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# Lessons from international experience for China's microgrid demonstration program

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## HIGHLIGHTS

- We discuss major microgrid demonstration programs in the U.S., E.U., and Asia.
- We identify barriers faced by microgrids to date and propose policy solutions.
- Two detailed case studies of government sponsored microgrid demonstrations are provided.
- We outline eight recommendations for microgrid demonstration programs, with a focus on China's upcoming program.

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## ABSTRACT

Microgrids can provide an avenue for increasing the amount of distributed generation (DG) and delivery of electricity, where control is more dispersed and quality of service is locally tailored to end-use requirements, with applications from military bases to campuses to commercial office buildings. Many studies have been done to date on microgrid technology and operations, but fewer studies exist on demonstration programs and commercial microgrid development. As China prepares to launch the largest microgrid demonstration program in the world, we review progress made by demonstration programs across Europe, Asia, and the Americas as well as microgrid benefits and barriers. Through case studies, we highlight the difference in experience for microgrids developed under the auspices of a government-sponsored demonstration program versus those that were commercially developed. Lastly, we provide recommendations oriented towards creating a successful microgrid demonstration program.
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## 1. Introduction and motivation

Ustun et al. (2011) found that technical challenges still must be overcome for microgrids to cost-effectively and reliably integrate distributed generation into the grid. Basu et al. (2011) highlight that the microgrid sector is promising but still immature in its development, and that more research and pilot projects are needed to push microgrids to deployment stage. NYSERDA (2010) and Schwaegerl (2009), however, emphasized the economic and regulatory barriers that microgrids are facing as opposed to the technical challenges. This study continues along in this vein through the lens of demonstration programs across Europe, Asia, and the Americas, with a discussion of microgrid benefits and barriers, illustrated by relevant case studies.

China has shown growing interest in microgrids as one avenue to a low-carbon electricity transition. Difficulties with China's large-scale centralized renewables installations and low-carbon electricity transition have been highlighted in the literature, including problems with wind energy grid integration (Wang et al., 2012), lack of utility planning and regulatory tools (Kahrl et al., 2011), and needed improvements to China's Renewable Energy Law (Schuman and Lin, 2012). Meanwhile, China's National Energy Administration (NEA) has promoted distributed generation as an additional source of low-carbon electricity. The targets laid out in the 12th Five Year Plan are to build 100 *New Energy City* pilots, 1000 natural gas-fired distributed generation projects, and 30 new energy microgrid demonstration projects (NEA, 2011a, 2011b). In preparation for China's launch of the microgrid demonstration program, Lawrence Berkeley National Laboratory (LBNL) conducted an international survey of microgrid technology and policy to date for the Chinese Academy of Sciences – Institute for Electrical Engineers (Marnay et al., 2012). The main findings of this study are summarized in this paper.

Section 2 provides an overview of microgrid definitions, technologies, and drivers. Section 3 reviews major international publicly

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funded microgrid demonstration programs over the past 15 years. Section 4 describes the main benefits that microgrids provide and the barriers that both demonstration sites and commercially developed microgrids have often faced, while Section 5 provides additional evidence of these benefits and barriers through case studies. Finally, Section 6 outlines concrete policy recommendations for emerging economies undertaking microgrid demonstration programs, and Section 7 provides extra context for China's planned program. The outcome of China's program will have important ramifications not only for its own low-carbon energy transition but also for the continued global development of microgrid technology and policy.

## 2. Overview of microgrids

### 2.1. Definition of microgrid

The term microgrid loosely refers to any localized cluster of facilities whose electrical sources (generation), sinks (loads), and potentially storage (both electrical and thermal) and load control function semi-autonomously from the traditional centralized grid, or macrogrid. Researchers have created a wide variety of microgrid definitions depending on the context of technology and function, but few formal definitions exist. Following are two efforts:

> *Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded (CIGRÉ C6.22 Working Group).*

> *A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode (U.S. DOE Microgrid Exchange Group (MEG), 2010).*

The above CIGRÉ C6.22 and U.S. Department of Energy (DOE) MEG definitions have two common basic requirements: (1) a microgrid must contain both sources and sinks under local control, and (2) a microgrid must be able to function both grid connected and as an electrical island. *Control* represents the key microgrid feature that differentiates it from traditional distributed generation. A microgrid must have islanding capability, which implies a control regime available for macrogrid blackouts. Additionally, while parallel to the macrogrid, the microgrid acts as a locally controlled system, in stark contrast to the wholly passive loads of the legacy power supply paradigm. Note that the CIGRÉ C6.22 and DOE MEG definitions say nothing about required microgrid technologies, scale, motive, fuels, or the quality of power delivered to loads, while both definitions emphasize control.

The microgrid's ability to present itself to the macrogrid as a controlled entity has two important implications: (1) it can provide complex macrogrid services, e.g. buffering small-scale variable renewable generation or providing ancillary services to the macrogrid, and (2) it can coordinate with other entities in the network, such as other microgrids or other sites with generation, storage and/or controlled loads. In addition to the benefits of potentially providing clean and affordable energy under local control and supplying valuable grid services, some microgrids can locally control power quality and reliability (PQR) and tailor it to meet individual load requirements, in contrast to the universal homogeneous PQR service provided by the macrogrid. For example, this might mean a small local DC system involving solar PV and storage is the best solution even though PQR may be poor, whereas in another case it may mean highly reliable and clean power is required, such as for a site whose loads demand it, e.g. an urban telecom facility (Marnay and Lai, 2012). In other words, the PQR of delivered power should be compatible with the PQR requirements of the loads and constrained by what is economically available and environmentally desirable. Note that, matching PQR in this way can expand economic benefit compared to the homogeneous PQR of the legacy grid. Also, lower power generation emissions are not guaranteed by microgrids, since local generation can be dirty, e.g. uncontrolled diesel generation. Further, distributed generation can result in higher human exposures if emissions at ground level in urban centers substitute for remote emissions from high stacks.

Microgrids can be wholly within one traditional customer site, and in fact most existing demonstrations are of this type, especially in the U.S. Alternatively, a microgrid might involve several sites connected by a fragment of the existing distribution network. The difference between these two types is critical from the regulatory and policy perspectives. The former is downstream of a single meter or point of common coupling (PCCs), which implies a significantly simpler regulatory environment quite distinct from the latter case in which some part of an existing regulated electricity provider's (REP) distribution network assets are involved.

### 2.2. Common microgrid technologies

Fig. 1 displays the components seen in current microgrid demonstrations. There are both loads and generation sources. Among loads, there may be *critical loads* which require high or

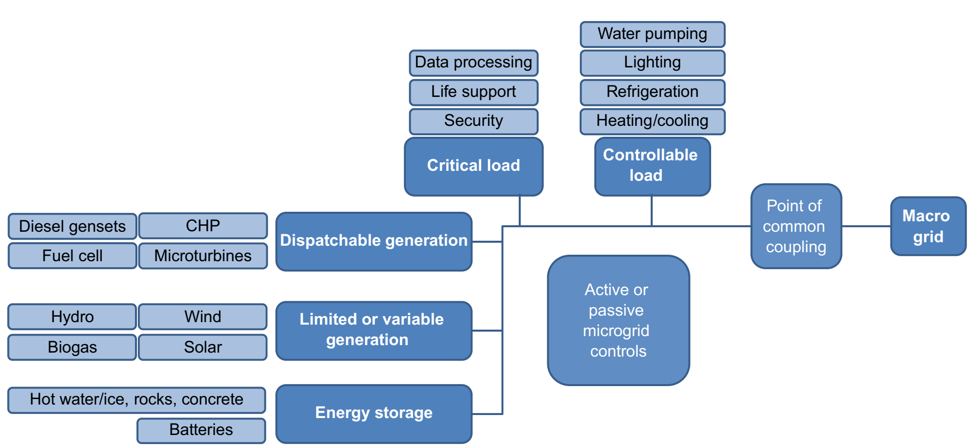


**Fig. 1.** Overview of the main components in a common microgrid.
*Source:* adapted from Siemens (2011).