between the micro-grid owner/operator and its customers will depend on which type of micro-grid is installed (e.g. Landlord model, Coop model, District Heating model), but there are several issues that deserve consideration. They include but are not limited to: rate-setting; billing and collection; dispute resolution; insurance holdings; credit; and demand management for reliability.

Many of these issues are currently handled in rules designed for public utilities. In the survey, regulators from several states suggested that these rules would likely apply to micro-grids. However, since micro-grids are most likely to operate without public utility status in most states, the relevance of such laws is unclear. Respondents from a few states indicated that consumer protection laws would probably apply, but did not know what this meant in terms of specific requirements. Most respondents indicated that such issues would be handled on a case-by-case basis, subject to interpretation by the regulatory authority.

While protection for micro-grid customers is important, it is likely that ad-hoc requirements set by the regulatory authority would be inefficient for both the micro-grid and regulators, and would likely lead to requirements that either overly stringent or focus too much attention on certain issues such as rate-setting. On the other hand, adopting broad, uniform standards – especially if they are based on current rules for public utilities – may be very burdensome and limit the ability of micro-grids to cater to specific customer needs.

Environmental and siting laws

When asked about environmental and siting laws, most respondents indicated that it was outside of their jurisdiction and they were reluctant to offer much interpretation of the law in this area. Environmental issues are typically handled by a state environmental protection agency and/or local air quality regulator. Siting is often handled by local agencies, especially when the proposed plants are fairly small.[9] Despite the lack of jurisdiction, questions and concerns about the environmental impacts of micro-grids did arise in conversations with regulators and it is worth some discussion here.

Micro-grids with combined heat-and-power (CHP) have three important impacts on environmental and human health quality. First, they move the production of electric power and its resulting emissions nearer to population centers, which may increase the harmful effects of certain air pollutants (e.g. SOx, NOx, PM). Second, by capturing heat from the generators, they displace combustion from gas boilers and water-heaters and possibly reduce cooling loads through the use of adsorption chillers or dessicants. Third, they alter the traditional emissions control regime by replacing large, customized, centralized plants with small, off-the-shelf, distributed plants.

The proximity of DERs to population centers raises a lot of concern among regulators, but it can be effectively offset by the increased overall efficiency of DERs with combined-heat-and-power applications (Gulli 2004; Strachan and Farrell 2004). DERs and micro-grids also use more environmentally benign fuel sources than conventional centralized sources, and provide opportunities for clean generating technologies such as photovoltaics and small-scale wind turbines.

The dispersed nature of DERs presents some pragmatic concerns about the ability of micro-grids to control emissions in response to future regulatory action. Conventional wisdom suggests that large plants are easier to monitor and control because they are fewer in number. However, the regulation of multiple sources in the automobile and aerospace industries has been effective thanks to the presence of pre-designed, pre-fabricated, off-the-shelf technologies. This is a useful model for emission control in micro-grids, since the cost-effectiveness of these systems will depend on the mass-production of their components. As more stringent emissions controls are required, generator manufacturers will simply have to develop and adopt design changes to make next-generation equipment that is compliant with new aggressive air quality targets.

Public programs

Many states have public programs known as public benefit trusts that are designed to encourage energy-efficiency, provide support to older and low-income households, encourage research and development, etc. These programs are funded through small usage fees that are levied against utility customers, and money is awarded through the State.

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[9] For example, power plants that are smaller than 25 MW are exempt from state regulation in Iowa and Oregon. Plants under 75 MW are exempt from state regulation in Florida and South Carolina. Plants under 100 MW are exempt from state regulation in Wisconsin.

If micro-grid customers are granted the right to operate without utility status, they may not be legally required to participate in these programs. This is a small problem if micro-grids remain a niche, but as micro-grids market penetration increases, regulators may want to require micro-grid customers to participate in public programs and make micro-grid customers eligible to receive benefits from these programs.

4. Recommended Regulatory Changes

An uncertain regulatory environment poses an unnecessary barrier to the development and adoption of micro-grid systems. Regulators and legislators should create new rules and laws and make changes to existing ones so that micro-grids systems can participate and compete in a new market for energy and energy services. These changes need to be effective, while still limiting system risk and protecting the rights of both the micro-grid and the utility customers. The following are a set of regulatory changes that can be adopted to facilitate measured, low-risk micro-grid development. These changes can be written into law by legislators or created within rules by regulatory agencies. Policymakers are encouraged to adopt these changes now, while there is considerable activity in the arena of distributed energy resources.

Formalize the definition and legal rights of micro-grids
Micro-grid owners should have the right to provide electricity and heat to interested co-located customers. Micro-grids should have the right to buy from and sell to the local electric utility, and negotiate bilateral agreements with the utility to provide ancillary services. Micro-grids should have the right to buy and sell on the wholesale market. Regulatory law may want to recognize different types of micro-grids (e.g. landlord model, co-op model) and customize licensing and interconnection procedures for each type.

Require utility tariffs for micro-grids
Utilities should be required to develop and submit micro-grid tariff structures for review and scrutiny by state PUC/PSCs. Regulators should not allow tariffs to be punitive or discriminatory, and tariffs should not include stand-by fees based on installed capacity. Such fees do not provide micro-grid operators with any incentive to design or manage their system optimally to reduce the utility burden. Stand-by fees should instead be replaced by demand charges and emergency stand-by rates, which incent micro-grid operators to adopt measures that are economically sensible and mutually beneficial, including internal redundancy, demand response measures, and aggressive maintenance schedules.

Adopt standardized interconnection procedures that are applicable to micro-grids
Regulators should consult the model interconnection procedures developed by NARUC and implemented in many states, and make these types of procedures applicable to micro-grids. Timelines, procedural steps, and the responsibilities of both parties should be clearly laid out.[10] These procedures should be mandatory, not voluntary, and utilities should not be able to impose additional studies without clear justification. Additionally, PUC/PSCs should develop and

[10] The Texas Distributed Generation Interconnection Manual, most recently revised and published by the PUC of Texas in May 2002, is a good model for clear, standardized interconnection procedures.

maintain a list of interconnection and generation equipment that is pre-certified.[11] Micro-grids that use this pre-certified equipment should be granted expedited processing.

Limit system and utility risk

Regulators should adopt standardized minimum technical interconnection requirements that are applicable to micro-grids. In many cases, this may only involve an extension of existing DER requirements to micro-grids. Technical requirements – and associated equipment requirements – should not be subject to much interpretation or expansion by the utility without approval from regulators.

If regulators are concerned about the system impacts of emerging micro-grid growth, they may choose to initially limit the number or size of interconnected micro-grids. However, these limits should be set based on demonstrable deleterious system impacts, not politics.[12] Regulators should also promote tariff design that encourages micro-grid development in areas of the grid that are congested or experiencing rapid demand growth.

Micro-grid owners and operators should be required to provide utilities with information that will affect planning. Utilities should receive information about capacity, system design, and location well before a micro-grid is constructed and interconnected. Utilities should also receive advanced notice of planned micro-grid outages due to maintenance, upgrades, etc.[13]

Formalize the responsibilities of micro-grid owners

Regulators should construct clear rules or guidelines for how micro-grid owners interact with their customers. States may want to require licensing procedures for billing, collecting, dispute resolution, insurance, credit, etc. These procedures should be limited in scope so as to reduce cost and administrative burdens for the micro-grid and the State. Regulators should look at rules and requirements that exist for similar systems, such as district energy plants and energy service companies (ESCOs). There are district energy systems in 38 states[14] and in most cases these systems serve a small, contiguous group of customers and strongly resemble the structure of a micro-grid. The energy services industry is a multi-billion industry in the U.S. that is active across the country (Osborn, Goldman et al. 2002) and although ESCOs usually serve individual customers based on contractual agreements, these services often include installation and management of infrastructure (HVAC equipment, building improvements, etc.), and may provide a useful model for insurance and credit requirements.

The State should develop model contract language to encourage bilateral contracts between micro-grid owners and customers, and to ensure that such contracts are clear and understandable for consumers. According to survey respondents, the use of contracts could reduce the need for regulatory oversight. This reduced oversight can save the customers and the State valuable time and money.

[11] See the California PUC (http://www.energy.ca.gov/distgen/interconnection/certification.html) and the New York PSC (http://www.dps.state.ny.us/SIRDevices.PDF) for examples of pre-certified equipment lists.
[12] For example, Texas DG interconnection laws apply to customers with 10 MW of capacity or less, and proposed FERC interconnection procedures for small generators will apply to systems with 20 MW of capacity or less.
[13] This type of information exchange is typically defined within the “maintenance power” component of current utility tariffs for customer-generators.
[14] According to the International District Energy Association, http://www.districtenergy.org/city_system_list.htm.

Micro-grid operators should provide information to utilities and the State both prior to and during operation. This information should include installation plans (schedules, capacities, expected demand, etc.) as well as operational plans (scheduled maintenance outages, estimates of unscheduled outages) that can be used by utilities and system operators when making plans for new capacity upgrades or additions.

Micro-grid should be required to participate in public programs such as Public Benefit Funds, and both the owners and the customers should be eligible for benefits from such programs. Provision of information to the utilities and the State for public programs should be mandatory.

Acknowledgements

The author would like to thank the regulatory officials that participated in the survey (and their staff), as well as various individuals that assisted with both the creation of the survey and the completion of this paper – particularly Granger Morgan, Jay Apt, and Michael Dworkin.

References

Alderfer, R. B., M. M. Eldridge, et al. (2000). Making Connections: Case studies of interconnection barriers and their impact on distributed power projects. Golden, CO, National Renewable Energy Laboratories**:** 91.

Bailey, O., C. Creighton, et al. (2003). Distributed Energy Resources in Practice: A Case Study Analysis and Validation of LBNL's Customer Adoption Model. Berkeley, CA, Lawrence Berkeley National Labs**:** 209.

Gulli, F. (2004). "Small Distributed Generation Versus Centralised Supply: A Social Cost-Benefit Analysis in the Residential and Service Sectors." Energy Policy **Article in Press**.

IEA (2002). Distributed Generation in Liberalised Markets. Paris, International Energy Agency.

King, D. and G. Morgan (2003). Guidance for Drafting State Legislation to Facilitate the Growth of Independent Electric Power Micro-Grids. Pittsburgh, PA, Carnegie Mellon University.

Kueck, J. D., R. H. Staunton, et al. (2003). Microgrid Energy Management System. Oak Ridge, TN, Consortium for Electric Reliability Solutions.

Lasseter, R., A. Abbas, et al. (2002). Integration of Distributed Energy Resources: The CERTS MicroGrid Concept, Consortium for Electric Reliability Technology Solutions.

Meyers, E. and M. G. Hu (2001). "Clean Distributed Generation: Policy Options to Promote Clean Air and Reliability." The Electricity Journal (January/February 2001): 89-98.

Morgan, M. G. and H. Zerriffi (2002). "The Regulatory Environment for Small Independent Micro-Grid Companies." The Electricity Journal: 52-57.

Osborn, J., C. Goldman, et al. (2002). Assessing US ESCO Industry Performance and Market Trends. Berkeley, CA, Lawrence Berkeley National Lab**:** 13.

Pepermans, G., J. Driesen, et al. (2005). "Distributed Generation: definition, benefits and issues." Energy Policy **33**: 787-798.

Stovall, T. K., S. W. Hadley, et al. (2005). "Distributed Generation: Who Benefits." Public Utilities Fortnightly(March 2005): 34-37.

Strachan, N. and H. Dowlatabadi (2002). "Distributed Generation and Distribution Utilities." Energy Policy **30**: 649-661.

Strachan, N. and A. Farrell (2004). Emissions from Distributed Generation. CEIC Working Paper, Carnegie Mellon Electricity Industries Center. **02-04:** 14.

Strachan, N. D. (2000). Adoption and Supply of a Distributed Energy Technology. Engineering and Public Policy. Pittsburgh, PA, Carnegie Mellon University**:** 216.

Willis, H. L. and W. G. Scott (2000). Distributed Power Generation Planning and Evaluation. Raleigh, NC, Marcel Dekker, Inc.

Appendix

Table A1. Micro-grid Survey Respondents

State	Respondent*	Organization
AK	Jerry Burton, Utility Engineering Analyst	Regulatory Commission
AL	Janice Hamilton, Director	Alabama PSC, Energy Division
DC	Grace Hu, Chief Economist Dan Cleverdon, Technical Advisor	Washington, DC PSC Washington, DC PSC
DE	Robert Howatt, Public Utilities Analyst	Delaware PSC
FL	Hurd Reeves, Government Analyst	Florida PSC
GA	Philip Bedingfield, Public Utilities Engineer	Georgia PSC
IA	David Lynch, General Counsel John Pearce, Utility Specialist	Iowa Utilities Board
IL	Philip Roy Buxton, Program Manager	Illinois Commerce Commission
IN	Erin Peters, Assistant General Counsel	Utility Regulatory Commission
LA	Tulin Koray, Economist	Louisiana PSC
MA	Robert Harrold, Assistant Director, Electric Power Division	Department of Telecommunications and Energy
MI	Tom Stanton, Technical Assistant	Michigan PSC
MN	Jen Peterson, Energy Tech Team Supervisor Alvin Bierbaum, Staff Engineer	Minnesota State Energy Office Minnesota PUC
MO	Warren Wood, Energy Dept. Manager	Missouri PSC
NJ	Carl Dzierzawiec, Principle Engineer Scott Hunter, Renewable Energy Program Admin.	Board of Public Utilities
NY	Leonard Van Ryn, Assistant Counsel	Department of Public Service
OH	Jan Karlak, Utilities Specialist	Ohio PUC
OR	Lisa Schwartz, Senior Analyst David Stewart-Smith, Asst. Dir. Energy Resources	Oregon PUC Oregon Department of Energy
PA	Karen Oill Moury, Executive Director	Pennsylvania PUC
SC	Phil Riley, Advisory Staff Engineer	South Carolina PSC
SD	not provided	South Dakota PUC
TX	Jess Totten, Electric Division Director	Texas PUC
UT	Lowell Alt, Executive Staff Director	Utah PSC
VT	Ed McNamara, Staff Attorney	Vermont Public Service Board
WA	Douglas Kilpatrick, Assistant Director of Emergency & Planning	Utilities and Transportation Commission
WI	Scott Cullen, Chief Engineer , Gas & Energy Div.	Wisconsin PSC
WY	Ruth Hobbs	WY PUC

** Many respondents conferred with associates to ensure that their responses were valid and representative.*

Table A2. Responses to questions about micro-grid legality

If a group of customers wants to build a micro-grid that is interconnected with the area grid at *distribution voltages*, are there any circumstances under which it is legal?		
Yes / probably	No / probably not	Uncertain or unclear
17 states	5 states	5 states
AK, DE, FL, GA, IA, IL, MI, MN, MO, NY, OR, PA, TX, UT, VT, WI, WY	IN, LA, MA, SC, WA	AL, DC, NJ, OH, SD

Table A3. Responses to questions about micro-grid – utility interactions

	Have applicable rules for traditional DERs?	Would these rules that apply to DERs also apply to micro-grids?				
		Yes	Probably	Probably Not	No	Unclear / Respondent Unsure
Tariff Arrangements	25 states	FL, GA, MA, MN, TX, WA, WI	AL, IL, MO, PA	DC, IN, LA, NJ, OH, UT, WY	AK	IA, MN, NY, OR, SD, VT
Interconnection Procedures	24 states	DE, GA, IA, MA, MI, MN, TX, WA, WY	AL, MO, PA, VT	IN, OH, UT	AK, FL, LA	DC, NJ, NY, OR, WI
Technical Interconnection Requirements	19 states	AK, GA, IA, MN, WA, WI, WY	DE, MI, MO, PA	DC, IN, NJ, OH	-	NY, OR, SD, VT

In-text tables

Table 1. Applicability of State DER interconnection rules to micro-grids*
(total # of states, out of 27 total respondents)

	Have applicable rules for traditional DERs?	Would these rules that apply to DERs also apply to micro-grids?				
		Yes	Probably	Probably Not	No	Unclear / Respondent Unsure
Tariff Arrangements	25	7	4	7	1	6
Interconnection Procedures	24	9	4	3	3	5
Technical Interconnection Requirements	19	7	4	4	0	4

* A state-by-state breakdown of these results is provided in Table A3 in the Appendix.