1

Introduction

1.1 Why Competition?

For most of the twentieth century, when consumers wanted to buy electrical energy, they had no choice. They had to buy it from the utility that held the monopoly for the supply of electricity in the area where these consumers were located. Some of these utilities were vertically integrated, which means that they generated the electrical energy, transmitted it from the power plants to the load centers, and distributed it to individual consumers. In other cases, the utility from which consumers purchased electricity was responsible only for its sale and distribution in a local area. This distribution utility in turn had to purchase electrical energy from a generation and transmission utility that had a monopoly over a wider geographical area. In some parts of the world, these utilities were regulated private companies, while in others they were public companies or government agencies. Irrespective of ownership and level of vertical integration, geographical monopolies were the norm.

Electric utilities operating under this model made truly remarkable contributions to economic activity and quality of life. Most people living in the industrialized world have access to an electricity distribution network. For several decades, the amount of energy delivered by these networks doubled about every 8 years. At the same time, advances in engineering improved the reliability of the electricity supply to the point that in many parts of the world the average consumer is deprived of electricity for less than 2 min per year. These achievements were made possible by ceaseless technological advances. Among these, let us mention only the development and erection of transmission lines operating at over 1 000 000 V and spanning thousands of kilometers, the construction of power plants capable of generating more than 1000 MW and the on-line control of the networks connecting these plants to the consumers. Some readers will undoubtedly feel that on the basis of this record, it may have been premature to write the first paragraph of this book in the past tense.

In the 1980s, some economists started arguing that this model had run its course. They said that the monopoly status of the electric utilities removed the incentive to operate efficiently and encouraged unnecessary investments. They also argued that the cost of the mistakes that private utilities made should not be passed on to the consumers. Public utilities, on the other hand, were often too closely linked to the government. Politics could then interfere with good economics. For example, some public utilities were treated as cash cows, others were prevented from setting rates at a level that reflected costs or were deprived of the capital that they needed for essential investments.

Fundamentals of Power System Economics, Second Edition. Daniel S. Kirschen and Goran Strbac.

These economists suggested that prices would be lower and the overall economy more efficient if the supply of electricity was subjected to market discipline rather than monopoly regulation or government policy. This proposal was made in the context of a general deregulation of Western economies that had started in the late seventies. Before attention turned toward electricity, this movement had already affected airlines, transportation and the supply of natural gas. In all these sectors, a regulated market or monopolies had previously been deemed the most efficient way of delivering the "products" to the consumers. It was felt that their special characteristics made them unsuitable for trading on free markets. Advocates of deregulation argued that the special characteristics of these products were not insurmountable obstacles and that they could and should be treated like all other commodities. If companies were allowed to compete freely for the provision of electricity, the efficiency gains arising from competition would ultimately benefit the consumers. In addition, competing companies would probably choose different technologies. It was therefore less likely that the consumers would be saddled with the consequences of unwise investments.

If kilowatt-hours could be stacked on a shelf – like kilograms of flour or television sets – ready to be used as soon as the consumer turns on the light or starts the industrial process, electricity would be a simple commodity, and there would be no need for this book. However, despite recent technological advances in electricity storage and micro-generation, this concept is not yet technically or commercially feasible. The reliable and continuous delivery of significant amounts of electrical energy still requires large generating plants connected to the consumer through transmission and distribution networks and careful attention must be paid to reliability.

In this book, we explore how various aspects of the supply of electricity can be packaged into products that can be bought and sold on open markets. Because these products cannot be fully separated from the supply infrastructure, we also discuss how their trading affects the operation of the power system and, in turn, how operational constraints impinge on the electricity markets.

In the long run, the need always arises to invest in new facilities, either because a new technology holds the promise of greater profits or simply because equipment age and need to be replaced. Here again we will need to examine the interplay between market-driven behavior, physical constraints, and the need for reliability.

1.2 Market Structures and Participants

Before we delve into the analysis of electricity markets, it is useful to consider the various ways in which they can be structured and to introduce the types of companies and organizations that play a role in these markets. In the following chapters, we will discuss in much more detail the function and motivations of each of these participants. Since markets have evolved at different rates and in somewhat different directions in each country or region, not all these entities will be found in each market.

1.2.1 Traditional Model

In the traditional market model (Figure 1.1), trading is limited to consumers purchasing electricity from their local electric utility. This utility has two main characteristics. First, it

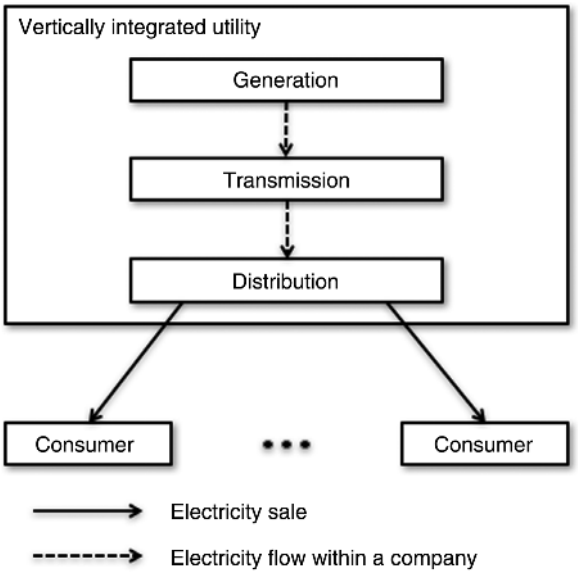

Figure 1.1 Traditional model of electricity supply.

has a monopoly for the supply of electricity over its service territory. If consumers want to purchase electricity, they do not have a choice: they have to buy it from this utility. Second, the utility is vertically integrated. This means that it performs all the functions required to supply electricity: building generating plants, transmission lines and distribution networks, operating these assets in a reliable manner, and billing the consumers for the service provided.

In a fairly common variant of the traditional model (Figure 1.2), the vertically integrated utility is split in two parts. One organization generates and transmits electricity over a fairly wide area and sells it to several distribution companies (*Discos*), each of which has a local monopoly for the sale of electricity to consumers.

Because monopolies could take advantage of the fact that their customers do not have a choice to charge them extortionate prices, they must either be government entities or be subject to oversight by a government department, which we shall call the regulator. In the traditional model, the regulator enforces what is called the regulatory compact. This is an agreement that gives a utility a monopoly for the supply of electricity over a given geographical area. In exchange, the utility agrees that its prices will be set by the regulator, that it will supply all the consumers in that area, and that it will maintain a certain quality of service.

This model does not preclude bilateral energy trades between utilities operating in different geographical areas. Such trades take place at the wholesale level, i.e. through interconnections between transmission networks.

The problem with the traditional model and its variant is that monopolies tend to be inefficient because they do not have to compete with others in order to survive. Furthermore, because their operations are rather opaque, regulators have difficulties assessing where improvements could be made.

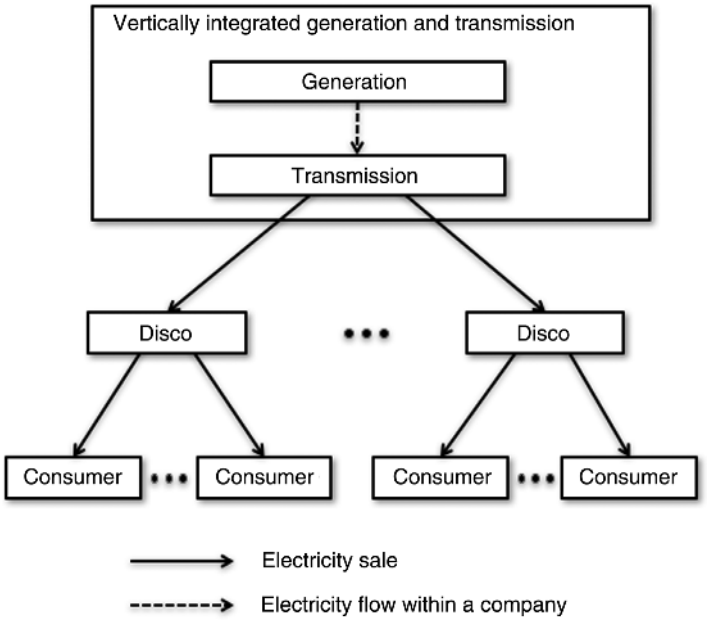

Figure 1.2 Variant on the traditional model of electricity supply.

1.2.2 Introducing Independent Power Producers

A first step toward a more competitive industry structure consists in allowing other companies (called *independent power producers* or *IPPs*) to produce part of the electrical energy that the incumbent vertically integrated utility must supply to its customers. Figure 1.3 illustrates this arrangement. While this model introduces a degree of competition at the generation level, it does not provide a mechanism for discovering cost-reflective prices in the same way that a free market does (see Chapter 2). The incumbent

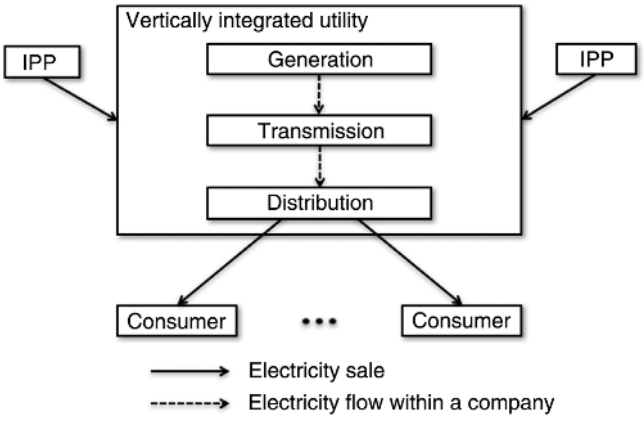

Figure 1.3 Incumbent vertically integrated utility with independent power producers (IPPs).

utility would like to pay as little as possible for the energy produced by the IPPs to discourage them from expanding their generation capacity. It must therefore be forced by law to buy the power produced by the IPPs. Given this guarantee that their production will be purchased, the IPPs will try to get as high a price as they can. This leaves the regulator with the task of deciding what an equitable price would be. In the absence of detailed and reliable information, the result will often be economically inefficient.

1.2.3 Wholesale Competition

A further step toward competitive electricity markets consists in getting rid of the incumbent utility. As illustrated in Figure 1.4, all the companies that own large generating plants (*Gencos*) then compete on an equal basis to sell electrical energy.

Distribution companies purchase the electrical energy consumed by their customers on this wholesale electricity market. The largest consumers are often allowed to participate directly in this market. As we will discuss in Chapter 3, this wholesale market can operate in a centralized manner or can be based on bilateral transactions. In this model, the wholesale price of electricity is determined by the interplay of supply and demand. On the other hand, the retail price of electrical energy must remain regulated because each distribution company retains a local monopoly over the sale of electrical energy flowing through its network.

When the wholesale market is operated in a centralized manner, an organization called *independent system operator* (*ISO*) must be created. This ISO has two main functions. First, it must manage the market in an impartial and efficient manner. Second, it is responsible for the reliable operation of the transmission system. As its name implies, to ensure the fairness of the market, the ISO has to be institutionally independent from all market participants.

In a bilateral wholesale market, these functions are often split between one or more *market operators* (*MOs*), whose role is to facilitate commercial transactions between buyers and sellers of electrical energy, and a *transmission system operator* (*TSO*), who keeps the system in balance and operationally reliable. While TSOs often own the transmission assets (lines, transformers, substations, etc.), ISOs usually do not.

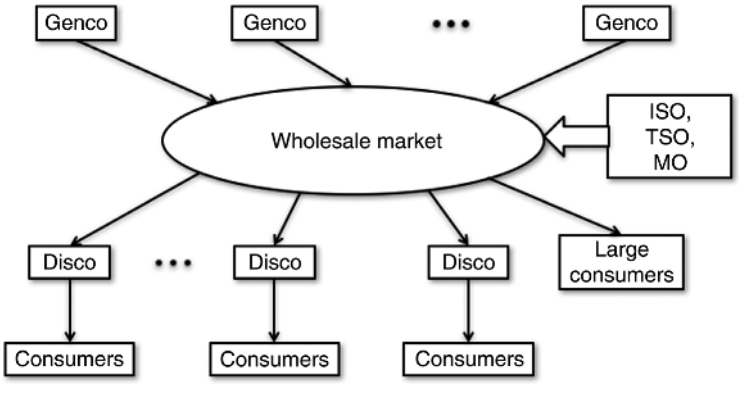

Figure 1.4 Wholesale electricity market structure.

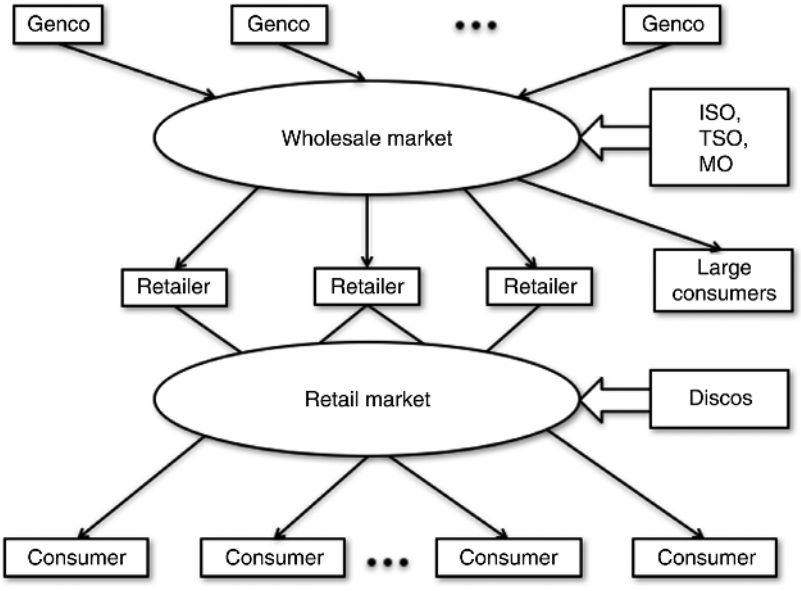

Figure 1.5 Market with retail competition.

1.2.4 Retail Competition

Competition can also be introduced in the retail market. This leads to the structure illustrated in Figure 1.5, where *retailers* purchase electrical energy in bulk on the wholesale market and resell it to small- and medium-size consumers. In this model, the "wires" activities of the distribution companies are normally separated from their retail activities because they no longer have a local monopoly for the supply of electrical energy in the area covered by their network. One can view the wholesale market as operating over the transmission network while the retail market takes place over the distribution network. Building and operating the transmission and distribution networks remain monopoly activities because it is generally agreed that building competing sets of wires would be wasteful. The regulator thus has to decide what investments in network assets are justified and how the cost of these investments should be allocated to the users of the networks.

Once sufficiently competitive markets have been established, the retail price no longer has to be regulated because small consumers have the option to change retailer if they are offered a better price or better service. As we will see in Chapter 2, from an economics perspective, this is desirable because market interactions lead to the discovery of economically efficient prices.

1.2.5 Renewable and Distributed Energy Resources

Over the last two decades, public policies aimed at reducing carbon emissions to mitigate climate change have significantly altered the mix of generation technologies in many parts of the world. Because wind and solar generation now contribute a substantial fraction of the overall production of electrical energy, electricity markets have had to

adapt to their intermittent and stochastic nature. To deal more efficiently with the larger imbalances between generation and load that renewable generation causes, markets operate on a much shorter time frame than before. Another adaptation is the increasing reliance on flexibility from the demand side to help maintain this balance. Marshaling demand-side resources is challenging because they tend to be small and distributed throughout the system. Direct participation in the wholesale electricity markets by distributed energy resources (such as demand response, small-scale energy storage, and photovoltaic generation) is not possible because it would vastly increase the number of market participants and render these markets unmanageable. In addition, the rules of the wholesale markets are complex and the requirements for participation are strict, making the transaction costs prohibitively expensive for small participants. To overcome this problem, new entities called *aggregators* are emerging. Their role is to serve as a commercial and technical intermediary between the wholesale markets and the owners of distributed energy resources who could contribute to the economic efficiency of the overall system.

1.3 Dramatis Personae

This section summarizes the roles of the different types of organizations that operate in the various market structures. Some of these organizations were already introduced in the previous section. In some markets, a single commercial entity or subsidiaries of this entity may be allowed to perform the functions of two or more of the organizations listed below. The names given to different types of organizations may also differ from country to country.

Vertically integrated utilities own and operate all the assets needed to supply electrical energy: generating plants, transmission networks, and distribution networks. In a traditional regulated environment, such a company has a monopoly for the supply of electricity over a given geographical area. Once a wholesale electricity market has been established, the functions and assets of the vertically integrated utilities are divided between other types of organizations.

Generating companies (*gencos*) own generating plants and sell electrical energy. They may also sell services such as regulation, voltage control and reserve that the system operator needs to maintain the quality and operational reliability of the electricity supply. A generating company can own a single plant or a portfolio of plants of different technologies. Generating companies that coexist with vertically integrated utilities are called IPPs.

Distribution companies (*discos*) own and operate distribution networks. Unless a retail market has been organized, discos have a monopoly for the sale of electrical energy to all consumers connected to their network. When a retail market is in operation, discos are no longer responsible for the sale of energy to consumers and their role is limited to the operation and development of the distribution network.

Retailers buy electrical energy on the wholesale market and resell it to consumers who do not wish or are not allowed to participate in this wholesale market. Retailers do not have to own any power generation, transmission or distribution assets. Some retailers are subsidiaries of generation or distribution companies. All the customers of a retailer do not have to be connected to the network of the same distribution company.

Market Operators (*MOs*) run computer systems to match the bids and offers that buyers and sellers of electrical energy submit. They also take care of the settlement of the accepted bids and offers, i.e. they forward payments from buyers to sellers following delivery of the energy. Independent for-profit MOs often manage electricity markets that close some time ahead of real time. On the other hand, the ISO runs the market of last resort, i.e. the market where load and generation are balanced in real time.

The primary responsibility of an **Independent System Operator** (*ISO*) is to maintain the stability and operational reliability of the power system. It is called independent because in a competitive environment, the system must be operated in a manner that does not favor or penalize one market participant over another. ISOs normally own only the computing and communications assets required to monitor and control the power system. An ISO usually combines its system operation responsibility with the role of operator of the market of last resort. ISOs are also called **regional transmission organizations** (*RTOs*).

Transmission companies (*transcos*) own transmission assets such as lines, cables, transformers, and reactive compensation devices. They operate this equipment according to the instructions of the ISO.

Transmission System Operators (*TSOs*) combine the function of ISOs with the ownership of transmission assets.

Small consumers buy electrical energy from a retailer and lease a connection to the power system from their local distribution company. Their participation in the electricity market usually amounts to no more than choosing one retailer among others when they have this option. **Aggregators** contract with a number of small consumers to reduce or shift their demand in time on request. The combined effect is then sufficiently large to be sold on the wholesale market.

On the other hand, **large consumers** often have the skills and technical resources needed to trade directly on the wholesale electricity markets.

A **regulator** is a governmental body responsible for ensuring the fair and efficient operation of the electricity sector. It determines or approves the rules of the electricity market and investigates suspected cases of abuse of market power. The regulator also sets the prices for the products and services that are provided by monopolies. Regulatory functions are sometimes divided between two levels of government. For example, in the United States, the Federal Energy Regulatory Commission regulates interstate transmission and wholesale electricity markets, while the public utilities commission of each state regulates the retail markets and the distribution networks. In addition to their purely economic function, regulators also set the rules required to ensure the reliability and quality of the electricity supply. In some cases, the technical details of these rules are administered by a specialist organization, such as NERC in North America or ENTSO-E in Europe.

1.4 Competition and Privatization

In many countries, the introduction of competition in the supply of electricity has been accompanied by the privatization of some or all components of the industry. Privatization is the process by which publicly owned utilities are sold by the government to private investors. These utilities then become private, for-profit companies. Privatization is not,

however, a prerequisite for the introduction of competition. None of the models of competition described above implies a certain form of ownership. Public utilities can coexist with private companies in a competitive environment.

1.5 Experience and Open Questions

In the monopoly utility model, all technical decisions regarding the operation and the development of the power system are taken within a single organization. In the short term, this means that, at least in theory, the operation of all the components of the system can be coordinated to achieve least cost operation. For example, the maintenance of the transmission system can be scheduled jointly with the maintenance of the generation units to co-optimize reliability and economy. Similarly, the long-term development of the system can be planned to ensure that the transmission capacity and topology match the generation capacity and location.

Introducing competition implies renouncing centralized control and coordinated planning. A single integrated utility is replaced by a constellation of independent companies, none of which has the responsibility to supply electrical energy to all the consumers. Each of these companies decides independently what it will do to maximize its private objectives. When the idea of competitive electricity markets was first mooted, it was rejected by many on the grounds that such a disaggregated system could not keep the lights on. There is now ample evidence to demonstrate that separating the operation of generation from that of the transmission system does not necessarily reduce the operational reliability of the overall system.

Having a separate, independent organization in charge of operating the power system has the significant advantage that it makes processes more open and transparent. Buyers and sellers have an interest in exploring how market rules and operational procedures can be improved to reduce costs and improve the profitability of their assets. This attitude has led to markets operating much closer to real time and to the development of "products" to accommodate the increasing amount of renewable energy sources as well as new technologies such as demand-side participation and energy storage.

Electricity markets have also grown geographically because bigger markets provide more trading opportunities and are thus more liquid and efficient. This growth happened either through additional participants joining an existing market or through the establishment of market coupling mechanisms. Increased trading opportunities result in more frequent and larger transactions between distant generators and loads. Such power flows increase the physical interdependence between parts of the grid that used to be loosely connected. Maintaining the stability and operational reliability of large interconnections under these conditions has forced system operators to enhance the scope and functionality of their data acquisition and analysis capabilities.

As we will discuss in Chapter 4, electricity markets have some unique characteristics that facilitate the abuse of market power. Many, if not most, electricity markets therefore have had to deal with the fact that they were often less than perfectly competitive. This has led to a number of inquiries by regulators, the creation of market monitoring bodies, the implementation of price caps, and other less controversial market power mitigation measures.

In terms of long-term development, the argument in favor of competition is that central planners always get their forecasts wrong. In particular, monopoly utilities have a

tendency to overestimate the amount of generation capacity that will be needed. Their captive consumers are then obliged to pay for unnecessary investments. With the introduction of competition, it is hoped that the sum of the independent investment decisions of several profit-seeking companies will match the actual evolution of the demand more closely than the recommendations of a single planning department. In addition, underutilized investments by a company operating in a free market represent a loss for its owners and not a liability for its customers. Some markets rely entirely on the profits that power plants can obtain from the sale of energy and services to motivate investments in generation capacity. In other jurisdictions, market designers have introduced additional revenue streams to ensure that enough generation capacity is available to supply the load in a reliable manner. We will discuss this issue in more detail in Chapter 7.

Vertically integrated utilities can plan the development of their transmission network to suit the construction of new generating plants. In a competitive environment, the transmission company does not know years in advance where and when generating companies will build new plants. This uncertainty makes the transmission planning process much more difficult. Conversely, generating companies are not guaranteed that enough transmission capacity will become or will remain available for the output of their plants. Other companies may indeed build new plants in the vicinity and compete for the available transmission capacity.

The transmission and distribution networks have so far been treated as natural monopolies. Having two separate and competing sets of transmission lines or distribution feeders clearly does not make sense. From the economic and the reliability points of view, all lines, feeders, and other components should be connected to the same system. On the other hand, some economists and some entrepreneurs argue that not all these components must be owned by the same company. They believe that independent investors should have the opportunity to build new transmission facilities to satisfy specific needs that they have identified. Taken individually, such opportunities could be lucrative for the investors. However, the prevalent view is that such investments must take place within a framework that maximizes the overall benefits derived by all users of the network while minimizing their environmental impact.

Electricity is not a simple commodity whose trading is governed by the principles of classical economics. In addition to the need to maintain reliability, electricity markets are also affected by policy decisions driven by a desire to promote renewable energy sources and protect the environment, concerns about energy security and independence, as well as subsidies aimed at spurring the development of new technologies or helping a national industry.

1.6 Problems

1.1 Determine the electricity market structure that exists in your region or country or in another area where you have access to sufficient information. Discuss any difference that you observe between the basic model and the electricity market implementation in this area.

1.2 Identify the companies that participate in the electricity market in the area that you chose for Problem 1.1. Map the basic functions defined in this chapter with these

companies and discuss any difference that you observe. Identify the companies that enjoy a monopoly status in some or all their activities.

1.3 Identify the regulatory agencies that oversee the electricity supply industry in the area that you chose for Problem 1.1.

1.4 Identify the organizations that fulfill the functions of market operator and system operator in the area that you chose for Problem 1.1.

1.5 Identify policies that have been implemented to promote the development of renewable energy sources in the area that you chose for Problem 1.1.

Further Reading

European Commission (1999). Opening up to choice – the single electricity market. https://bookshop.europa.eu/en/opening-up-to-choice-pbCS1798782 (accessed 28 February 2018).

Federal Energy Commission (2015). Energy primer: a handbook of energy market basics. www.ferc.gov/market-oversight/guide/energy-primer.pdf (accessed 28 February 2018).

Hunt, S. and Shuttleworth, G. (1996). *Competition and Choice in Electricity*. Chichester: Wiley.