Distributed generation (DG) is a broad term that encompasses myriad technologies that generate, store, and distribute electricity close to the end user. DG technology is rapidly developing and being deployed around the world. Subsequent chapters of this book describe the legal and economic issues as well as implications of the ever-increasing prevalence of DG. In this chapter, the authors introduce, in non-technical terms, the basic concepts and technologies most frequently used in DG installations in the United States. Any discussion of rapidly developing DG technology comes with the inherent risk that it will be outdated soon after it is written. Therefore, this introductory chapter serves to provide the reader with a foundation for further inquiry and a general introduction of the chapters that follow, rather than a comprehensive technical exposition of DG.

1.1 Introduction: Distributed Generation

The moniker “distributed generation” is often used in conjunction with the generation of renewable energy, but the term primarily describes how electricity is deployed, not necessarily how it is generated. The term DG refers to electricity generated from renewable and fossil fuel-based sources located near the point of end use instead of
from centralized generation sources, such as large power plants. DG, also sometimes referred to as district or decentralized energy, can be generated and stored by a variety of small sources that are not directly a part of the bulk power system (i.e., electric power transmission), but are capable of actively interconnecting with it to add or draw electricity. Those sources along with energy efficiency, energy storage, electric vehicles, demand response, and microgrids are generally referred to as distributed energy resources (DERs) because they are distributed throughout the grid rather than from a central location.

DG can serve a single structure (e.g., a home or an office building) or it can be part of a microgrid, which is a smaller electric grid tied into a larger electricity delivery system, such as at a port or industrial complex, a military base, or a large college campus. In the residential sector, common DG systems include the following:

- Solar photovoltaic panels
- Small wind turbines
- Natural-gas-fired fuel cells
- Emergency backup generators, usually fueled by gasoline or diesel fuel

In the commercial and industrial sectors, DG can include resources such as:

- Combined heat and power systems (cogeneration)
- Solar photovoltaic panels
- Wind
- Hydropower
- Biomass combustion or cofiring
- Municipal solid waste incineration
- Fuel cells fired by natural gas or biomass
- Reciprocating combustion engines, including backup generators, which are fueled by oil.¹

These resources are discussed in further detail later in this chapter. To fully appreciate the promise and challenges of DG, one must first understand the conventional architecture of the electric grid in the United States. Traditionally, in the United States, we have relied on large, centralized generation facilities to provide electricity. The nation’s system of electric power generation and distribution (the grid) is a vast and complex structure of over 9,000 electric generating units, 600,000 miles of high-voltage transmission lines, and 10,000 substations covering the continental United States and parts of Canada.  

It is a marvel of modern engineering that, with very few exceptions, reliably generates and delivers energy to billions of end uses at the flip of a switch. As discussed in chapters 2 and 4, large centralized plants became the norm for the grid, in part, because of the economies of scale they provide.

Until the last few decades, almost all electricity was generated by large, centralized coal, natural gas, oil, nuclear, and hydropower plants. Since its inception, the electric grid has operated on the same basic traditional model in which electricity flows in one direction, from large centralized generating facilities to the end user. In the United States, our electricity travels long distances from centralized generating facilities to local distribution substations through a transmission grid of high-voltage transmission lines. Generating facilities provide power to the grid at low voltage, from 480 volts (V) in small generating facilities to 22 kilovolts (kV) in larger power plants. Once electricity leaves a generating facility, the voltage is increased, or “stepped up,” by a transformer to minimize the power losses over long distances. At various points in the transmission system, the electric load is distributed to local distribution areas via substations. But this much voltage is not usable by the consumer, so transformers are used to lower the voltage. As electricity is transmitted through the grid and arrives in the load areas, voltage is stepped down by transformers at distribution substations (ranges of 69 kV to 4.16 kV) and finally lowered further for use by customers via transformers on power poles (residential customers use 120V and 240V; commercial...

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and industrial customers typically use 120V, 208V, and 480V). Power is then distributed to the end user, and meters are used to keep track of consumption.³

However, our existing traditional centralized system has disadvantages. For example, in the transmission and distribution of electricity from centralized plants to the end user over long distances, some electricity is lost and not used because of the interplay between the basic characteristics of electricity—voltage, current, and resistance.⁴ The U.S. Energy Information Administration (EIA) estimates that electricity transmission and distribution losses average about 5 percent of the electricity that is transmitted and distributed annually in the United States.⁵ In DG systems, because the electricity is generated at or near the point of consumption, the amount of energy lost in transmitting electricity is significantly reduced.

The distances that power lines traverse in the traditional central station model raise vulnerabilities for security and reliability. The increasing frequency and intensity of natural disasters such as hurricanes, earthquakes, floods, and wildfires in recent years illustrate this vulnerability when power lines are taken out of service by falling trees, flying debris, shifts in land, or extreme heat or cold. Additionally, in recent decades, fossil fuel-fired centralized systems have been criticized for environmental impacts such as the emission of sulfur, particulates, and greenhouse gases. Coal-fired and nuclear power plants produce large amounts of coal ash or nuclear waste as a byproduct of electric generation.⁶

Most of our centralized utility-based national grid was not designed to accommodate active generation and storage at the distribution

³ This is where the phrase “behind the meter” originates.
⁴ The fundamental relationship between voltage (V), current (I), and resistance (R) is described in physics as Ohm’s law, which states that the current flowing in a circuit is directly proportional to voltage and inversely proportional to the resistance in the circuit. The relationship is expressed using the formula, V=IR, and means that the rate at which electrons move through a wire (current) is directly proportional to the amount of voltage in the wire. For example, doubling the voltage across a transmission line doubles the current.
⁶ EPA, supra note 1.
level. Therefore, as a nation, we are now researching and deploying solutions to effectively integrate the technologies and operational concepts of DG and DERs into the existing grid. By some estimates, DER may relatively soon supply as much as one-third of the nation’s capacity.\(^7\) Nonetheless, there are still challenges such as “unintentional islanding”\(^8\) and “free-rider” issues.\(^9\) As technology evolves to realize greater benefits and to avoid negative impacts on system reliability and safety, DG also faces market and regulatory challenges to implementation, which differ from state to state and in different utility services territories. DG systems presently are subject to a varying and different mix of local, state, and federal policies; regulations; and markets compared with traditional centralized generation. Policies and incentives vary widely from one place to another, affecting the financial attractiveness of a distributed generation project. Chapter 6 discusses some of the challenges and tools associated with financing the costs of widespread deployment of DG. It presents some of the different mechanisms to provide homeowners, business owners, and developers access to capital so that the potential revenue streams can be realized that come from installing DG.

Use of DG has increased for various reasons, including the following:

- Increased electric system reliability
- Reduction of peak power requirements
- Provision of ancillary services, including reactive power
- Improvements in power quality

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\(^7\) Jeff St. John, *Will Distributed Energy Make Up One-Third of the US Power Supply by 2020?*, GREEN TECH MEDIA, (Feb. 13, 2014), https://www.greentechmedia.com/articles/read/distributed-energy-to-be-one-third-of-u-s-power-supply-by-2020#gs .cHg2mzAV. The EIA defines electricity generation capacity as the maximum electric output an electricity generator can produce under specific conditions. Nameplate capacity is determined by the generator’s manufacturer and indicates the maximum output of electricity a generator can produce without exceeding design thermal limits. U.S. ENERGY INFO. ADMIN, *supra* note 5.

\(^8\) Unintentional islanding occurs when distributed resources become isolated from the rest of the electric grid and inadvertently continue to serve loads separately from the utility system. This condition is of concern because utilities can lose control of the voltage and the frequency that can have consequences on utility loads.

6 Distributed Generation Law

- Reductions in land-use effects and rights-of-way acquisition costs
- Reduction in vulnerability to terrorism and improvements in infrastructure resilience.\(^{10}\)

As renewable energy technologies have become cost-effective, communities, homeowners, and businesses have turned to DG.\(^{11}\) States and local governments continue to advance and encourage the deployment of DG, especially DG powered by renewable sources, because of real and perceived improvements in financing, cost effectiveness, energy security, resiliency, and improved environmental outcomes.

1.1.1 The Evolution of Distributed Generation

The concept of DG is as old as the electric power industry.\(^{12}\) In the early twentieth century, at the infancy of national electrification, all energy needs—including heating, cooling, lighting, and mechanical power—were supplied at, or near, their point of use. As the role of electricity in everyday American life expanded, and the demand for power increased, the national grid we know today began to emerge. Alternating current and large-scale steam turbines provided economies of scale in power production and delivery, enabling power plants to be built far from the ultimate consumer. This growing network of gigawatt-scale power plants far from the locus of demand in urban centers and connecting to end users through high-voltage transmission and lower voltage distribution lines was soon regulated as a public utility, cementing the structure of centralized power distribution.

In response to the oil crisis of 1973, Congress passed the Public Utility Regulatory Policies Act of 1978 (PURPA),\(^{13}\) which is discussed


\(^{11}\) EPA, supra note 1.


in greater detail in chapters 2 and 3. Section 210 of PURPA established a new class of non-utility generators called qualifying facilities (QFs) and required vertically integrated utilities to purchase energy from QFs to encourage the development of cogeneration and small power production. PURPA also contained a provision that spurred research and innovation in power generating technologies that use water, wind, or solar power to produce electricity. This sparked a new era of highly energy efficient and renewable DG for electric system applications. That research and innovation led to advancements such as a 70 percent drop in the cost of solar photovoltaic panels between 1980 and 1995 and led to costs for wind energy to be on par with conventional power plants by the mid-2000s.14

The success of these smaller-scale generation technologies challenged established paradigms. Regulators, academics, and consumers were encouraged by the increased innovations in energy efficiency and market competition spurred by PURPA. The traditional model of large utilities operating as public monopolies in a centralized system no longer seemed to provide the benefits to society it once had. In 1992, responding again to the rising cost of energy and the security of energy supplies, Congress passed the Energy Policy Act of 1992 (EPAct 1992),15 which gave the Federal Energy Regulatory Commission (FERC) the option to open transmission networks to competing power generators. The 1992 statute treats electric utility transmission lines like a “common carrier,” meaning any generator of electricity potentially could reach and sell power to any customer.16 After the passage of EPAct 1992 and the subsequent actions of federal regulators, states could compete on the retail level with utility companies.

Even in the traditional, centralized system of power generation, there have always been examples of DG. For example, in the industrial sector, some companies have long relied on their own self-generating

power systems, and some entities with needs for highly reliable power (such as hospitals and telecommunications centers) routinely install their own backup electric generation units to use in case of outages and during emergencies. The modern twist is that the creation of new technologies and the process of innovation that began with the implementation of PURPA Section 210, in conjunction with changing consumer needs and growing threats to reliability, continue to drive the demand for and expand the opportunities and applications for DG. Today’s technologies are allowing the consumer to use DG more broadly to meet their own needs while also providing a more nimble and reliable way for utilities to meet the needs of the system. The role of states in this evolution and in the regulatory system for DG are described in chapters 3 and 4.

1.2 Sources of Distributed Generation

1.2.1 Renewable Sources of Distributed Generation
Most renewable energy technologies can be used in centralized and distributed generation configurations and include solar, water (hydropower), wind, geothermal, biomass, and piezoelectric energy. Siting, permitting, and environmental issues associated with these technologies are addressed in chapter 5.

1.2.2 Solar Power
Solar power is used in a variety of configurations for DG. The primary form of distributed solar generation is solar photovoltaic (PV) in a number of rooftop and ground-mounted applications. Solar PV cells create electricity by harnessing the photons in sunlight, which releases electrons in the solar cell and uses conductors attached to each side of the cell to convert the sunlight into electricity. A collection of solar PV cells arranged in modules in various sizes and configurations is referred to as solar PV panel arrays, which, when combined with other components required to use the collected power, is referred to as a solar PV system. A PV system can be used for industrial, commercial, or residential use by a single customer at a business or home, or the PV system can be combined with multiple owners to create a shared PV system. Shared PV systems have been defined as “those
systems that allocate the electricity of a jointly owned system, or a third-party-owned system, to offset multiple individual businesses’ or households’ consumption participation in the program.”¹⁷ Shared PV systems provide the opportunity to own and benefit from distributed solar generation, where individual businesses or homeowners do not have the option for a roof or ground-mounted system.¹⁸ Shared PV systems can be on-site at a multi-unit building or offsite, in what are sometimes referred to as solar gardens. Shared PV systems may provide electricity directly to a home or business or in the instance of community solar gardens, provide the opportunity to subscribe to a solar PV installation that feeds into the electric grid and provides the subscriber credits on monthly utility bills.¹⁹

1.2.3 Water (Hydro) Power

Water power once served as the United States’ main form of electricity generation and continues to play a significant role in centralized and DG systems, despite movements to decommission dams to restore fish populations and the overall health of river systems. Water power can be a viable part of DG in various configurations of different sizes and storage impoundments based on end user location and needs. Hydropower projects large and small can serve as DG. The two most common types of distributed hydropower are: (1) small conduit hydropower and (2) energy recovery hydropower, described as follows. Although small hydropower does not have an exact definition and multiple thresholds are used at the international, federal, and state levels, for the purposes of this book we use the small hydroelectric exemption definition used by International Energy Agency

¹⁸ Id. at 35 (estimating that in 2015, 49 percent of households and 48 percent of businesses were not able to host their own PV system due to various reasons, including insufficient roof space and lack of ownership rights in the building).
and FERC; namely, small hydropower refers to those projects that are 10 MW or less.\textsuperscript{20}

In 2013, U.S. Congress passed the Hydropower Regulatory Efficiency Act, which defined conduit hydropower as hydropower using any “tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of agricultural, municipal, or industrial consumption and not primarily for the generation of electricity.”\textsuperscript{21} Small conduit hydropower may be connected to the grid or used solely to provide power directly on-site to a business or home. Energy recovery hydropower is a subset of small conduit hydropower, which has been defined as “hydropower built using an existing, pressurized, manmade water conveyance that is already diverting water from a natural waterway for the distribution of water for agricultural, municipal, or industrial consumption and not primarily for the generation of electricity.”\textsuperscript{22} Energy recovery hydropower is generally used on-site to offset energy costs (particularly for moving water) with hydropower generation. To date, energy recovery hydropower is most common in the western United States within the municipal (e.g., water supply or treatment) and agricultural industries.\textsuperscript{23} In the municipal water sector (e.g., water and waste water treatment), small hydropower generators may be installed in parallel to pressure-reducing valves to generate electricity while also reducing water pressure. In the agricultural sector, small hydropower generators are installed within the water infrastructure


\textsuperscript{23} \textit{Id.} at 7.
used to transport water to farms and ranches for irrigation and other agricultural purposes.\textsuperscript{24}

\subsection*{1.2.4 Wind Power}
Wind power can be used in commercial and residential configurations for distributed generation. The U.S. Department of Energy has identified two key attributes to characterize distributed wind:

- The proximity to end use (e.g., wind turbines either meeting purposes of on-site energy demand or supporting the local electric distribution grid)
- Point of interconnection (e.g., wind turbines connected on the customer side of the meter (behind the meter)), to the distribution grid, or in off-grid remote locations.\textsuperscript{25}

Distributed wind energy may be used in residential, agricultural, industrial, and community settings, ranging from 5 kW to multiple MWs; however, wind turbines with a rated capacity of 100 kW or less are the primary technology used in distributed wind applications.\textsuperscript{26} Importantly, this excludes large-scale wind development, which electric utilities use under the traditional model of large central station service to procure larger sources of firm energy. They can exceed 1,000 MWs in size.

\subsection*{1.2.5 Geothermal}
Geothermal power, particularly hydrothermal resources (i.e., geothermal resources that naturally contain the requisite fluid, heat, and permeability to generate electricity),\textsuperscript{27} are found deep beneath the earth’s surface and can be used in a variety configurations for distributed generation. These configurations include small grid-connected units,

\begin{thebibliography}{99}
\bibitem{24} Id. at 9.
\bibitem{26} Id.
\end{thebibliography}
units designed for co-production in an active oil and gas field to offset on-site energy costs, or even units in no longer active oil and gas fields in close proximity to distribution systems. To date, none of these applications of distributed geothermal have gained widespread support or use in the United States. However, small distributed grid-connected geothermal units exist elsewhere, including in Iceland.

Geothermal exploration and resource confirmation have high upfront costs and risks associated with confirming the existence of a geothermal resource suitable for electricity generation, which presently makes small distributed geothermal projects difficult to finance in a greenfield (area without a producible known geothermal resource). Development of geothermal resources in active and abandoned oil and gas fields has yet to gain widespread use from either the oil and gas or geothermal industries.

1.2.6 Biomass

Biomass power plants generate energy from natural organic and other sustainable sources, such as wood, crop residue, dried vegetation, and organic waste products. Distributed biomass power plants have generally ranged from 1 MW to 50 MW in size, based on the fuel available for generation. These sustainable sources of bioenergy contain energy stored from the sun through the process of photosynthesis. Biomass power plants generate electricity (and heat) by burning the biomass material in a hot water or steam boiler in a process similar to that used for generating electricity from fossil fuel sources such as coal and natural gas.

1.2.7 Piezoelectric Energy

Piezoelectric energy is a source of renewable energy that converts the kinetic energy from vibrations or shocks into electrical energy using

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piezoelectric crystals.\textsuperscript{30} Sources of piezoelectric energy may include footfall from pedestrian walkers and potentially road vibrations from automobiles and trucks.

\section*{1.3 Fossil Fuel Sources of Distributed Generation}

Fossil fuel sources can serve as sources of centralized and DG (e.g., in diesel generators, microturbines, combined heat and power \texttt{[CHP]}, and natural gas generators as distributed sources of generation).

\subsection*{1.3.1 Natural Gas Generators}

Distributed natural gas generators describe a group of gas-fueled technologies, including fuel cells, microturbines, reciprocating engines, and turbines, to produce distributed generation, which may also include CHP.

Natural gas generators are commonly used as a source of DG at a single location or as part of a larger microgrid. For example, the medical area total energy plant (MATEP) in Boston, Massachusetts, is a microgrid and district energy system serving five hospitals affiliated with Harvard Medical School and the Harvard Institutes of Medicine and School of Public Health. The microgrid is a CHP facility powered by natural gas-fired combustion turbines with heat recovery steam generators, steam generators, and a chilled water system. MATEP generates and distributes electricity, steam (heat), and chilled water throughout the network for lighting, heating, and air conditioning, among other uses.\textsuperscript{31} MATEP can produce 99 MW of electricity, 1,100 pounds per hour of steam, and 42,000 tons of chilled water.\textsuperscript{32} In the event of an electric outage, the system can operate in island mode or as independent from the larger grid.\textsuperscript{33}


\textsuperscript{33} Gorman, \textit{supra} note 31.
1.3.2 Diesel Generators
The most common small-scale generator used in DG configurations is fueled by diesel, which can be quickly deployed and refueled. This makes diesel fuel particularly useful for DG installations that either depend on an intermittent resource such as solar PV or which are in place as emergency alternatives during outage crises such as storms. Easy transportation and storage of diesel fuel also make it a common choice for stand-alone systems such as those on islands. Diesel generators combine an electric generator with a diesel engine (powered by diesel gas) to generate electricity. Diesel generators are grid-connected and grid independent, depending on the location and use (e.g., backup/emergency generation, or on-site power generation).

1.3.3 Microturbines
Microturbines are a distributed generation technology approximately the size of a refrigerator that use small combustion turbines to produce between 23 kW and 500 kW of power. Microturbines burn gases or liquids (e.g., natural gas, sour gas, gasoline, kerosene, diesel, or heating oil) to drive an electrical generator and produce electricity.34

(a) Combined Heat and Power. CHP systems, also known as cogeneration, generate electricity and useful thermal energy in a single, integrated system, typically through a heat engine or power station. CHP is not itself a technology, but an approach to applying technologies for cogeneration. The heat from CHP systems can play a central role in district heating, water heating, and use in other domestic and industrial processes as well as in electricity generation.

(b) Fuel Cells. Fuel cells use the chemical energy of hydrogen or an alternative fuel to produce electricity. Fuel cells vary in size considerably and are able to provide power for large and small applications. Fuel cells work similar to batteries, but rather than depleting and or

needing to recharge; they produce electricity and heat continuously as long as fuel is supplied.\textsuperscript{35}

### 1.4 The Role of Energy Storage

Energy storage devices include battery energy storage, flywheel energy storage, and pumped storage hydropower. They are a collection of technologies designed to store power for flexible use as needed. Energy storage devices can play an integral role in distributed generation systems, offering added resiliency, on-demand use, and increased market value. Energy storage devices may play a particularly important role in managing load for a distributed system with high levels of variable renewable energy, such as wind or solar. That is, the sun does not always shine and the wind does not always blow. As technology advances, increasingly cost-effective energy storage options are bolstering the move from large, centrally located power generation to a more distributed and renewable energy supply. Simultaneously, federal policies are facilitating the development and integration of energy storage systems into the grid. Chapter 9 discusses the role of energy storage in DG.

#### 1.4.1 Battery Energy Storage

Various battery technologies provide energy storage solutions, including solid-state batteries and flow batteries. Solid-state batteries (e.g., lithium ion, nickel cadmium, and sodium sulfur), consisting of electrochemical cells that convert chemical energy into electrical energy.\textsuperscript{36} Flow batteries (e.g., redox flow, iron-chromium flow, vanadium redox flow, zinc-bromine flow) are a type of battery that recharges through two chemical components dissolved in liquids contained within the system and are most commonly separated by a membrane. Flow batteries are similar to a fuel cell and a battery.\textsuperscript{37} Specific battery issues (e.g., charge times and range) are discussed in chapter 9.


\textsuperscript{37} Id.
1.4.2 Flywheel Energy Storage
A flywheel is a rotating mechanical device that stores rotational energy, which is available on demand. A flywheel contains a spinning mass driven by a motor in its center, and when power is needed, it uses a device similar to a turbine to produce electricity.38

1.4.3 Pumped Storage Hydropower
Pumped storage hydropower systems, while generally used for utility-scale energy storage, have the potential to downscale for storage in distributed generation. Pumped storage hydropower systems typically include an upper and lower reservoir, in which water is pumped from the lower reservoir into the upper reservoir to store the water that would otherwise be spilled and used to generate hydropower. When electricity is needed, the water from the upper reservoir is diverted through a penstock and a turbine, using gravity and water flow to produce electricity. Closed-loop pumped storage projects (i.e., those not connected to a naturally flowing water feature) using man-made reservoirs/storage tanks have the potential to serve as distributed generation storage devices.39

1.5 The Role of Energy Efficiency and Demand Response
In addition to a distributed source of generation, other DERs can reduce electricity demands for businesses and homes. These technologies include geothermal resource direct use, solar thermal and passive solar, and energy-saving devices. Energy efficiency and demand response technologies can save energy through increased efficiency or reduced consumption. Savings from these technologies can be calculated in negative megawatts of energy savings (negawatts).

1.5.1 Geothermal Direct-use and District Heating (including Ground-Source Heat Pumps)

Direct use of geothermal resources involves using underground hot water for heating buildings and other industrial or agricultural uses (i.e., not for directly generating electricity, but which reduce the need for electricity). Geothermal direct-use applications use low-temperature geothermal resources in the temperature range of 20°–150° C or 68°–302° F. Direct-use systems are typically composed of three components: (1) a production facility (most likely a well) to bring the hot water to the surface, (2) a mechanical system (e.g., piping, heat exchanger, control systems) to deliver the heat for the applicable use; and (3) a disposal system (e.g., an injection well, storage pond, or sump; or river to receive the cooled geothermal fluid). In commercial settings, direct-use and district heating can provide heating for hospitals, university campuses, and businesses (e.g., plant growth in greenhouses; heating water for fish farms; heating for commercial hot springs; snowmelt on runways, streets, and sidewalks).

In residential settings, geothermal or ground source heat pumps can meet residential heating and cooling needs for aggregation of homes or an individual residence using the constant temperature of the earth as an exchange medium instead of outside air temperatures. The process results in using the temperature of the earth for a heating source in the winter months and a cooling source in the summer months.

1.5.2 Solar Water Heating and Passive Solar Technologies

Solar thermal technologies, such as solar water heating systems, include storage tanks and solar collectors to heat water for commercial or residential use. Solar water heating systems can be either “active” or “passive.” Active solar water heating systems include circulating pumps and control systems, while passive solar water heating systems do not.

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Passive solar technologies may also be used to collect heat through windows with southern sun exposure and retain the heat through materials, known as thermal mass. The thermal mass may include concrete, brick, stone, tile, and other sources that absorb the heat brought into the home during the winter months while using thermal mass in summer months to absorb hot air in the house for cooling purposes.41

1.5.3 Demand Response Technologies
Demand response generally refers to the concept of consumer behavior influencing the operation of the electric grid through a reduction or shifting of electricity usage during periods of peak demand to assist in balancing the overall supply and demand for electricity. Demand response programs may take the form of time-based rates or other financial incentives to encourage electricity users to assist in reducing peak load. Demand response programs also may include interruptible direct load control programs that allow electric utilities to access and cycle individual customers’ air conditioners and water heaters on and off during peak demand in exchange for financial incentives. For example, a utility may offer a program that provides reduced electric charges in exchange for the ability to turn an air conditioning unit on and off in twenty-minute intervals on a hot summer day to reduce total electricity demand on the system.42

1.6 Microgrids
A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously.43 According to the Department of Energy Exchange Group, microgrids have the following criteria:

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 grid-connected or island mode.44

The key features of a microgrid is that it is locally controlled and that it can disconnect from the main grid and operate autonomously—for physical or economic reasons. Microgrids are not defined by a particular type of DER or generation source. In fact, many microgrids employ a combination of generation sources.

The defining characteristic of a microgrid is that it is not dependent on its interconnection with the main grid. This means during times of crisis such as extreme weather, power outages for repairs or heavy demand, terrorism, or even for economic and environmental reasons, a microgrid can switch off from the main grid and operate independently using own locally generated electricity. A microgrid connects to the main electric grid at a point of common coupling that maintains voltage at the same level as the main grid unless there is some sort of problem on the grid or other reason to disconnect.

A switch can separate the microgrid from the main grid automatically or manually. When switched off, it functions as an electric generation and use island.45 Microgrids are also not defined by size. A microgrid can power a single facility like the Santa Rita Jail microgrid in Dublin, California, or can be part of a community’s larger goal to create an entire district that produces the same amount of energy it consumes, such as in Fort Collins, Colorado.46

The Lawrence Berkeley National Lab describes two major types of microgrids.47 The first type are microgrids that operate wholly on one site such as a university, military base, or corporate or industrial facility are commonly called a campus microgrid, a customer microgrid, or true microgrid. A well-known example of this type of microgrid is a CHP system serving a university. This on-site system may consist of a combustion turbine that burns natural gas to turn generators to

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44 Id.
45 Id.
46 Id.
47 Id.
produce electricity as described above. The system operates in parallel with the grid under normal conditions and serves as a backup source of power during an outage.

The second type of microgrid serves multiple customers within a community, typically to provide power to community assets, such as hospitals, police, and fire stations, and water treatment facilities. These microgrids are like customer microgrids in that they typically operate in synchrony with the traditional grid until there is an outage. A unique characteristic of community microgrids, however, is that they integrate with the local utility by using the existing distribution-level infrastructure, which accounts for their increased capabilities and potential to expand. This kind of microgrid, which involves a segment of the legacy regulated grid, also has been called a milligrid. Finally, it should be noted that remote places, such as islands or the deep wilderness, may use off-grid systems because it is technically or economically infeasible to connect with the traditional grid. These systems are examples of DG, but they do not fit the Department of Energy’s definition of microgrids because they cannot operate in grid-connected and island mode.

The benefits of microgrids include improved energy efficiency, minimization of overall energy consumption, reduced environmental impact, and improvement of reliability of supply. There are also benefits to the overall grid, such as loss reduction, congestion relief, voltage control, or security of supply and more cost-efficient electricity infrastructure replacement.

A key advantage of microgrids is that by allowing localized control, they are more likely to lead to wiser energy consumption choices and can be used to coordinate and integrate DER into current grid operations. The use of microgrids is also often used to support the smart grid concept.


50 The smart grid concept is a way to modernize the grid to make it smarter and more resilient by using technologies, equipment, and controls that communicate...
1.7 Impact of Electric Vehicles on Distributed Generation

The expected electrification of the automotive sector will have a significant impact on the design of the power system. By some estimates, there will be seven million plug-in electric vehicles (PEVs) on the road by 2025. That equates to about 3 percent of registered vehicles in the United States. These vehicles will require five million charging ports by 2025. The growth and expansion of the PEV market is such that, if managed and treated as a pooled resource, PEVs could provide a significant distributed energy resource by providing, for example, demand response and voltage regulation. Utility planners are expending significant efforts trying to anticipate how changes in mobility will affect lifestyle and demand for power. Of significance to DG, plug-in hybrid electric vehicles and all-electric vehicles (often collectively referred to as PEVs) will need to be charged and will have batteries that store electricity in batteries to power one or more electric motors. The batteries are charged primarily by plugging into off-board sources of electricity.

and work together to deliver electricity more reliably and efficiently. These technologies are made possible by two-way communication technologies, control systems, and computer processing. Such technologies can greatly reduce the frequency and duration of power outages, reduce storm impacts, and restore service faster when outages occur. Consumers can use the technology to better manage energy consumption and costs based on real-time data. Utilities can use the technology to improve security, reduce peak loads, increase integration of renewables, and lower operational costs. See The Smart Grid: An Introduction, Dep’t of Energy Off. of Electricity, https://www.energy.gov/oe/downloads/smart-grid-introduction-0 (last visited Dec. 28, 2019).


52 Id.


This impact has two facets. First is the impact that such an increase in demand for electricity will have on our electric grid. The second is the capacity of PEVs that are connected to the grid to be used as storage. Although it can be anticipated that a significant portion of PEV charging will occur at night or on weekends, when the PEVs are not in use, at least some PEV charging will occur during the day and likely even during peak demand periods when the grid is already providing the maximum amount of power. This presents an issue because utilities will have to provide sufficient capacity to accommodate the extra power needs from the growing number of PEVs. Alternatively, DERs could be used to add needed capacity.

There are three types of PEV-charging infrastructure: **Level 1 (L1)**—120-volt, alternating current (AC) power, **Level 2 (L2)**—240-volt, AC power, and **direct current fast charger (DCFC)**. Level 1 charging refers to charging stations, as well as typical electric outlets that a driver plugs into via a cord set included with the vehicle. A PEV connected to a Level 1 charger presently takes about twelve hours to charge a fully depleted fifty-mile battery (about four miles of electric range per hour of charging). Level 2 chargers typically are mounted on a wall or a pedestal. A PEV connected to a Level 2 charger presently takes between three and five hours to charge a fully depleted fifty-mile battery (about ten to twenty miles of electric range per hour of charging depending on the PEV). A DCFC converts AC electricity to direct current (DC) and delivers a charge to the vehicle at higher power, typically 50 KW or greater. A PEV connected to a DC fast charger presently takes about thirty minutes to charge a fully depleted battery to about 80 percent, depending on battery size. It should be noted that not all PEVs can accept DC fast charging.

Although there is widespread consensus that PEVs will have an impact on the grid, there are open questions about vehicle-to-grid infrastructure. For example, will PEV-charging infrastructure be able to serve as energy storage devices at either the large-scale fleet level (e.g., school buses, delivery trucks, ride-share fleets) or the individual level (e.g., home battery storage solutions)? Utilities, vehicle manufacturers, charging equipment manufacturers, researchers, and

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55 Vehicle-to-grid technology allows PEVs that are connected to the grid to be used in lieu of or in conjunction with electricity storage to supply power to the grid.
consumers are working to ensure that PEVs are smoothly integrated into the U.S. electricity infrastructure. Researchers at the National Renewable Energy Laboratory (NREL) have developed deployment models\textsuperscript{56} that show the diversity of household electricity loads and EV loads should allow for the introduction and growth of the PEV market while smart grid networks expand. The NREL analysis also demonstrated the potential for synergies between PEVs and distributed sources of renewable energy. Notwithstanding the continued growth of EVs, the number of public EV charging stations across the country has remained low. Chapter 10 considers the hazy regulatory environment that continues to surround EV charging stations. Although there are legal and technical challenges, it is possible that EVs could be a non-trivial electric supply resource during the times when the grid is facing a crisis or emergency.

1.8 Conclusion and Subsequent Chapters

That DG is a fast-growing trend in energy delivery is not contested. It is also arguably one of the most transformational developments in restructuring the nation’s electric power grid. The proliferation of DG is impacting every facet of the power industry, including planning, engineering, operations, economics, and governance. This book seeks to provide readers with an overview of these emerging legal and policy issues through the following chapters:

Chapter 2 tells the story of the historical development of electricity markets and the federal law applicable to electricity more generally. Focused on the traditional cooperative federalism structure, whereby the federal government regulates wholesale electricity markets and states regulate retail electricity markets, chapter 2 sets the stage for chapter 3, which discusses the state role in this regulatory scheme. Chapter 2 introduces fundamental electricity laws, including the Federal Power Act (FPA) and the PURPA, as well as the role of FERC and relevant FERC orders related to the development of regional transmission organizations and independent system operators as well as energy storage.

Chapter 3 analyzes the state’s role in the development of law and policy applicable to distributed generation, including the state role within the FPA and PURPA. Chapter 3 includes key precedents related to jurisdictional issues concerning distributed generation and a discussion of state policies such as net-metering, renewable portfolio standards (RPS), and feed-in tariffs. Chapter 4 further illustrates the state role in distributed generation law and policy by providing state specific summaries for Illinois, Minnesota, Hawaii, New York, and California.

Chapter 5 introduces the economics of distributed generation, including valuation and pricing. It explains, in the context of DG, renewable energy certificates (RECs) under state renewable portfolio standards (RPS) structures, power purchase agreements, and the role of evolving grid architecture in light of increased distributed generation and the use of microgrids.

Chapter 6 discusses siting, permitting, and environmental issues associated with the development of distributed generation. It provides an overview of applicable federal environmental laws, land use planning and zoning, interconnection and permitting, and property laws related to easements for wind and solar installations.

Chapter 7 presents some of the challenges and tools associated with financing the costs of the widespread deployment of DG. It explains discretely (1) soft costs associated with customer acquisition, permitting, inspection, interconnection to the electric grid, installation, taxation and system financing, and (2) design, construction, engineering, and operating costs. It describes some of the different mechanisms to provide homeowners, business owners, and developers access to capital so that the potential revenue streams can be realized that come from installing DG.

Chapter 8 lays out the state and federal legal frameworks that have evolved to address the privacy and cybersecurity concerns that accompany DERs and their data. DG and DERs generate a large amount of data that provides valuable information for utilities, policymakers, and private industry that includes not only the customer data typically collected by companies (e.g., payment information and addresses) but also data about amount and times of collection. DG and DERs also collect information to support new technologies such as wireless monitoring systems and remote start capability that allow
third parties to monitor grid conditions and optimize the deployment of energy in real time. This sort of usage data can be a potential point of entry for hackers seeking access to the grid. Alternatively, if the data is not protected, end users are vulnerable to potential misuse of individual data by third parties.

Chapter 9 discusses the important role of energy storage in DG. It examines the commercial aspects of energy storage transactions, as well as the types of policies that are used to encourage the cost-effective deployment of energy storage. At the distribution level, state incentives and public utility regulatory policy have been major drivers of energy storage deployment. Increasingly cost-effective energy storage options are bolstering the move from large, centrally located power generation to a more distributed and renewable energy supply. Simultaneously, federal policies are facilitating the development and integration of energy storage systems into the grid.

Chapter 10 considers the regulatory environment for EV charging stations. It discusses the three approaches regulators have generally followed: (1) refraining from taking any action; (2) affirmatively deciding that utilities may own and operate EV charging stations; or (3) exempting EV service providers from existing public utility regulations through legislation or the interpretation of statutes and regulations.

Chapter 11 looks at the climate change-related policies that influence the development of distributed energy resources. It discusses the various international policies and frameworks and their use to promote DG investment and further DG deployment.

Energy is essential to the U.S. military’s mission and is a critical need for all aspects of military operations. The U.S. military is the largest consumer of energy in the world, with an annual energy budget of between $12 billion and $20 billion. Therefore, it is no surprise that the U.S. Department of Defense is increasingly integrating DG systems into its operational and installation energy portfolio to support its missions worldwide. Chapter 12 examines the evolution of the military’s approach to DG positioned within or nearby military installations in the United States.