

# 1. Introduction

**Pippo Ranci and Guido Cervigni**

---

## 1.1 OVERVIEW

Over the last 20 years great efforts have been made in all the advanced economies to introduce the market into the electricity industry, which had traditionally been dominated by a monopoly integrated horizontally – typically on a national scale – and vertically, from production to supply to the end users.

The reasons for this development are many, and exist in different combinations in different countries. First, some of the conditions that justified the adoption of monopolistic models no longer held. Liberalisation policies were typically developed and implemented in a situation of relative maturity of the sector, that is, when the phase of major investments required for provision of electricity to the population as a whole had essentially been completed. This suggests that recipes for liberalisation drawn from the experiences of industrialised countries should not be transposed to developing countries without an in-depth understanding of the specific situation.

Developments in technology also contributed to overcoming the perception that a monopoly in electricity generation was the ‘natural’ solution. Towards the end of the 1980s, combined-cycle gas turbine generation technology became available. Compared to traditional thermal technologies, combined cycles offered lower installation and management costs, a low environmental impact, and a standardised, modular design. At the same time, developments in information technology and telecommunications allowed low-cost management of the large quantities of information necessary for the operation of the wholesale and retail electricity markets.

Second, liberalisation policies were often motivated by dissatisfaction with the services of the monopoly suppliers and of the institutions responsible for their regulation. The reasons for dissatisfaction ranged from investment gold-plating to poor-quality service. The limitations of the regulatory bodies were identified as a lack of independence from the

companies they were regulating, an excessive tendency towards micro-management, and a lack of accountability.

In this perspective, the creation of wholesale electricity markets can be interpreted as removing an anomaly. Electricity began to be considered and traded as a good like many others. Yet, liberalisation policies also reflected genuine ideological motives, such as the conviction that competition and privatisation would deliver superior investment decisions, better quality of service and lower supply costs in the electricity industry, and that the possibility for consumers to choose between several suppliers is intrinsically valuable.

As a result of a series of institutional experiments carried out in North America and the United Kingdom between 1990 and the early years of the twenty-first century, reasonably robust and efficient wholesale electricity markets now operate in many countries. By 2010 more than half of the countries in the world had introduced a reform process in their wholesale power sectors, accounting for about 60 per cent of the worldwide electricity production. Liberalisation of the retail segment has been less popular: by 2008 only 23 OECD countries had fully liberalised electricity retailing, accounting for about 20 per cent of the worldwide electricity demand.

An effective market design can make electricity very much like other commodities as far as production, trading and retailing are concerned. Social and political concerns, rather than engineering or economics, still make electricity 'special'. However, the unique technical features of electricity, such as the lack of cheap techniques for storing it, make complex organisational arrangements necessary to support trading and deal with some well-justified competition policy concerns.

This book addresses the main issues arising when competition is introduced in the electricity industry. The selection of topics and perspective of the analysis reflect the background and experience of the authors. These include economists who lived through various moments of the opening of the European electricity markets in their positions as professionals working for governments, system operators, power exchanges and energy businesses, or who were engaged in regulatory activity exposed to the political dimension of the liberalisation process, or indeed were carrying out research.

Our work aims to be broadly useful and applicable. Most references are to stylised settings. However, we also draw extensively from specific arrangements in order to illustrate the practical relevance of the general concepts. The book was conceived as an educational tool for courses on the economics of the electricity industry, but also as a straightforward and accurate guide to be used by industry professionals. The only requirement for reading it is a basic knowledge of economics.

The authors would like to thank Simona Benedettini and Silvia Concettini for precious research assistance. Our special thanks go to our reviser Sally Winch, who ironed out any inconsistencies and language issues.

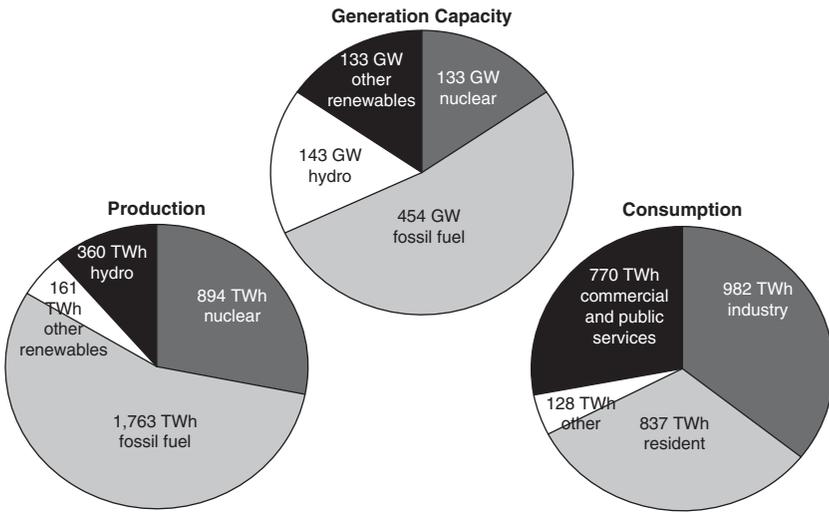
The remainder of this chapter provides an overview of the topics developed in the following chapters. In Section 1.2 we introduce the basics of electricity supply technology. In Section 1.3 we investigate why power systems need to be run by a central entity, known as a system operator (SO). In Sections 1.4 and 1.5 we discuss how the technical features of electricity shape the arrangements governing the trading and delivery of electricity. In Section 1.6 we address the concern that liberalised electricity markets may not be able to attract adequate investment in generation capacity. In Section 1.7 we focus on the issues related to electricity networks. In Section 1.8 we analyse the market-power issues specifically identified in electricity generation. In Section 1.9 we discuss electricity retailing. Finally, in Section 1.10 we address the changes to the organisation of electricity markets following the measures being implemented to address climate change.

## 1.2 TECHNICAL AND ECONOMIC FEATURES OF ELECTRICITY SUPPLY

Power is the quantity of electricity produced or consumed at a certain point in time, measured in Watts (W).<sup>1</sup> The quantity of electricity produced or consumed during a certain period of time is measured in Watt-hours (Wh). A Wh is the energy consumed by the continuous application of 1 W of power for one hour. Figure 1.1 provides some basic information about the European electricity industry in 2009, when total European generation capacity was 840 GW and electricity consumption amounted to 2,810 TWh. The order of magnitude of annual consumption by large industrial customers is the GWh. Annual consumption by residential customers is in the range of a few MWh.

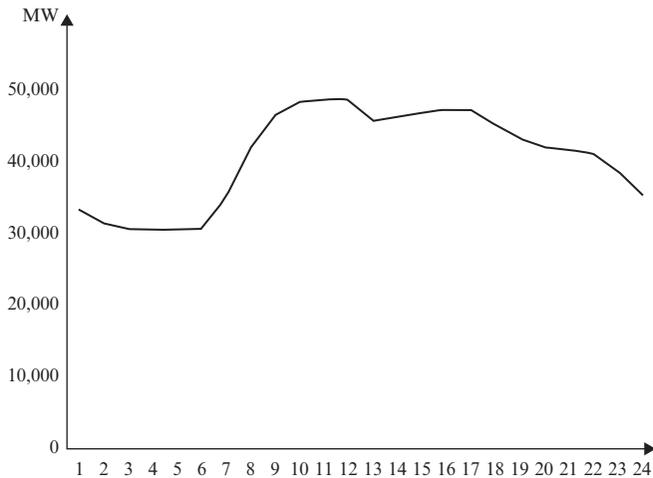
Several features combine to make electricity different from other commodities. First, electricity cannot be economically stored on a large scale. It must constantly be produced in the same quantity as it is consumed. Widespread and uncontrolled service interruptions ensue if electricity injections into and withdrawals from the network do not match, even just for seconds.

Second, electricity demand varies significantly during the day and across the seasons. Figure 1.2 shows electricity consumption in Italy on a typical working day. Withdrawals can vary considerably within a day. In



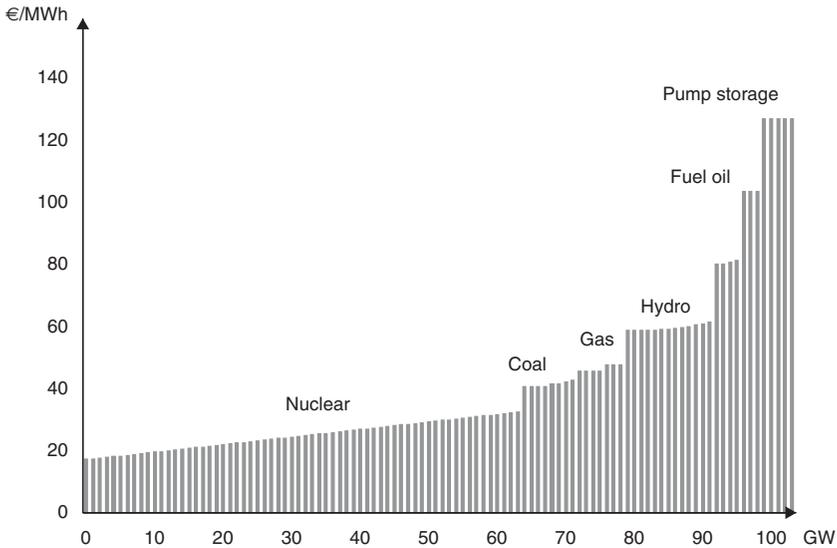
Source: Data International Energy Agency.

Figure 1.1 EU27 generation capacity, production and consumption in 2009



Source: Data Terna S.p.A.

Figure 1.2 Hourly load values for the third Wednesday of June 2009 in Italy



Source: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 'Renewable energy policy in Germany and the European Union', JREF Conference, Tokyo, 9 March 2012.

Figure 1.3 Generation merit-order curve, France, 2009

the day shown in the figure, for example, withdrawals at 11.00 were 60 per cent greater than those at 04.00.

Since electricity must be generated at the same time it is consumed, and demand varies, an efficient generation fleet consists of a mix of different generation technologies with different fixed/variable cost ratios. High fixed-cost and low variable-cost units include run-of-river hydroelectric, nuclear and coal units. These typically produce all the time, and are therefore available to meet the base load. Higher variable-cost units produce when consumption is greater than the available base-load generation capacity. Combined-cycle gas generators typically have intermediate load factors. Old steam generators burning oil or gas are positioned further up in the system variable-cost curve, and are activated when demand is higher than the cheaper available capacity. Finally, high-variable cost open-cycle gas turbines and controllable hydropower generators operate at peak times only.

Figure 1.3 represents the estimated variable-cost curve in France in 2009. The variable-cost curve is also referred to as the generating units' 'merit order'. Since the supply function includes units with different variable costs, the variable cost of the most expensive active generator, or the system

marginal cost, fluctuates as demand varies, hitting different segments of the supply function. The system marginal cost may be one order of magnitude greater in peak hours than in low-demand hours.<sup>2</sup> In order to address these large cost differences, in most wholesale electricity markets electricity produced and consumed in different hours, or half-hours, is regarded as a different product, so that the market-clearing price varies from hour to hour.

Third, electricity differs from other commodities because a large portion of the demand for electricity is currently price inflexible, at least in short timeframes. Consumers may not react to spot prices for several reasons. The meters currently operating at most small consumers' premises only record total consumption over a long period. Traditional meters only record total consumption since the meter was first activated, which only allows calculation of the consumer's withdrawal between two readings. More recent meters record total consumption over fixed periods, such as one month. It is generally impossible to assess a consumer's withdrawal per hour or half-hour. Furthermore, even if hourly or half-hourly consumption is recorded, adjusting consumption in response to spot prices could entail high transaction costs for monitoring the spot prices and adapting appliances. In addition, the current arrangements do not allow price-dependent consumption decisions in situations of scarcity, that is, when available generation capacity is insufficient to meet demand. In fact, when scarcity occurs, rationing is implemented at distribution area level and not on a consumer-by-consumer basis.

When hourly consumption is not known, retail prices cannot directly reflect wholesale market prices, and therefore cannot convey to consumers the economic signals of the cost caused by consumption at each time. The consumers can only be charged a price that reflects the estimated average cost caused during the period between two meter readings, based on a conventional time pattern. This practice is known as 'load profiling'. As a consequence, the consumers' demand cannot respond to the high hourly prices that clear the wholesale spot market when generation falls short of demand, because they pay the same price irrespective of when consumption takes place.

Fourth, electricity is delivered to consumers via transmission and distribution networks. Transmission networks allow electricity to be moved long distances from the generators to the consumption areas.<sup>3</sup> Transmission networks are subject to congestion, that is, the power flows corresponding to the electricity market transactions may violate some of the network's security constraints. Congestion is relieved mainly by changing the distribution of total production across the generating units connected at different locations.

Distribution networks are used to transfer electricity from the

transmission network to the customers' premises. Distribution networks are typically dimensioned in such a way that congestion does not occur in normal conditions, as congestion on the distribution network could result in service interruptions.

In the following sections we discuss how electricity's technical features affect the market design and industry operations, and refer to the chapter in which each issue is addressed.

### 1.3 THE SYSTEM OPERATOR

The rationale for a central entity running the power system is undisputed. Without a central system operator, coordinating the production and consumption decisions of all network users to ensure that system security conditions are met at all times would be impossible or prohibitively expensive. Service disruptions caused by failures to meet the system security constraints would result in extremely large welfare losses. For those reasons, placing the responsibility of maintaining security at all times on a system operator is, in practice, the only feasible solution.

System security requires production and consumption to constantly match, power flows not to violate any network constraints, and sufficient spare transmission and generation capacity to be available in order to avoid service interruptions in the event of outages or unexpected surges in demand.

In order to ensure that the power system is balanced and secure at all times, the system operator buys ancillary services from generators and possibly from large consumers with the necessary capabilities. Ancillary services include reserve capacity, the commitment to make generation capacity with certain technical capabilities available at a certain time.

In addition, the system operator operates the real-time or balancing market, where additional injections or reduced production are procured at short notice in order to offset any mismatch between production and consumption at the time of delivery. We discuss the design of the ancillary service and real-time markets in Chapter 2, and in the context of congestion management in Chapter 4.

Finally, the system operator is typically responsible for planning development of the transmission network.

### 1.4 MARKET DESIGN

The definition of standard products is crucial to make electricity trading possible. Since the value of electricity varies continuously over time,

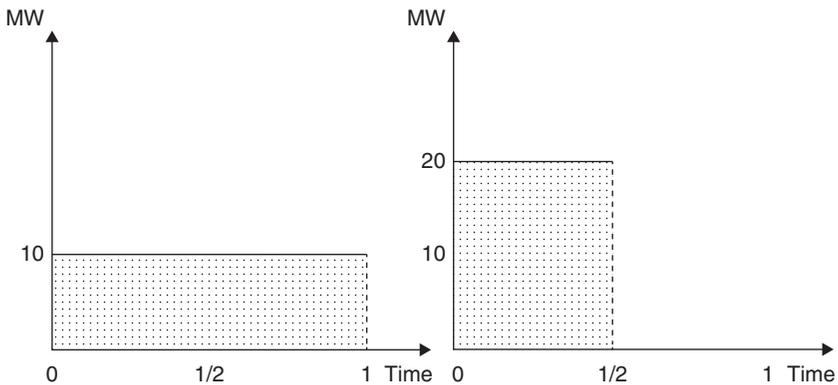


Figure 1.4 Consumption pattern of standardised hourly products

in the absence of any standardisation, the number of traded products would be unmanageably large: electricity delivered in one minute would be a different product with a different price from electricity delivered the following minute. Furthermore, each party would seek to trade different bundles of the many different products, because the pattern of each consumer's electricity withdrawal is different over time. As a result, transaction costs would be prohibitively high and inefficiencies would result.

Product standardisation means that, for the purpose of trading, different items are treated by all the market participants as identical products. In most wholesale electricity markets the basic standard traded product is the hourly-block. The hourly-block is the total production or consumption taking place over a fixed hour, irrespective of the pattern of production or consumption during the hour. The purchase of, say, 10 MWh in a given hour entitles the buyer to vary its consumption considerably during the hour. Figure 1.4 illustrates the effect of standardisation implemented on hourly products. The figure shows two of the many possible patterns of consumption of a buyer of 10 MWh in a given hour  $t$ . During the first half-hour the buyer could consume the entire amount purchased, that is, it could consume 20 MW for the first half-hour and nothing afterwards, as shown in the right panel. Alternatively, the buyer could consume the 10 MW at a constant rate throughout the hour, as shown in the left panel. In both cases the buyer is regarded as having consumed exactly what it bought on the market, that is, a total electricity volume of 10 MWh. The seller enjoys the same flexibility, as it can discharge its obligation to deliver 10 MWh, by implementing any production time pattern resulting in 10 MWh, of total injections during the hour.

Product standardisation in the locational dimension means that the seller can discharge its delivery obligations by producing the quantity sold on the market at any node of the network, and the buyer can consume the electricity purchased anywhere. Product standardisation is beneficial in as much as it increases market liquidity and lowers transaction costs. However, product standardisation may generate system operation costs. In our example, ignoring for simplicity's sake all other injections and withdrawals, we assume that the buyer consumes 10 MWh during the first half-hour, as shown in the right panel of Figure 1.4, while the generator delivers 10 MWh at a constant rate throughout the hour, as shown in the left panel. In order to maintain system security, the system operator must procure additional injections in the first half-hour, when the buyer's consumption exceeds the seller's production. Conversely, reduced injections will have to be procured in the second half-hour, when the seller's production is greater than the buyer's consumption. Locational standardisation also can generate system operation costs, in the event that the available network capacity does not allow the power generated at the delivery node selected by the seller to be transferred to the buyer's node. In this case the system operator has to reallocate production across locations in order to enable the parties to the transaction to exercise their right to deliver and collect electricity wherever they want.

In principle, product standardisation is sufficient to enable trading, as it reduces the number of products that market participants can exchange. However, in the electricity industry the number of standard products is still very large. In the case of hourly products, 24 different products are traded per day; furthermore, in some markets electricity delivered at each network location is traded as a different product. In addition, the expected conditions of demand and supply and hence the expected market-clearing price for a given time of delivery may vary dramatically at different times before delivery. This can be the result of unexpected generating unit outages, changes in the availability of renewable sources such as wind and solar power, and changes in the weather conditions affecting demand. Discovering via bilateral negotiations the market-clearing price of all the products traded and updating the assessment as new information becomes available involves significant transaction costs. Furthermore, imperfections in the price-discovery process could lead to major inefficiencies should the wrong set of generators be activated. Power exchanges where electricity transactions are centralised are the answer to this coordination issue.

Each end-customer's consumption is also assessed in terms of standard products. The consumption of standard products by larger consumers is typically measured directly, since hourly or half-hourly meters are

generally installed on their premises. Consumption of standard products by smaller consumers are typically assessed conventionally, by allocating part of the consumption that took place over the longer metering interval to each hour.

We discuss the special arrangements governing electricity transactions in Chapter 2.

## 1.5 ELECTRICITY TRANSACTIONS

Technology determines the arrangements through which electricity exchanged on the market is delivered by the sellers and collected by the buyers. For most commodities, a consumer whose supplier fails to deliver the contracted quantity at the agreed time simply does not consume (at that time). This does not happen with electricity, since it is technically impossible to inhibit the buyer's consumption in the event that the seller fails to produce the corresponding amount of electricity. However, since the power system must be kept continuously in balance, the system operator has to make up for the electricity not produced by the seller and consumed by the buyer. The seller will then pay the system operator for the quantity that it was unable to deliver at the contractual time. In this way commitments to produce and consume entered into on the market are enforced financially.

In practice, each market participant's commitments to produce or consume the electricity respectively sold and bought on the market are separately enforced. Each party to an electricity transaction notifies the system operator the volume that it committed to deliver (the seller) or to consume (the buyer). The notification creates two independent obligations: one between the seller and the system operator, committing the seller to produce the notified quantity, irrespective of the buyer's actual consumption; the other between the buyer and the system operator, committing the buyer to consume the notified quantity irrespective of the seller's actual production.

This process is illustrated in Chapter 2.

## 1.6 GENERATION CAPACITY ADEQUACY

The economic mechanism driving investments in electricity generation capacity is conceptually the same as the one operating in all other industries. Persistently high electricity and ancillary service prices attract capital to the industry when existing capacity is below the equilibrium level;

persistently low electricity and ancillary service prices discourage capital accumulation at times when installed capacity is above the equilibrium level.

However, widespread concerns exist that investments in generation capacity may not be sufficient and that specific policy measures are needed to ensure that installed capacity is enough to match demand at all times.

A number of features, to varying degrees specific to electricity, motivate these concerns. First, some elements of the market design, industry regulation or industry practices may cause generators' revenues to be systematically insufficient to attract the efficient level of investment. Second, imperfections in the administrative process that sets the market price for electricity in the event of scarcity may bias the incentives to invest in generation capacity. Third, capacity adequacy concerns are sometimes motivated by the specific risk structure of the generation business, such that small changes in demand or supply conditions can have a dramatic impact on generators' profitability. While the first two issues call for mechanisms that integrate the generators' income in order to attract an efficient level of investment, the third issue can be handled by coordinating the timing of investments in generation capacity in order to reduce the risk for investors. A more certain environment is expected to reduce the rate of return required by investors, to the ultimate benefit of consumers.

In Chapter 3 we discuss the rationale for the introduction of capacity support schemes and analyse alternative approaches followed in different markets.

## 1.7 THE ROLE OF THE NETWORK

Electricity is transported on a transmission network from the place where it is generated to the place where it is used. Electricity flows on the network according to the laws of physics, and it is impossible to force power to follow predefined routes between a production node and a consumption node. The flows of electricity on the network depend mainly on how total consumption and production are spread across the different nodes of the network. As a consequence, the primary and often only way to modify power flows across the network is to reallocate production among the different generating units.

Congestion occurs in the event that the network is not capable of hosting the power flows matching the electricity market transactions. When this happens there is a limited possibility of delivering power

generated in low-price areas to consumers located in high-price areas. As a consequence the value of electricity at different locations is different.

Arrangements differ in the way they induce market participants to deviate from the volumes they would produce or consume if transmission capacity were unlimited. Two general approaches can be identified. The first limits the set of transactions that market participants can enter to those corresponding to power flows that the network can safely host. This is achieved by allocating and enforcing a set of feasible transmission rights, that is, rights to inject and withdraw power at different network locations. As a result, the wholesale electricity market clears at different prices in different locations in the event of congestion.

The second approach consists of compensating market participants for deviating from their desired level of production and consumption. In this approach, the electricity market ignores any transmission constraints, so that the market participants can freely select where the electricity exchanged will be produced and consumed. Subsequently, if the corresponding power flows violate one or more transmission constraints, generators and possibly consumers are paid to modify the level of production and consumption that they had scheduled at the different locations. This practice is known as 're-dispatch'.

In some markets, the transmission network is split into large market zones, areas where congestion is more likely to result. Trading within each zone is unconstrained and intra-zone congestion is dealt with via re-dispatch, whereas trading across zones is limited by enforcing a set of transmission rights.

In Chapter 4 we illustrate the impact of network congestion on the wholesale electricity market outcome and look at how congestion management is implemented.

## 1.8 COMPETITION POLICY IN THE ELECTRICITY INDUSTRY

Market power is a primary concern in wholesale electricity markets for two broad reasons. The first is that electricity is a primary commodity purchased by every household and business, and its price is extremely important for the economy.

The second is that the unique technical and economic characteristics of electricity make wholesale electricity markets particularly prone to market power. Since electricity demand does not respond to price in the short term and electricity is not storable, when the system is tight even relatively small generators may enjoy significant market power. This happens because,

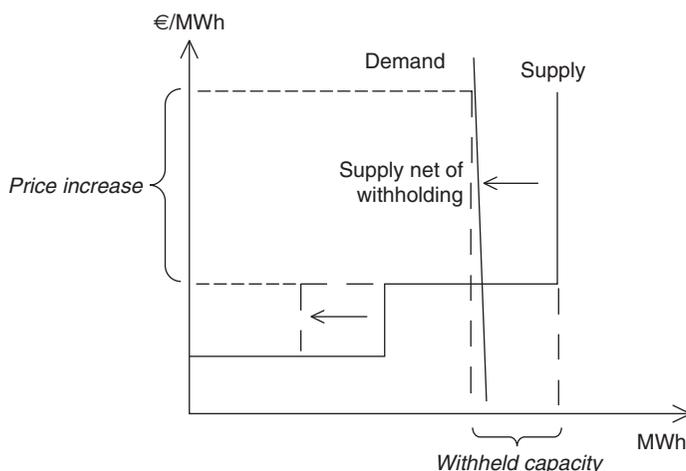


Figure 1.5 Generation capacity withholding when the system is tight

when existing generation capacity comes close to full utilisation, the withholding of even a small quantity of supply from the market may cause a sharp increase in price. Figure 1.5 illustrates a situation in which the withholding of generation capacity leads to scarcity, that is, increases the market-clearing price to the level necessary to ration demand.<sup>4</sup> The major discontinuity between the system marginal cost (the market-clearing price in normal conditions), and the value of electricity for consumers (the market-clearing price in the event of scarcity) creates a strong incentive to exercise market power.

Transmission constraints add to the problem, since they reduce the scope for competition between generators connected in different locations. In addition, the owners of generating units in multiple locations may find it profitable to implement bidding strategies specifically aimed at creating network congestion, if this allows them to reap the benefits of lower competition at certain locations.

In some countries, market power in the wholesale electricity market is addressed by regulatory statutes. In the US, the federal regulator has the duty and the power to ensure that wholesale electricity prices are ‘just and reasonable’. In Europe, charging excessive prices is addressed by competition law and considered an abuse of dominant position, although historically the prohibition on charging excessive prices has proved hard to enforce in this context.

In Chapter 5, we discuss how the specific technical features of electricity supply impact on the competition policy tools used to determine market

boundaries and to assess the degree of competition in the industry. We also analyse the main types of policy measures implemented in electricity markets to mitigate market power, including asset divestitures, the imposition of long-term sales on the dominant generator, price caps and bid-mitigation mechanisms.

## 1.9 ELECTRICITY RETAIL COMPETITION

Like retailers in other sectors, electricity retailers bundle the inputs necessary to provide their electricity services to clients. Specifically, electricity retailers:

- are responsible for procuring from the wholesale market the electricity consumed by their clients;
- buy system operation, transmission, distribution and metering services;
- design and advertise offers addressed to consumers;
- act as an interface for their clients on matters related to the electricity service; and
- issue invoices and collect payments.

Since retail costs account for only a small share of the total cost of the electricity service, the potential for competition to reduce consumers' bills by reducing retail costs is limited. Therefore most of the benefits of retail liberalisation are linked to the ability of competitive retailers to provide services that are tailored to consumer preferences. Large consumers have diverse needs of energy price certainty, sophisticated procurement strategies and may possibly take advantage of their ability to control their use of electricity. They are therefore in a position to take full advantage of retail competition.

The benefits of a more diversified offer for smaller consumers are less evident, at least at this stage of the liberalisation process. In addition, smaller consumers appear to face significant transaction costs in order to identify, assess the offers of and switch to a different supplier. As a consequence, the incumbent retailer enjoys significant market power over its passive customers. This has led regulators in most jurisdictions to retain price controls long after the legal liberalisation of electricity retailing, and in some cases to question the opportuneness of retail liberalisation altogether.

We discuss electricity retailing in Chapter 6.

## 1.10 SUSTAINABILITY TARGETS AND THE FUTURE OF THE ELECTRICITY MARKETS

The main driver of the expected evolution of electricity systems, at least in industrialised countries and Europe especially, is the reduction of greenhouse gas emissions, which are responsible for the increase of global mean temperature.

In Europe, the Climate and Energy Package passed at the end of 2008 sets the 20–20–20 targets to be achieved by 2020: greenhouse gas emissions at least 20 per cent below 1990 levels, 20 per cent of energy consumption provided by renewable resources, and a 20 per cent reduction of primary energy use against a baseline scenario.

Given that the deployment of renewables in electricity is more cost efficient than in transport and – to a lesser extent – heating, the burden of the total renewable energy target placed on the electricity sector will be large. The production of electricity from renewable sources in Europe is expected to rise from 21 per cent in 2010 to 33 per cent in 2020.

The sustainability objectives appear to have radically changed the trade-offs relevant in the 1980s and in the 1990s when the decisions to liberalise generation activity were taken. At the time, regulated decision-making processes for deciding generation and transmission investments were perceived to be inefficient due to the incentives for regulated utilities to overinvest, errors in fuel price forecasts and political interference. These considerations and the reduction of economies of scale in generation, due especially to the development of combined-cycle gas turbine technology, were among the main motivations for the transfer of investment decisions from the government to the private sector.

However, the current policies addressing climate change increase political involvement in generation investment decisions. The development of renewable generation capacity is taking place under a variety of support schemes so that the size, composition and in some cases the location of new capacity are determined by public authorities. Most of the risk in investing in renewable generation capacity is placed on electricity consumers through measures that make renewable generators' revenues independent of market prices for electricity. The same holds in some countries for investment in nuclear generation, the viability of which appears to be increasingly dependent on the possibility of transferring part of the risk to electricity consumers via regulation.

It remains to be seen whether a hybrid system, in which planning governs the development of renewable and possibly nuclear capacity while conventional capacity is supplied by the market, is sustainable. The profitability of non-renewable capacity may be dramatically impacted by the

level of renewable capacity set by public decision makers. In the event that such regulatory risk makes private investment in conventional generation capacity unattractive, electricity consumers could end up bearing the risk of all investment in generation capacity, for example in the form of more expensive capacity support schemes.

Renewable energy sources are intermittent, and their availability can be accurately predicted only a short time in advance of the time of delivery. As a consequence, the production programmes of an increasing share of generation capacity may have to be modified close to real time, as the expectations of renewable production are updated. This means that an increasing number of financial transactions need to take place close to the time of delivery, at prices that may significantly depart from those clearing the day-ahead market. Moving generation scheduling decisions closer to real time might be particularly difficult in Europe, where electricity trading between market participants and the procurement of ancillary and balancing services by the system operator are carried out close to real time in separate venues with different rules. In this context, the consistency of the clearing prices of multiple markets run separately in a very short timeframe might not be achieved. This could result in an inefficient use of generation capacity.

Furthermore, if the trends currently observed continue in the future, network congestion will become a recurring feature and the need for fast-response generation capacity will increase. A greater need for re-dispatch to relieve congestion leads to an increase in total supply costs. This could lead to greater reliance on regulatory and administrative measures aimed at limiting system operation costs, with distortive effects on the prices prevailing in all markets cleared near real time. We explore these issues in Chapter 7.

The expansion of renewable production appears to be modifying the relative merits of the market and regulation in electricity generation. The assumption that the market is the most efficient way to govern the development of generation capacity is one of the drivers of the wave of liberalisation that took place in the 1990s and early 2000s. However, liberalisation can hardly be claimed to yield benefits in terms of short-term efficiency. On the contrary, a vertically integrated monopoly with unified control of the generation fleet and the transmission network makes implementing minimum-cost dispatch easier, compared with a market setting where the decisions of multiple independent generators are coordinated through price signals.

In this perspective, the politicising of capacity development decisions and exacerbating of short-term coordination issues brought about by the expansion of renewable generation reduces the market's relative merits compared with a centralised model.

It remains to be seen if competition can still play a significant role in the new environment, which is largely based on planning. Auctions could be implemented to select efficient renewable investments, for example. However, the main feature of the liberalised model, which is the allocation of investment risk to market investors rather than consumers, would be lost.

Finally, electricity demand is expected to contribute to the achievement of sustainability objectives. Policy measures to reduce consumption are being implemented in most countries, and further benefits are expected from an increase in the responsiveness of demand to spot prices. Many aspects of the technical, commercial and organisational arrangements enabling small consumers to respond to prices are still undetermined. The evidence that evolution of the electricity systems in that direction will deliver a net positive benefit is still weak. In any case, exploiting the full price-response potential of small electricity consumers will require massive investment and take a long time.

## NOTES

1. KWh, MWh, GWh and TWh are commonly used multiples of Wh. KW, MW and GW are commonly used multiples of W.
2. Hydro peakers have a high opportunity cost, since their production is limited by the size of the reservoirs and needs to be allocated in time in the most valuable way. The opportunity cost of a hydro peaker is the cost that the system would bear if that capacity were not available. It can be thought of as the cost of the most expensive thermal generator that has been displaced by hydro production.
3. Typically the withdrawal nodes of a transmission network are the points of connection with distribution networks. Large industrial customers are sometimes directly connected to the transmission network.
4. A condition that we shall analyse in Chapter 2, Section 2.2.1.