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Liberalisation of Network Industries: Is Electricity an Exception to the Rule?

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The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Bank of Belgium.

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Abstract

For quite a long time, network industries used to be regarded as (natural) monopolies. This was due to these industries having some special characteristics. Network externalities and economies of scale in particular justified the (natural) monopoly thesis. Recently, however, a trend towards deregulation of such industries has been observed. This trend started with the successful introduction of competition in the telecommunications sector. The main reason behind this success is that the economies of scale have disappeared as a result of emerging new technologies. The successful deregulation in telecommunications is in line with micro-economic theory, which predicts an increase in efficiency and lower prices when markets are opened up to competition.

The success in the telecommunications sector is often used as an argument for opening up other network industries to competition as well. In this paper we analyse whether this reasoning can be transposed to the electricity sector. It is argued that the two sectors, electricity and telecommunications, are similar in that they are both network industries which used to be characterised by economies of scale, and that technological progress might have put an end to this scale effect. There are however certain differences. Firstly, technological progress on the supply side was accompanied by a strong growth in demand in the telecommunications sector. This demand side effect is absent in electricity. Moreover, due to physical characteristics, the electricity sector seems to be more complicated: in order to introduce competition in the sector, it has to be split up into subsectors (production, transmission, distribution and supply). Competition is introduced in production and supply, transmission and distribution remain monopolies. This splitting up creates a new kind of costs, the so-called transaction costs.

The paper is centered around two issues: (a) are the basic assumptions behind the theoretical model of the perfectly free market met in the deregulated subsectors? and (b) do the transaction costs (partly) offset possible price decreases in competitive segments ?

There is no hard evidence that the hypotheses behind the theoretical model are met in the electricity sector, and there are strong indications that these transaction costs might be substantial. Moreover, in addition to the deregulation process, the electricity sector is also subject to other changes such as the internalisation of externalities (see the Kyoto protocol) and the debate on nuclear energy. These elements could exert an upward pressure on prices. Since electricity is ubiquitous, the deregulation process should be closely monitored.

JEL Classification: D23, D41, D42, D43, D62, L12, L13, L94, L96.

Key words: Welfare economics; market structure and pricing; organizational behaviour, transaction costs, property rights, Electric Utilities, Telecommunications.

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Liberalisation of network industries : Is the electricity sector an exception to the rule ?

F. Coppens
D. Vivet

Introduction

Liberalisation of the network industries in Europe can undeniably be regarded as one of the most radical economic changes since the creation of the single market. Furthermore, it is not only a process which generates heated debate, it also raises many questions. That is, of course, due in part to the complexity of the sectors concerned, certainly in the case of the electricity sector.

This study attempts to discuss the issue of the liberalisation of the electricity sector for the non-specialist reader. The specific characteristics of the sector are discussed in the light of the liberalisation of the electricity market and its potential impact. The reader will find that most of the statistical data relate to the Belgian context, but they serve only to clarify a number of concepts and are therefore intended purely as an example. The aim is to offer a general analysis of the electricity sector without taking account of the situation in any particular region. Articles to be published later will go into more detail on specific situations (such as the European electricity directive and its implementation in Belgian law, a detailed discussion of the Belgian electricity sector, etc.).

The first chapter will give a very brief explanation of a few aspects of economic paradigms on which both the idea of liberalisation and the criticisms of it are based. That chapter is theoretical and is intended as a brief résumé of the relevant economic theory. It is meant for readers with an economics background. Non-economists are asked to follow the general outline, at least, in order to become familiar with such concepts as cost curves, marginal costs, free markets, transaction costs, etc.

Chapter 2 discusses the special characteristics of the electricity sector in order to find out whether those various peculiarities of the industry are compatible with its liberalisation. In order to gain a clear idea of that, the characteristics are often compared with the telecommunications sector, a network industry which has already been liberalised in most countries. Finally, the conclusion sets out a summary of the main findings. The text contains a number of boxes which offer readers unfamiliar with certain technical concepts sufficient information to follow the train of thought in the analysis.

1. Theoretical aspects of liberalisation

1.1 Neoclassical micro-economic theory

According to neoclassical micro-economic theory (1), in a free market equilibrium is reached at the point where the price equals the marginal production costs. In contrast, in a monopoly situation the equilibrium price is higher than the marginal costs. The price on a monopoly market is therefore higher so that demand is lower. This difference between the two types of market can be largely explained by stating that in a market with perfect competition the producer's price is regarded as given, whereas in a monopoly the producer can influence the price level.

Chart 1 illustrates this. On the free market, equilibrium is reached at price P_c, which corresponds to the quantity of production Q_c, i.e. at the point where the supply and demand curves intersect. On the monopoly market, equilibrium occurs at the point where price P_m intersects with quantity Q_m. These two equilibrium situations are based on marginal revenue equalling marginal costs, the point at which firms therefore maximise their profit (2). However, for the reasons described below, the two markets are not in equilibrium at the same point. Given totally free competition, the marginal revenue is always equal to the market price since, as stated earlier, that is always imposed on the firms: for each additional unit sold, a firm earns additional income equal to the market price P_c. In contrast, in a monopoly the marginal revenue falls as output increases. If the monopolist sells an additional unit, his marginal revenue is determined by two factors: on the one hand, his revenue increases by the price charged for that unit, but on the other hand it falls because the price of the rest of his output is equal to the (lower) price of the last unit sold (3). Marginal revenue in a monopoly is shown by the curve R_m.

In the light of that situation, the monopoly leads to inefficient economic allocation, or "Pareto inefficiency". A market is Pareto-optimal if it is not possible to improve the situation of any one of the economic players without impairing that of another player. That is not the case in a monopoly. To understand this, consider the meaning of the demand and supply curve. The demand curve shows the maximum price that consumers are willing to pay for a given quantity. The supply curve shows the minimum price – equal to the marginal costs – that the producers are willing to accept for a particular quantity of production.

CHART 1 INEFFICIENT ALLOCATION IN A MONOPOLY

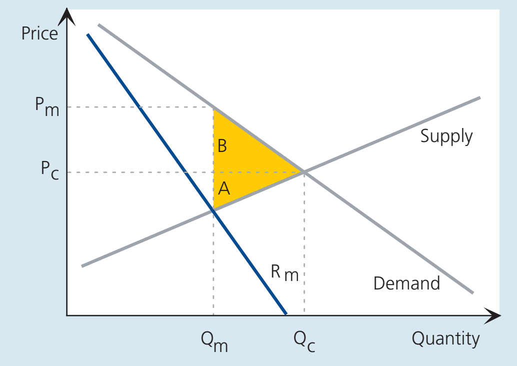


Chart 1 reveals that if production increases above the monopoly equilibrium (Q_m, P_m), consumers are prepared to pay a higher price than the minimum required by the producers, since the demand curve is above the supply curve at this point. That finding is true for all levels of production between Q_m and Q_c. By expanding production from Q_m to Q_c, it would be possible to achieve Pareto improvements, since for each price between the supply and demand curves the satisfaction of certain economic players would increase without affecting that of the other players. In contrast, above Q_c no further Pareto improvement is possible: in contrast to the monopoly, free competition is therefore an efficient market. Furthermore, it is easy to show that the increase in well-being, typical of free competition, is equal to the area A + B.

That reasoning is the most important theoretical basis for the policies aimed at liberalisation which have been defined in the European Union in recent years. As with Adam Smith and his theory of the invisible hand, it refers to the idea that, by allowing the free market to operate, we achieve the optimum allocation of resources. However, that logic gives rise to objections which, more particularly, *call into question its basic assumptions*. Those objections are discussed in the next section.

(1) See in particular the following manuals: Carlton D. and Perloff J. (1990), Cohen S.I. (2001) and Varian H. (2003).

(2) The marginal revenue is the additional income that a firm earns if it increases its production by one unit. The marginal costs are the additional costs that a firm incurs if it increases its production by one unit.

(3) This argument is described in detail in Varian H. (2003).

1.2 Criticism

Perfect competition is based on a number of assumptions:

– *the market determines the price*: producers and consumers cannot influence the price. That condition is met if the producers and consumers are very numerous;
– *the information is perfect*: producers and consumers have all the necessary information on the operation of the market;
– *the product being traded is homogenous*: all producers sell an identical product;
– *freedom to enter and leave the market*: firms can enter and leave the market without incurring special costs.

In reality, the conditions are very seldom met. Most of the markets monitored fall between the two extremes: free competition and monopoly.

If the first condition is not met, that is usually because the market is an oligopoly, which means that there are only a few competitors active on the market. In an oligopoly, one of the competitors – usually the biggest firm – frequently has market power (or monopoly power) and can therefore impose a price higher than the competition price. For example, a firm may have market power because it produces more cheaply than its competitors, or because its product is better in quality. When setting their prices, the other firms will have to take account of the behaviour of the dominant firm. In the electricity production sector, for example, the Belgian regulator (CREG) published a study in 2001 which focused on the problems relating to market power [(1)].

The degree to which the perfect information condition is met depends on the market. Inadequate information leads to uncertainty which hampers the optimum operation of the market, leading to higher prices or lower quality products. The economic players seek information, but that search has a price (in time and/or money). If they find that that price exceeds the benefits of the information, they stop their search and base their decision on the available data. If the information is inadequate, players who are not interested in risks are inclined to stick to their earlier decisions. For example, in a context of liberalisation, that explains why – at least in an initial phase – consumers do not necessarily choose the cheaper products offered by a new competitor. Uncertainty also affects the behaviour of firms, which may postpone their investments pending more information on future prospects [(2)].

The situation in which the homogeneity condition is not met is known as monopolistic competition. On such a market, each firm sells a product that differs to some degree from its competitors' products (at least, that is how the consumers see it). Those differences give the firms a certain amount of market power. If a firm increases its price, it will not lose all its customers, as the customers consider that the products of other firms are not a perfect substitute for the product of the firm in question. Examples of monopolistic competition are very numerous and extremely varied.

Freedom to enter or leave a market is another condition which is seldom met in the real world. Many markets have access barriers, i.e. impediments hampering or delaying the entry of new competitors. Examples are the cost advantages enjoyed by established firms, the existence of economies of scale necessitating substantial investments for new players wishing to enter the market, and specific rules or restrictions. Since they limit competition at source, access barriers enable the established firms to increase their prices without having to take account of the entry of new competitors. The utility companies, for example, traditionally face substantial access barriers, more particularly as regards access to the network and the existence of economies of scale [(3)]. Finally, according to the contestable markets theory, a market can operate competitively with a small number of producers. If a market is contestable, i.e. if newcomers are liable to enter it, firms in fact feel obliged to adjust the competition price. If they were to charge a higher price, then new competitors would immediately enter the market [(4)].

This hypothetical research shows that perfect competition is in fact very rare: it must be viewed primarily as a reference framework for assessing other types of market. In the light of the liberalisation of a monopoly, the real aim is therefore never to achieve the optimum situation but rather to come close to it. If the conditions are clearly not met, the increase in efficiency may not outweigh the costs associated with regulating and rectifying the market's shortcomings.

(1) CREG (2001b).
(2) See Dixit A. and Pindyck R. (1994) for the effects of uncertainty on investment decisions.
(3) See Pénard T. (2002).
(4) See Baumol W., Panzar J. and Willig R. (1982) on contestable markets.

Most economists do in fact consider that, in a number of situations, if a market is not operating well it can no longer allocate resources efficiently. The commonest reasons for an inefficient market are: natural monopolies and externalities.

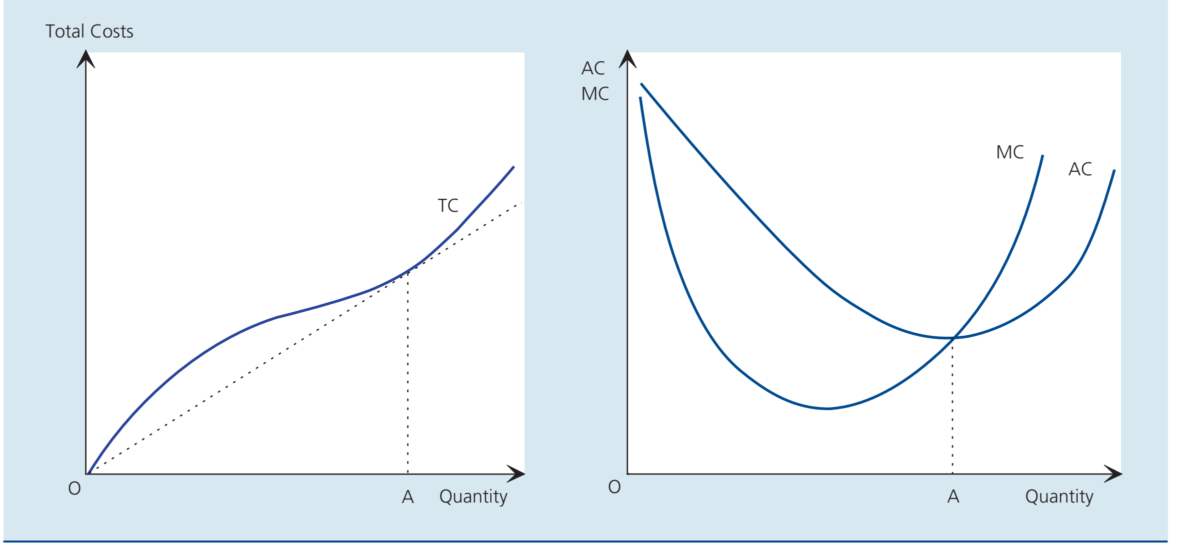
A natural monopoly is a situation in which the average production costs fall continuously as the quantity produced increases. The market's total production costs are always lower if just one, and no more than one, firm produces the goods. Natural monopolies occur most frequently in the utility sector, because the fixed costs are very high and the marginal costs are very low (cf. box 1).

Box 1 – The cost curves

Micro-economic theory assumes that the average cost and marginal cost curves are U-shaped. This is because of the hypothesis that, as a firm grows, it achieves returns to scale which initially increase, then stagnate and ultimately decline (given constant technology). That hypothesis is illustrated in chart I which shows, on the one hand, the pattern of total production costs (TC) and, on the other, the pattern of average (AC) and marginal (MC) costs. For a given level of production, the level of the average costs is determined by the slope of the line through the origin and the point on the costs curve. The change in marginal costs is derived from the slope of the tangent at each point on the total costs curve.

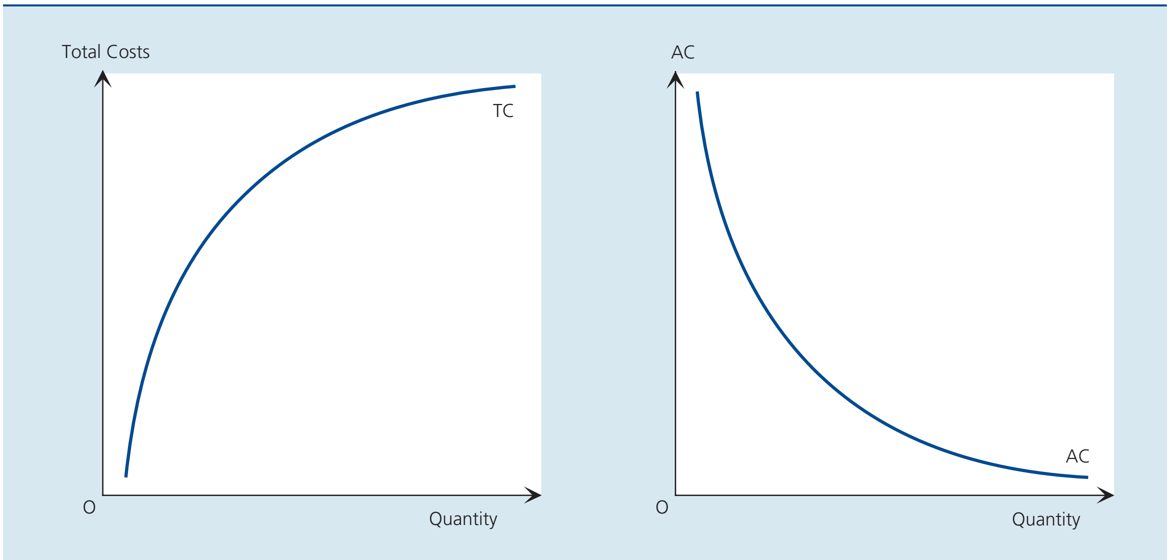
This hypothesis concerning the pattern of costs is based on the following economic argument. If a firm's activity expands, the firm can use its workers more efficiently by making them specialise or by making more rational use of basic materials. The firm is then in a phase of increasing returns to scale: production rises faster than the production costs, which means that the average cost price falls. That phase corresponds to the production interval OA in chart I. However, the advantages of increasing the size of the firm are not unlimited. From a certain point onwards, problems arise in regard to labour organisation or the exchange of information. If those disadvantages increase, the firm enters a phase of diminishing returns to scale: the costs increase faster than the production, so that the average cost begins to rise. Beyond point A in chart I, that phase applies to all levels of production.

CHART I U-SHAPED COST CURVES



The natural monopoly is an exception to the cost hypothesis. In a natural monopoly, the average costs continue to fall as production increases: returns to scale continue to increase. In contrast to the classic hypothesis of the U-shaped cost curve, the average costs take the form of a declining curve as shown in chart II.

CHART II COST CURVES FOR A NATURAL MONOPOLY



We talk about external effects if an economic player's activity leads to benefits (positive external effects) or costs (negative external effects) for other players. The supplier-producer takes no account of these costs. Pollution (negative external effect) is the most commonly cited example of external effects. For example, in the case of polluting industrial sectors, the producer takes account only of the firm's own production costs, whereas there are also external costs, such as the costs of cleaning up rivers, global warming or health care for residents who become the victims of air pollution.

Finally, it must be said that *Pareto-optimality does not guarantee the fair distribution of wealth*: an efficient market may be an unfair market. Researchers have actually shown that an economy based on slavery may be efficient in the sense of Pareto[(1)]. That is precisely why the government intervenes and requires firms to provide public services, such as the obligation to supply all consumers at an affordable price (universal service). More generally, certain economists such as J. Stiglitz, Nobel prize winner in 2001, are opposed to over-systematic use of the market, denouncing its excesses[(2)].

1.3 Vertical disintegration and transaction costs

Electricity is brought to the end user in four phases (this will be discussed in detail in the next section): production, transmission, distribution and sale. In the transmission and distribution phases, competition is excluded because they exhibit the characteristics of a natural monopoly and feature network externalities. In the context of its liberalisation, the electricity sector must therefore undergo vertical disintegration in order to separate non-competing segments (transmission and distribution) from the potentially competitive segments (production and sale). That vertical disintegration is associated with transaction costs between the various segments, costs which are unavoidable in the case of purchase and sale on a market[(3)].

To sum up, we can say that, according to the transaction cost theory, there are two methods of effecting any transaction: internally, within a firm, or externally, on the market. There are numerous "hybrid" forms between the two methods, such as fixed-term contracts or alliances. Any method can be used for certain transactions in so

(1) Bergstrom T. (1971).
(2) See for example Stiglitz J. (2003).
(3) The theoretical ideas on transaction costs and vertical disintegration are mainly the work of R. Coase and O. Williamson. For example, see Coase R. (1937) and Williamson O. (1975).

far as it makes it possible to limit the transaction costs. If the internal transaction costs are lower than costs on the market, firms decide to arrange certain activities themselves rather than calling on the market, and vice versa.

The transaction costs on the market include more particularly the costs of collecting information, the costs of negotiating and executing contracts and the potential costs associated with coordination and supervision of the market by an independent body. The transaction costs for internal governance consist mainly of the costs of monitoring and coordinating personnel. The larger the firm, the greater the interaction between the workers and the higher the costs.

In theory, the *vertical integration of activities is desirable if the market transaction costs are higher than the costs of internal governance*. That is generally the case if :

- the transaction relates to a *specific asset*, i.e. a product or service which is produced specially for the specific needs of a limited number of customers. That situation makes the customer and the supplier vulnerable ;
- the transaction is associated with an *exchange of information* : in that case there is the risk that one of the parties may fail to meet his obligations, and that is difficult to monitor ;
- the transaction is subject to *uncertainty* : in that case it is difficult to achieve a balance in the application of the contract to future developments, and that may place one of the parties in a risky position ;
- the transaction requires intensive *coordination*, necessitating the establishment of a coordinating body, for example.

As emphasised by P. Joskow, the gains from the liberalisation of certain segments of the sector has to be compared with any increase in the transaction costs resulting from vertical disintegration [(1)]. The second part of this document argues that the transaction costs arising from the vertical disintegration of the electricity sector may be considerable, even if they cannot be quantified owing to the lack of data.

2. The electricity sector ; specific characteristics in the light of the liberalisation debate

2.1 Introductory concepts

Chapter 1 of this article examined the theoretical background and the motives for introducing free markets. On the one hand, theory shows that competition leads to efficiency and lower prices. On the other hand, it was pointed out that the theoretical model is based on many underlying assumptions, and that this paradigm never occurs in reality. Moreover, the latest economic findings seem to indicate that a liberalised market, and more particularly the way in which it is implemented, entails new costs and therefore does not necessarily lead to lower prices.

This chapter takes a closer look at a number of very special characteristics of the electricity sector. Each individual characteristic is undoubtedly present in other sectors, but the combination and interaction of the characteristics make the electricity sector unique. The result is that some basic assumptions of the theoretical free market model are only partly satisfied. Furthermore, the breaking up of the previously vertically integrated operation entails additional transaction costs.

Since experience gained from the telecommunications sector is often cited in the debate between advocates of liberalisation and its opponents, the specific characteristics of the electricity sector will be addressed as far as possible by reference to the similarities and differences in relation to the telecom sector.

Deregulation of the electricity sector begins with breaking up the sector into four basic segments :

1. Electricity production.
2. Transmission of the electricity via the high voltage network.
3. Distribution of the electricity via the low and medium voltage network.
4. Sale of the electricity to the end users.

It is generally assumed that the transmission and distribution remain monopolies, while the production and sale can be liberalised. To prevent any distortion of competition, there has to be strict segregation between the monopolistic and liberalised segments.

(1) Joskow P. (2002).

The remaining monopolies require a regulatory body which, jointly with the national competition authorities, supervises competition in the liberalised segments. This is:

5. The electricity sector regulator.

This chapter will reveal why a sector-specific regulator is necessary. It will also show that, with a view to the reliability of the system, a coordinating body is necessary, namely:

6. The independent system operator in charge of coordination.

The presence of an *independent system operator* in the electricity sector is due to the need for coordination between the various players in the electricity sector. That coordination is necessary because there is no direct link between producers and consumers, so that the stability of the entire system can only be guaranteed with the cooperation of all producers (this is explained in sections 2.3 to 2.7). As already stated, the price fixed in a free market should comprise the necessary incentives to ensure that coordination. The presence of a system manager is therefore already an indication of a number of shortcomings in the free market.

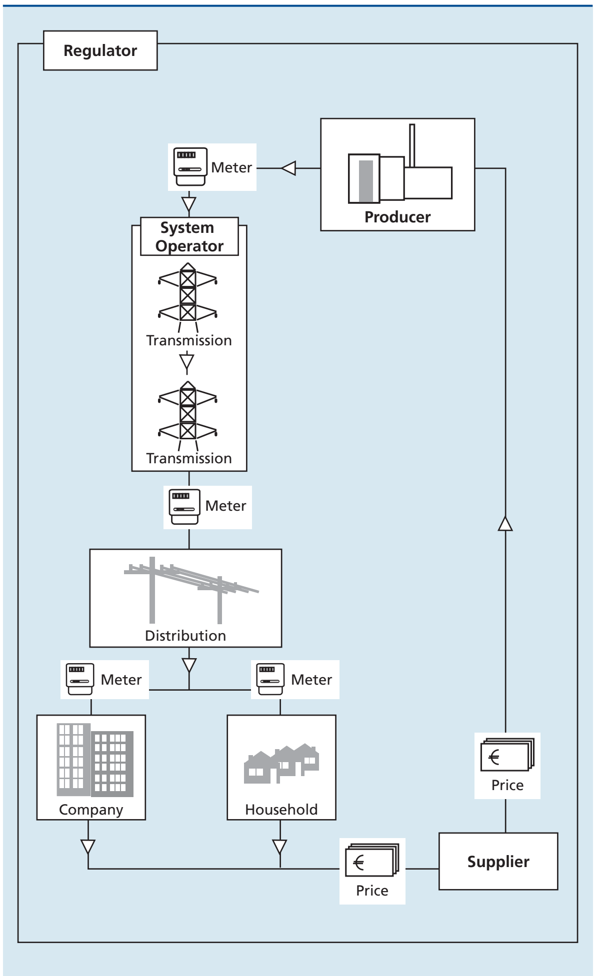
Finally, there must be a mechanism for setting prices in the liberalised segments:

7. The price mechanism and the derivatives.

It must be said that, except for point 7, all these functions are also performed in a vertical operation. In a vertically integrated firm, the internal decision-making process ensures that all these functions are mutually coordinated. The division into sub-segments creates a need for a new coordination mechanism. In the free market, this is of course the price mechanism.

The physical characteristics of electricity supply impose separate requirements on this price mechanism (see section 2.7.2). Replacement of the internal decision-making process by a market mechanism, and the need to coordinate the electricity system, necessitate an intensive exchange of information and hence additional transaction costs. As already remarked, these transaction costs could partly offset any price reductions in the liberalised segments.

FIGURE 1 STRUCTURE OF THE ELECTRICITY SECTOR AFTER LIBERALISATION



For a simple presentation of the structure, see figure 1.

A consumer (household or firm) concludes a contract with an electricity supplier for the supply of electricity during a specified period. The consumer is free to choose the supplier. A market therefore exists.

The supplier must in turn purchase electricity from an electricity producer. For that purpose, he concludes a contract direct with a producer, or turns to an electricity exchange (1).

Production and consumption seldom take place at the same location. The electricity which is generated therefore has to be transported to the consumer via the transmission and distribution network.

(1) This is a somewhat simplified situation, particularly as some large users are connected directly to the high voltage network. In addition, owing to several characteristics of the electricity supply, a number of markets are required (day-ahead, real-time, etc.). That point will be discussed later in this article.

The transport costs entailed are passed on to the consumer.

Metering equipment has to be built into the network to provide sufficient information for correct invoicing.

Box 2 translates figure 1 into the Belgian context.

Before all the segments are discussed in detail, the next section will first give a brief account of the liberalisation of the telecom sector, the reference sector for this study. Doing so the differences and similarities in relation to the electricity sector can then be properly assessed.

Box 2 – Liberalisation of the Belgian electricity sector

Transposition into Belgian law of European Directive 96/92/EC concerning common rules for the internal market in electricity has led to following structure for the sub-segments mentioned above.

- Production: like most of the Member States, Belgium opted for a licence system. The licences are granted by the federal minister responsible for Energy. The three main Belgian producers are Electrabel, SPE and EDF[1].
- Transport of electricity: a distinction is made between the transmission network (high voltage) and the distribution network (low voltage).
  The management of the transmission infrastructure was assigned to a newly established company, Elia Assets N.V. Elia is therefore responsible for extending and maintaining the high voltage network.
  The operational management of the network, mainly the coordination of demand and supply and the avoidance of overloading, was entrusted to Elia Systems Operator, which is therefore responsible for coordinating the actions of producers and consumers.
  The distribution network is the responsibility of the (pure or mixed) intermunicipal associations and public authorities. They take charge of the management of the physical distribution network.
- Supply: prior to liberalisation, the municipalities had a monopoly on the supply of electricity in their area. The directive provides for progressive liberalisation of the market according to the customer's annual consumption. However, the supply of electricity to households and SMEs is a regional matter, and when the directive was transposed into Belgian law the regions opted for a varying implementation timetable. In the Flemish region, consumers have all been free to choose their supplier since 1 July 2003. The Walloon and Brussels regions have not yet set any official date, but according to the directive every consumer must have a free choice there, too, by no later than 1 July 2007[2].
  In Flanders, licensed suppliers include Electrabel Customer Solutions, Nuon, Essent, Luminus, EDF, and SPE/Citypower.
- The regulator: at federal level, the regulator's task is entrusted to the CREG (Commissie voor Regulering van Electriciteit en Gas). The CREG advises the federal government.
  In addition, there is a regulator for each region. The regional regulators also act as both advisory bodies and supervisory authorities. For Flanders, this is the VREG (Vlaamse Commissie voor Regulering van Elektriciteit en Gas); for Wallonia it is the CWaPE (la Commission Wallonne pour l'Énergie); finally, for Brussels it is the BIM (Brussels Instituut voor het Milieu).
  The regional regulators also take charge of the procedures relating to electricity from renewable sources via the mechanism of the green electricity certificates and Combined Heat and Power certificates.
- Pricing: in Belgium, prices are set mainly via bilateral contracts. An electricity exchange is also being set up, in which Elia would be the main shareholder. APX (the Dutch exchange) and Powernext (the French electricity exchange) would be minority shareholders.

(1) EDF has a share of 50 p.c. – or 481 MW - in the Tihange 1 power station via its Belgian subsidiary, Semobis
(2) The big companies have access to a liberalised market since 1 january 2003.

2.2 The liberalisation of the telecommunications sector

The structure of the telecommunications sector is less complex than that of the electricity sector. A relatively simple device (telephone, fax, PC, GSM) is connected to a second device via a communication network. The devices can be identified by a number.

The activities of the telecom sector comprise the establishment and maintenance of a communication infrastructure (telephone cables, exchanges, GSM masts, etc.) which are used to provide the actual service (voice, SMS, data transmission, etc.).

Since telecommunication is a service, there is *no production segment*. Transmission and distribution in the electricity sector correspond to the network infrastructure of telecommunications, as the service that uses that infrastructure can be compared with the supply of electricity to end users.

In contrast to the situation in the electricity sector, it is not only the sale of services that is being liberalised, but *competition is also being introduced into the network infrastructures* (1). Within the telecommunication sector it is therefore possible to have multiple network infrastructures.

In Belgium, mobile network operators include Proximus, Base and Mobistar. Fixed telephony operators include Belgacom, Telenet, Codenet, British Telecom, etc.

The infrastructures of the various operators are interlinked so that the customers of one particular operator can be connected to customers of another network operator. In technical terms, it is relatively easy to interlink telecommunication networks (2) (later on, this article will show that this is not the case for electricity transmission).

The regulator regulates the tariffs charged for the mutual connections (also known as termination tariffs) between the various operators.

Most telecom service providers have their own infrastructure, though sometimes it is only small. In large cities and business parks, in particular, customers can choose among alternative suppliers. Naturally, the old monopolist (in Belgium that is Belgacom) has an advantage over newcomers for historical reasons. As its network offers wider coverage, it can take greater advantage of the "network effect" (the greater the number of customers, the greater the benefits for all customers). This network advantage is reduced somewhat (3) by the interconnections between the networks of various operators.

The greater coverage also implies that each customer, regardless of location, can be linked to the network at relatively low cost. The high level of coverage offered by the former monopolist in comparison with newcomers is the reason for the "local loop" problem: in many cases, a new network operator will only be able to give new customers access to his own network by making use of part of the network belonging to the historical operator.

The analogy between the electricity sector and the telecommunication sector is as follows:

Electricity	*Telecommunication*
production	–
transmission	network infrastructure
distribution	local loop
regulator	regulator
independent system manager	–
supply	service
price-setting	price-setting

In the telecommunication sector, competition was introduced in **both** the service **and** the network infrastructure. In the electricity sector, supply and production have been liberalised.

For a long time, the telecommunication networks (and electricity production) were characterised by economies of scale. Technological progress has changed that. For instance, in telecommunications new multiplexing techniques have made it possible for the network's capacity and speed to be greatly increased at relatively low additional expense (4). The fact that it is relatively simple to interconnect the various networks is also an essential condition (which is met in the case of the telecom sector) for introducing competition into the infrastructure segment.

(1) The competition between Belgacom and Telenet explains the success of broadband technology in Belgium. It is doubtful whether the same success would have been achieved by placing the network infrastructure with an independent operator (as in the electricity sector).

(2) This is only true from the technical angle. The invoicing of these mutual connections gives rise to various problems, the reason being that there is usually asymmetry of information between the operator and the regulator. That makes it impossible for the regulator to estimate the true costs of the mutual connection, so that excessively high termination tariffs may ensue (see for example BELTUG, "De liberalisering van de telecommunicatie – de balans van de zakelijke telecomgebruikers").

(3) The network advantage does not disappear entirely as a result of the relatively high tariffs for mutual connections. For example, calls between customers using the same mobile network are cheaper than between customers using different mobile networks.

(4) The ADSL (Asymmetric Digital Subscriber Line) broadband technology uses the existing copper wiring between the exchange and the end user. The operator only needs to install a DSLAM (DSL Access Multiplexer) in the exchange. The end user has to have a "splitter" (to split the voice signal and the data signal transmitted via the same pair of copper wires) and an ADSL modem.

Telecommunication networks are also multifunctional. They are used to transmit sound, data and images. Data transmission really took off with the advent of the internet. Apart from reducing the economies of scale, this has also led to increased volume on these networks.

The efficiency of a monopoly depends on the extent of the economies of scale (the "minimum efficient scale" or MES[1]) and market size.

Whether or not economies of scale will then lead to a natural monopoly depends on the relative size of the economies of scale in relation to the size of the total market; if the MES is larger than the market, then a monopoly is efficient. As the market expands, the efficiency of a monopoly may therefore decline.

At this point it must be said that such a phenomenon is not happening in the electricity sector[2]. Since the electricity network has only one function, namely the transport of electricity, and in view of the problems of interconnection, the market's size has not increased in practice.

The increase in volume on the telecommunication networks while costs have remained more or less steady has also led to a sharp fall in the average costs.

In telecommunications, liberalisation therefore took place in the context of technological improvements with low costs on the supply side, combined with increased demand generated by new applications. The two effects together bring down the average costs.

This *cross-fertilisation between the demand and supply sides is absent in the electricity sector*. The introduction of new technologies by the producers (CCGT power stations) is not accompanied by a growing number of applications, so that demand is not rising. On the contrary, in the electricity producing sector there is instead a tendency to inhibit demand for environmental reasons.

Finally, it should be pointed out that, after the broadband networks, the next generation of telecommunication networks is already in the pipeline (VDSL[3], operating at roughly 10 times the speed of ADSL). These new networks will facilitate digital television and video on demand, for example. However, in contrast to the previous generation, they will require very substantial investments in this new network infrastructure[4]. Consequently, the introduction of this new technology entails substantial costs. New applications on the demand side may lead to increased use. To what extent that will reduce the average costs (and hence the tariffs) depends on the relative size of the two effects. It is therefore far from certain whether liberalisation will be as beneficial in this case, because a producer will only decide on the necessary modernisation if he is more or less certain of his future market.

To sum up, we can say that in the telecommunication sector:

1. the production segment does not exist;
2. the network infrastructure corresponds to the transmission and distribution of electricity. However, it should be remembered that in the telecom sector competition was introduced in the network infrastructure as well. Later we shall show that this is more or less impossible in the electricity sector;
3. there is also a regulator supervising the sector;
4. there is no independent coordinator. We shall also show that a coordinator is in fact necessary for technical reasons in the electricity sector;
5. the provision of a service via the infrastructure is comparable to the supply of electricity;
6. apart from technological progress which has reduced the economies of scale, the telecommunication services market, unlike the consumption of electricity, has expanded strongly with an ensuing reduction in the average costs. That also reduces the relative importance of the MES and increases the potential number of operators.

Not only does the structure of the telecommunication sector therefore appear to be simpler than that of the electricity industry, the deregulation in the two sectors also took place in different segments: the production segment in the case of electricity and the network segment for telecommunications. The arguments in favour of deregulating these two different segments (particularly the disappearance of economies of scale) will be analysed later in this article.

The sections which follow examine the electricity sector sub-segments. However, the sequence has been adjusted to make the reasoning clearer and to avoid too many explanations of concepts.

(1) A natural monopoly is a theoretical concept in which the average costs continue to fall and the MES is therefore infinitely large. In practice, we talk about a natural monopoly if the MES is much larger than the market. This may therefore vary over time.

(2) It should be pointed out that, in theory, the market has in fact been extended from a national market to a European market.

(3) VDSL stands for Very High Rate Digital Subscriber Line.

(4) In order to implement VDSL in Belgium (the Broadway project), Belgacom will have to upgrade a major part of its network (for optimum capacity, the glass fibre network has to be brought as close as possible to the user, because the speed declines rapidly the greater the distance from the optical network); that was not the case when ADSL was introduced (when it was possible to use the existing copper wiring). The investment will total 520 million euro over a 10-year period. (See "Belgacom stopt 522 miljoen euro in superinternet", Tijd, 20.06.2003).

2.3 Sale (supply) and consumption

Society can no longer function without electricity; consumption continues to rise, both in the production process and in households.

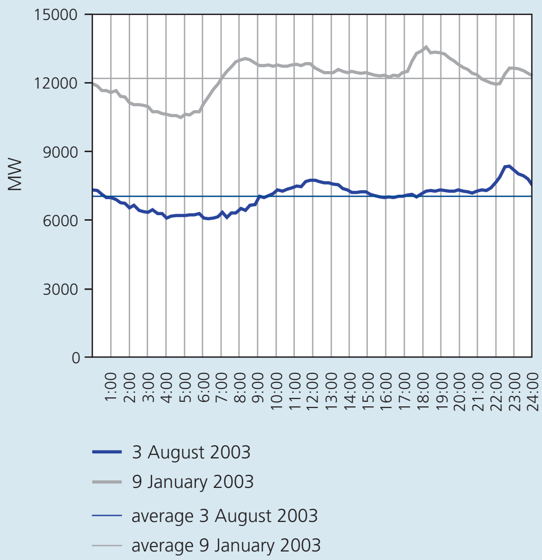
Increasing automation and the associated support processes are causing a huge increase in dependence on electricity worldwide.

The effects of the blackout in the US on 14 August 2003, in particular, demonstrated the importance of a reliable electricity system. Although there are variations in the estimates of the economic impact of that blackout, almost all of them come to between five and ten billion dollars [(1)]. The blackout in Italy on 28 September in the same year is actually said to have caused three people to lose their lives [(2)].

It is therefore not surprising that electricity supply is regarded as a *universal service* [(3)]; everyone must have ready access to it at all times and at a reasonable price (see also the last section of 1.2).

There are also few substitutes for electricity, so that demand for electricity is *not very price sensitive*. That is certainly true in the short term.

CHART 2 VOLATILITY OF BELGIAN DEMAND FOR ELECTRICITY; CAPACITY DEMANDED PER QUARTER



Source: Elia.

TABLE 1 ELECTRICITY CONSUMPTION IN BELGIUM IN 2002
(In GWh)

	Consumption in 2002	Part (in p.c.)
High Voltage	**53,470.3**	
Energy	1,899.5	2.36
Agriculture	265.8	0.33
Industry	38,026.5	47.27
Transport	2,125.2	2.64
Public Lighting	258.6	0.32
Trade and Public Services	10,894.7	13.54
Low Voltage	**25,920.2**	
Residential	17,602.1	21.88
Professional	7,155.5	8.90
Public Services	426.7	0.53
Public Lighting	735.9	0.91
Autoproducers [(1)]	**1,047.6**	
Energy	13.2	0.02
Agriculture	12.7	0.02
Industry	986.2	1.23
Transport	1.3	0.00
Public Lighting	34.2	0.04
Total	**80,438.1**	**100.00**

Source: FPE, Annuaire statistique 2002.
(1) Some industrial customers recover residual heat from their production process for the production of electricity.

On top of this limited price elasticity, there is also the *great volatility* of electricity consumption, both during the day and during the year. That is evident from chart 2, which shows Belgian electricity consumption on a winter's day (9 January 2003) and on a summer's day (3 August 2003), per quarter hour and also as a daily average.

The average demand for capacity varies in Belgium from 7,000 MW in the summer (for an explanation of the units, see box 3 below) to 12,000 MW in the winter [(4)].

The variation between the lowest and highest capacity during any day may be as much as 4,000 MW.

(1) ELCON (2004)
(2) See Le Monde, 30.09.2003
(3) The economic concept of a "universal service" is broader than the system of social tariffs.
(4) Capacity is not the same as consumption. This is explained in box 3. If capacity of 7,000 MW is used for a quarter of an hour, that implies consumption of 7,000 MW x 0.25 hr = 1,750 MWh during that quarter of an hour.

Furthermore, these peaks only occur during a limited period. The maximum capacity (approximately 13,500 MW) is demanded for between one and two hours a year. That has a considerable impact on the production segment, where sufficient reserve capacity has to be provided to *cope with these short-lived peaks*.

The volatility of demand gives rise to a *highly volatile demand* curve and therefore, in a liberalised market, to unstable prices as well. These volatile prices (1), combined with the universal service, do present risks for suppliers, as the latter have to obtain their supplies on a market where prices fluctuate very widely, whereas their selling prices are usually not very volatile, or are even virtually fixed owing to the universal service (2).

(1) This volatility can be the result of the production costs of the different types of power stations and/or an insufficient capacity of production (§ 2.4.2 – § 2.4.3).

(2) In this context, see the problems in California where market dominance in production and climatological factors drove up prices. This caused problems for electricity suppliers confronted by fixed selling prices.

(3) In periods of low demand, reserve capacity is used to raise the water level in these reservoirs so that subsequent peaks in demand can be covered.

Referring to figure 1 ; the price between the producer and the supplier is highly volatile, whereas that between the consumer and the supplier is far less volatile.

This price risk for the supplier does not exist in a vertically integrated operation. Indeed, that is also the reason for the *reintegration* taking place between producers and suppliers.

To illustrate this, table 1 shows Belgian consumption and its distribution among various types of consumer. The difference between high and low voltage is explained in a box in section 2.5.

Total consumption came to 80,438 GWh. That demand was met by production in both Belgium and other countries (see table 3 later on in this article). The supply totalled roughly 85,730 GWh. The difference between the two (5,292 GWh) is attributable to network losses (see box 5) (3,767 GWh) and to the use of electricity to pump water up into the reservoirs (3) (1,525 GWh).

Box 3 – A number of commonly used units

In physics, energy refers to the capacity to perform "work". There are various types of energy : mechanical energy (moving objects), thermal energy, electrical energy (kinetic charges), etc.

The various forms of energy are interchangeable. For example, kinetic energy is converted to thermal energy by friction.

Electricity generating stations are based on this principle. For example, gas power stations burn gas and the resulting thermal energy is converted to electricity.

However, the conversion from one form of energy to another always entails a loss of energy, and that applies equally to electricity generating stations. The ratio between the electricity produced by a generating station and the energy used as input (known as primary energy) denotes the power station's efficiency.

efficiency = electrical energy produced/primary energy used

The efficiencies of a number of electricity generating stations are given below as an illustration :

coal	40 to 45 p.c.
CCGT (1)	60 p.c.
gas turbine	40 p.c.
nuclear	33 to 36 p. c. (2)
hydro	90 to 95 p.c.
wind turbine	35 p.c.

Source : Eurelectric, "Efficiency in electricity generation", July 2003.

(1) CCGT : Combined Cycle Gas Turbine. A power station in which gas is used as fuel to drive a turbine, and in which the hot combustion gases are recovered and used to drive a steam turbine.

(2) Tarjanne (2003) assumes 37 p.c. efficiency for nuclear power stations.

Energy is expressed in joules. The letter J is the abbreviation for the unit joule.

A second key variable is the amount of "work" that can be performed per unit of time, in other words the speed at which work can be done. This is called power, and is expressed in watts (abbreviated W). A watt is equal to 1 joule per second.

The power generated is therefore equal to the energy produced divided by the time taken to produce the energy.

Power = energy produced / time

Energy can therefore also be expressed as power multiplied by time (watt x hours), so that an alternative unit of energy is the Watt-hour (Wh). In the electricity sector, the Wh is more commonly used than the joule.

The conversion is carried out as follows:

1W = 1J/1s = 1J/(1/3600h) = 3,600 J/h.
1Wh = 3,600 J

Another common unit is the Whe. As already stated, energy conversion is always accompanied by loss. The energy content of the input fuel for an electricity generating station is denominated in Whf. The resulting electrical energy is denominated in Whe. The ratio between the two is the power station's efficiency.

Finally, the prefixes should be explained:
- Kilo (K) means 1,000 units, i.e. 1 kilowatt is 1,000 watts
- Mega (M) means one million units or 1,000 kilo
- Giga (G) means one billion units or 1,000 Mega
- Tera (T) is 1,000 Giga

The biggest consumer is industry, accounting for roughly half the total Belgian consumption. One fifth of the total electricity consumption goes to households. Public lighting consumes barely 1 p.c.

2.4 Production

The production of electricity is the conversion from a particular form of energy into electrical energy (see also box 3). For instance, if fossil fuels are used (natural gas, coal, oil), heat is converted to electricity.

Deregulation of the electricity sector opens the production segment to competition. Nonetheless, it has long been thought that there are *economies of scale* available in electricity production, which was therefore monopolistic in its structure. Technological progress, and more particularly the advent of the CCGT and CHP power stations, should end these economies of scale and permit competition in this segment.

CCGT power stations have in fact made it possible to produce electricity on a small scale. However, their variable costs depend very much on the volatile price of oil. In addition, this small-scale production still does not allow consumers to arrange their own production. The question is therefore whether sufficient conditions are actually met for a free market to lead to efficient production. That requires an understanding of the cost structure.

Before considering a number of characteristics of electricity production, it should be remembered that *this production segment does not exist in the telecommunication sector*. Telecommunication is a service and therefore does not require any production, by definition. All the problems mentioned below are therefore typical of the electricity sector [1].

(1) It could be said that a telephone "produces" a signal, but the actual service is the communication between two devices; in other words the demand does not relate to the signal produced, but to the connection. The service therefore exists only on condition that the two devices are connected via the network. The network is therefore essential to the communication; in the case of electricity, the role of the network is different, as will become clear later on in this article.

2.4.1 Cost structure of electricity production

Broadly speaking, the internal *costs of electricity production* can be divided into three categories:

1. Investment costs: these are the costs of constructing the power station. They vary greatly according to the type of power station, and are highest for nuclear power stations and hydro-electric plants (see table 2). The investment costs determine whether or not economies of scale exist.
2. The costs of the primary fuels. Both the level and the volatility of these costs depend on the primary fuel selected. The level depends mainly on the size of the fuel reserves and the transport costs. The volatility depends on geopolitical factors and the concentration of the reserves.
   Fuel costs for renewable sources (hydro, wind and solar power) can be considered negligible. The prices of uranium and coal are generally low and relatively stable. In contrast, the price of gas is linked to that of crude oil, and tends to be volatile. The growing demand for natural gas and the limited, concentrated reserves imply widely fluctuating and increasing prices (1).
3. Operating costs; these include staff costs, maintenance costs and other expenses.

However, there are other expenses in addition to these internal costs:

4. Externalities. The emission of greenhouse gases, nitrogen oxide and sulphur oxide generated by burning fossil fuels, particularly coal, implies high but uncertain costs for this type of power station. In the case of nuclear power stations, the costs of waste disposal have to be taken into account.

Table 2 is an example of this cost structure, based on Finnish data.

As regards the cost structure of what are called renewable energy sources (water, sun and wind), see the AMPERE report (2): for wind turbines, the investment costs are the biggest expense. Although the conditions are more favourable if the turbines are installed at sea (more wind), the investment costs are much higher. Finally, it should be pointed out that wind turbines do not produce at full capacity throughout the year since their output depends on the strength of the wind.

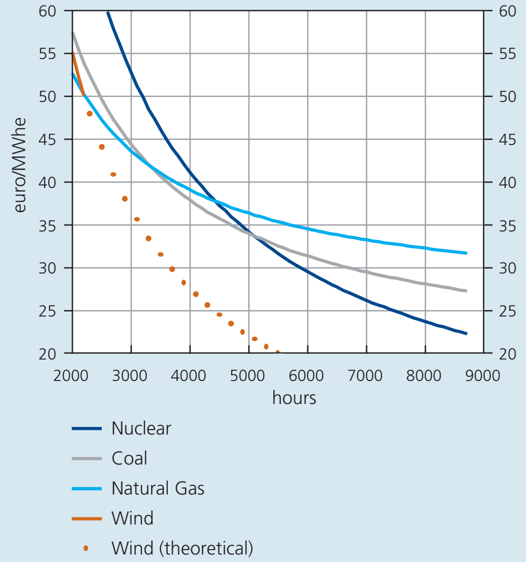
(1) In this connection, see also: Federaal Planbureau (2004).
(2) AMPERE (2000), section F, chapter 3 for wind power and section F, chapter 6 for HEP.

TABLE 2 COST STRUCTURE OF POWER PLANTS

	Nuclear	Coal	Gas	Wind
Power (MWe)	1,250	500	400	1
Efficiency (in p.c.)	37	42	58	
Lifetime (years)	40	25	25	20
Investment costs per KWe (€/KWe)	1,900	860	600	1,100
Real Intrest rate (in p.c.)	5	5	5	5
Annuity factor	17.16	14.09	14.09	12.46
Annual investment costs per (€/MWe) (1)	110,729	61,019	42,571	88,267
Annual fixed operation costs per MWe (€/MWe)	28,500	17,200	12,000	22,000
Annual fixed costs (€/MWe)	139,229	78,219	54,571	110,267
Fuel costs (€/MWhe)	2.70	13.10	23.45	
Variable operation and maintenance costs (€/MWhe) (2)	3.63	5.24	2.00	
Vaiable costs (€/MWhe)	6.33	18.34	25.45	0.00
CO_2 emissions costs				
CO_2 emissions (kg/MWhe)		811	346	
Emission allowances costs (€/tCO_2) (3)		10	10	
Variable CO_2 emissions costs (€/MWhe)		8	3	
Nuclear waste costs	(2)			

Source: R. Tarjanne, K. Luostarinen: Competitiveness comparison of the electricity production alternatives (price level March 2003).
(1) The annual investment costs take account of the total investment costs and the useful life of the power station.
(2) The variable operating costs of nuclear power stations also include the payments into the "nuclear waste fund" and therefore take account of the processing and the temporary and permanent storage of radioactive waste, and subsequent dismantling of the power stations.
(3) According to Tarjanne (2003), these emission costs fluctuate between 10 and 100 €/tCO_2.

CHART 3 AVERAGE PRODUCTION COSTS OF ELECTRICITY GENERATING STATIONS – EXCLUDING THE COSTS OF CO_2 EMISSIONS.



The investment costs for HEP (Hydro Electric Power) stations are very high, and make this type of power station unsuitable for small-scale production.

The data in table 2 were used to produce the graphs in charts 3 and 4, in order to provide a clearer idea of any economies of scale.

The chart shows the average costs (i.e. the total costs divided by the number of hours' production) for four types of power station: nuclear, coal, CCGT and a wind turbine. The cost of CO_2 emissions is disregarded. In view of the linear cost structure (see also box 4), the three curves decline.

For production ranging between 0 and 3,400 hours per annum, the average costs are lowest for a CCGT power station; for production ranging between 3,400 and 5,300 hours per annum, a coal-fired power station is cheaper, and from 5,300 hours per annum upwards the nuclear power station is cheapest to run. The chart also shows that where production exceeds 4,500 hours per annum, the CCGT cannot compete with a nuclear power station.

For the wind turbine, a distinction is made between what is possible in theory and what is feasible in practice, as it has already been pointed out that, owing to its dependence on wind strength, a wind turbine's production capacity is limited (in the chart it produces 2,200 hours[1] [2]). This limited availability implies that the declining cost curve cannot be fully exploited, which in turn means that the wind turbine comes out the most expensive despite the absence of variable costs. The use of multiple wind turbines does not resolve the problem.

Chart 3 takes account of the external effects in the case of a nuclear power station, but not in the case of the gas and coal-fired power stations[3]. Table 2 also offers information on CO_2 emissions. Estimates of the cost of CO_2 emissions vary widely. Tarjanne's study arrives at a cost of between 10 and 100 euro per tonne of CO_2[4]. By way of example, costs per tonne of CO_2 are taken as 10 euro/tCO_2. The results are shown in chart 4.

Owing to the higher CO_2 emissions of coal-fired power stations, the variable costs of the latter become so great that they cease to be competitive[5]. CO_2 emissions also increase the costs of gas-fired power stations, so that they

(1) This is the figure cited in Tarjanne (2003).

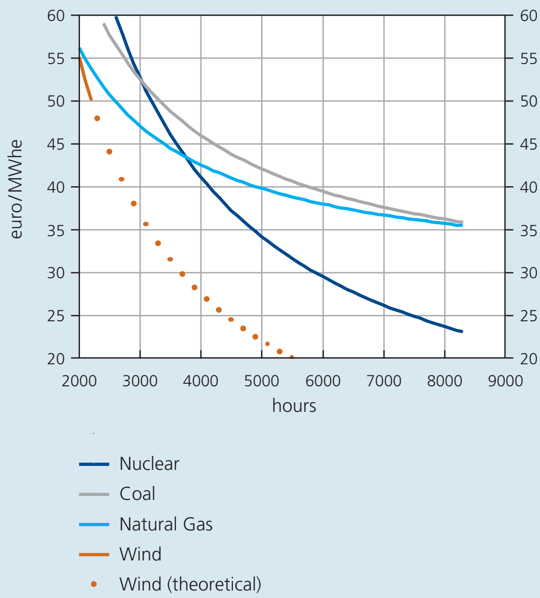
(2) AMPERE (2000), section F, chapter 3, reports production of 1,200 GWh/year for a capacity of 500 MW in the case of installation on land. This implies production for 2,400 hours per annum. In the case of installation at sea, production totals 3,000 GWh for a capacity of 1,000 MW, i.e. 3,000 hours per annum.

(3) This article does not address the question whether the payments into the "nuclear waste fund" will be sufficient to cover the subsequent dismantling of the power station and disposal of the radioactive waste. The interested reader is referred, for example, to Posiva Oy, "Into Olkiluoto bedrock, Final disposal of spent nuclear fuel in Finland" or, in the case of Belgium, to CREG (2001a).

(4) Other sources, such as DGEMP-DIDEME (2003), assume CO_2 costs ranging between 4 and 50 euro/tonne CO_2.

(5) This applies to the burning of coal. However, the same power stations can be used to burn biomass, which produces much lower CO_2 emissions.

CHART 4 AVERAGE PRODUCTION COSTS OF ELECTRICITY GENERATING STATIONS, INCLUDING CO_2 COSTS (10 €/tCO_2)



can no longer compete with nuclear power stations once production exceeds 3,800 hours per annum.

For a small number of hours' production, wind turbines are the cheapest to operate. In theory, they are therefore ideal for use in peak periods. However, owing to their dependence on the wind they are not entirely suitable for that purpose. From a financial/economic point of view, they cannot compete in terms of basic costs with a nuclear power station which produces for 7,000 to 8,000 hours per annum, bringing the average costs to roughly 25 euro/MWh. That is about half the production costs of the wind turbine.

However, wind turbines should be used as much as possible for ecological reasons, but that can only be done if alternative resources are available when there is no wind. Taking account of the external costs therefore not only increases the cost of the electricity production, but also changes the order in which the various types of power station should be used.

Box 4 – Linear cost structure

Micro-economic theory assumes a U-shaped cost structure, which is due to the duality between production and costs and to the law of diminishing returns. An electricity producer's cost curve is different, and has a non-convex shape. The implications of this non-convexity are discussed below in the specific case of a linear cost curve.

Studies on electricity production usually assume a linear cost structure (see for example Tarjanne R., Luostarinen K. (2003)), in other words

$$TC(Q) = FC + AVC \times Q, \text{ where}$$

TC = total costs,
FC = fixed costs,
AVC = average variable costs,
Q = quantity produced.

It follows that

$$MC = AVC$$
$$AC = FC/Q + AVC$$

MC = marginal costs
AC = average costs

Since the fixed costs are positive, the average costs always exceed the marginal costs.

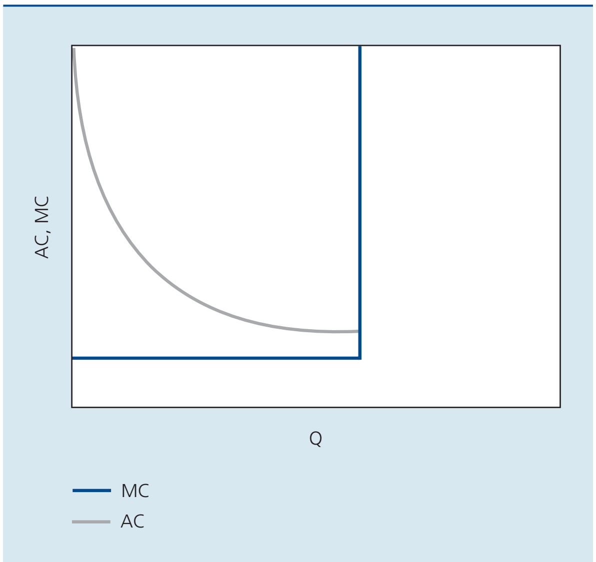
The behaviour of producers in a free market shows that the supply curve of a competing producer is equal to the part of the marginal cost curve that exceeds the average variable costs (this is known as the shut-down condition). However, the producer only makes a profit if the price exceeds the average costs.

But as demonstrated above, in the case of linear cost curves the marginal costs are always less than the average costs. *The marginal cost rule therefore always leads to a loss.* Because in this case

$$p = MC = AVC \text{ (where p represents the price) so that Profit} = p \times Q - FC - AVC \times Q = -FC$$

Given a linear cost structure, the marginal cost curve takes on an "unnatural shape", a horizontal line followed by a vertical line once maximum capacity is reached.

LINEAR COST STRUCTURE



Tariff-setting on the basis of marginal costs therefore always leads to negative profits in the case of a linear cost structure. This finding is crucial to the liberalisation debate.

2.4.2 The permanent equilibrium between demand and supply

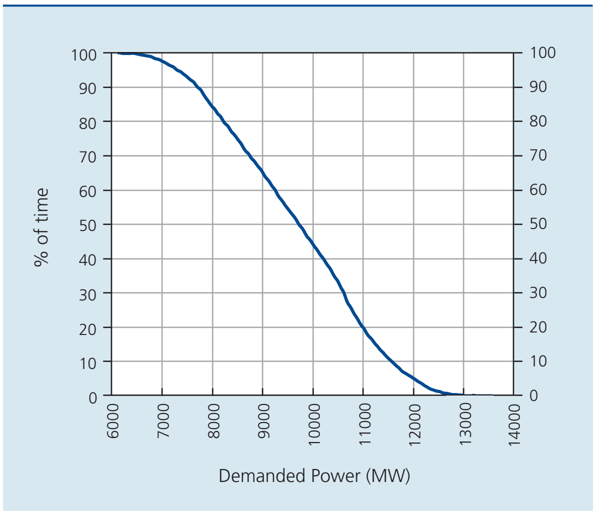
The various methods of producing electricity need to be combined with the characteristics of demand for electricity. The concept of the load duration curve is introduced for that purpose.

The daily demand profiles mentioned above make it possible to draw what is called a *load duration curve* which shows, for each level of capacity, the percentage of the year in which that capacity is required. The curve for Belgium is shown in chart 5.

The chart shows that a capacity of 6,000 MW is needed throughout the year. The load figure applicable more or less all the year is called the base load; the load required for only a small proportion of the time is called the peak load. The rest is the intermediate load[1]. The chart is based on the daily demand profiles as shown in chart 2, where the minimum load was 6,000 MW and had to be available throughout the year. The maximum load of 13,500 MW was required to be available for just a few hours each year. These two findings based on chart 2 are also apparent from chart 5.

(1) DGEMP-DIDEME (2003) defines the base load as a minimum of 5,000 hours per annum, the intermediate load is between 3,000 and 5,000 hours per annum and the peak load is below 3,000 hours per annum.

CHART 5 LOAD DURATION CURVE FOR BELGIUM



Source : Elia

Electricity *cannot be stored at reasonable cost*. Peaks and troughs in demand therefore cannot be covered by stock-piling, as they can for most goods.

This implies that any increase in demand has to be met immediately by increasing electricity production, in other words there is a *permanent equilibrium between demand and supply* in the case of electricity. That is particularly true (see the section on transmission and distribution) since any imbalance between demand and production could have *catastrophic consequences*[(1)] for the entire system.

The volatility of demand combined with the required permanent equilibrium between demand and supply necessitates:

1. Adequate *reserve (production) capacity* to cater for peak demand. However, in a free market it is by no means clear who will provide this reserve capacity, especially as it is already apparent (in charts 2 and 5) that peak capacity is only used for a few hours each year.
   Another problem is that it takes several years to build a power station, so that any shortage of capacity can only be rectified in the medium term. A shortage will therefore lead to higher prices which, in theory, will prompt expansion of capacity or entry to the market; it will take years to achieve a new equilibrium. Furthermore, there is the risk that higher prices may lead to excess capacity in the medium term, thus causing prices to fall too low. Equilibrium would then only be achieved after a number of oscillations (Cobweb theorem).

and/or

2. A *mechanism for controlling demand*. In a free market, that is the price mechanism. In peak periods, the consumer would therefore have to pay a higher price than in off-peak periods. However, passing on that price volatility to the "small" consumer would be viewed as contrary to the principle of the universal service.
   Day and night tariffs do exist, but they do not in any way reflect the volatility depicted in chart 2[(2)(3)].

The necessary balance between demand and supply has an additional implication. It must be possible to adjust production in line with every change in demand. That restricts the *scope for using "green" power stations*.

Although these power stations can be speedily adjusted, their availability is not always guaranteed. That applies particularly to wind and solar power stations, and to a lesser extent to HEP stations as well.

The above findings lead to the conclusion that the *production costs are inevitably highly volatile*. The load profile and the coordination of demand and supply require the use of means of production with a varying cost structure. At low loads, the cheapest power station is used and the market price is low. During peak periods, expensive capacity is brought in, and it has to be financially viable during this limited period of use; naturally, that means a high price (see chart 6).

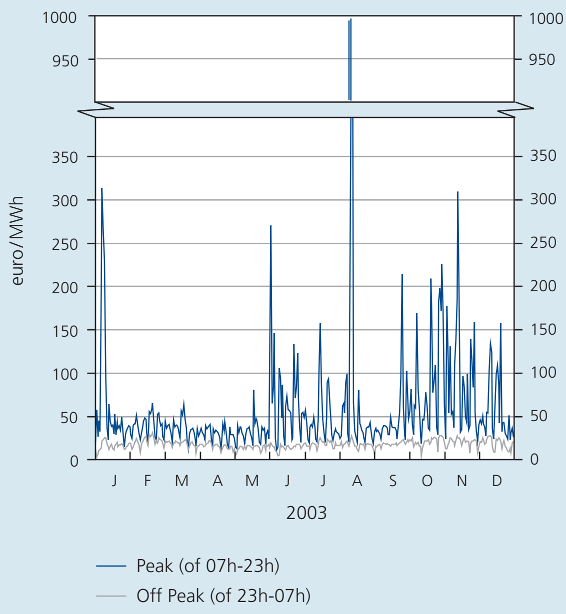
Here it must once again be stressed that this volatility is due to the cost structure and the usability of the various types of power station; in other words, that volatility will always exist, even if there is no shortage of capacity.

(1) Cf. the black-out in Italy on 28 September 2003 when, owing to the cessation of imports from Switzerland, within a few seconds 55 million people were cut off and left without electricity for several hours.

(2) In Norway, where liberalisation was initiated earlier, roughly 85 p.c. of households purchase electricity under contracts comprising an adjustable price (Statistics Norway (2003)).

(3) Passing on price volatility to the consumer is not without its costs, as it necessitates the installation of new metering equipment on the end user's premises, otherwise it is not possible to record the amount consumed per hour (or quarter hour).

CHART 6 ELECTRICITY PRICE ON APX[(1)]



Source: APX.
(1) APX: Amsterdam Power Exchange, the Dutch electricity exchange.

In the context of the liberalisation debate, it must be pointed out that producers with a combination of production facilities are in an advantageous position. There is only one market price, so that in peak periods the power stations with the lowest average costs make the biggest profit. The higher profits made by those "base load power stations" can be used to push down the price in peak periods, making it more difficult to enter the market.

Finally, we take a look at the characteristics of the Belgian production facilities (Table 3).

At the end of 2002 the generating capacity was roughly 15,500 MW. The load curve (chart 5) shows that this is sufficient to cater for the peaks so long as all units are available, because the maximum peak is roughly 13,500 MW. Chart 5 also shows that a capacity of roughly 6,000 MW is required at all times. The nuclear power stations therefore produce throughout the year (except during their maintenance periods). A power station's capacity factor is defined as the annual production divided by the theoretical maximum annual production. For the Belgian nuclear plants, that is 44,987 GWh/(5,761 x 365 x 24) GWh = 89 p.c. The Belgian nuclear power stations therefore produce for roughly 90 p.c. of the year. The remaining 10 p.c. consists of maintenance periods. For the thermal power stations, the capacity factor is 39 p.c., which means that thermal power stations (including combined heat and power) are therefore in use for less than 40 p.c. of the time. This is not only due to the maintenance periods but is mainly down to their use as peak capacity. Once again, this reveals that a large part of the production capacity is used for only very limited periods.

TABLE 3 GENERATION CAPACITY AND ELECTRICITY PRODUCT FOR BELGIUM

	Available Power end 2002 (in MW)	Production 2002 (in GWh)
Total	**15,546.4**	**78,142.7**
of which:		
Nuclear	5,761.0	44,986.7
Fossil	6,846.2	27,987.4
Combined Heat and Power	1,272.7	
Hydro	1,413.0	1,476.1
Wind	31.0	57.2
Import		**16,657.8**
of which:		
France		11,586.2
Export		**9,069.9**
of which:		
The Netherlands		6,817.3

Source: FPE, Annuaire Statistique 2002.

The total Belgian capacity is amply sufficient to cover total Belgian consumption (see table 1), as the total potential production is 15,546 MW x 8,760 hrs = 136,183 GWh, while total consumption (1) in the same year came to 85,730 GWh. This "excess" production capacity is necessary to cater for peak demand and maintenance periods.

Measures to smooth the demand curve (production cannot be levelled out because electricity cannot be stored) reduce the need for reserve capacity and therefore also cut the cost of the production capacity. In many cases, the reserve capacity also consists of relatively old power stations (i.e. ones which cause more pollution), so that *keeping down peak demand has two effects, namely cutting the costs of the production capacity and reducing CO_2 emissions*.

2.4.3 Increased uncertainty and investment

Earlier in this article, it has already been shown that the expansion of production capacity is "spasmodic". This has a significant influence on the market. Thus, bringing a new nuclear power station into use with a capacity of 1 GW will endanger the production of the existing, more expensive power stations. Such discontinuous increases in capacity lead to greater uncertainty over output.

Indeed, that uncertainty is further exacerbated by numerous other factors:

- unpredictable selling prices;
- uncertainty over the prices of the fuels used (especially the price of natural gas);
- the supplier's freedom of choice also increases uncertainty over output;
- the costs of externalities.

In a vertically integrated monopolistic market there was mainly uncertainty over the prices of the primary fuel. The monopolist was in fact the customer's only source of supply, the spasmodic expansion in production capacity took place within a single company and any impact on the existing capacity was therefore taken into account in the investment decision. The (uncertain) costs of CO_2 emissions are new, but are not due to liberalisation.

(1) This is true provided that all capacity is available, and that the consumption pattern is even.

Selling prices were regulated; the regulation was mostly based on cost-plus tariffs. In this case, the regulated consumer tariff is equal to the costs plus a "reasonable" margin. The producer is therefore sure of his income which (in absolute figures) continues to increase the more he invests.

This cost-plus tariff may, however, lead to excess capacity and hence to higher costs.

According to its supporters, the free market mechanism would overcome this problem and result in lower prices.

There is no doubt that the cost of electricity production is largely due to the need for reserve capacity. Even so, substantial excess capacity does push up the cost. Liberalising electricity production will therefore reduce that excess capacity. However, the question is whether this will result in the optimum reserve capacity, because the outcome could equally be a shortage of capacity. In that case, the cost of the electricity production will be lower, but the mismatch between demand and supply will drive up the consumer price to far above the cost price, so that producers make large margins. According to the theoretical model, these "above-normal" margins will attract new producers into the market and therefore lead to expansion of capacity. However, the assumption here is that access will be free and they will enter immediately.

It has already been demonstrated that the heterogeneity of the production capacity may form an access barrier; limited transmission capacity and regulation are other examples of barriers.

Nor do newcomers enter immediately, because it takes several years to build a new power station, and the increased uncertainty means that producers will not invest until there have been several successive periods of higher prices.

2.5 Transmission and distribution

Transmission and distribution are dealt with jointly because the associated problems are similar, although some of them are greater for one type of activity than for the other. This will be explained more clearly later on in this article.

The transmission network is essentially a meshed network where, for physical reasons, the voltage is maintained at a high level. The distribution network is primarily radial and operates at medium and low voltage (see box 5). It is the distribution manager who takes charge of connecting the customers.

The need to transport electricity arises because of the *difference in the size of the production and consumption units*, but also because production units cannot always be built in the vicinity of the consumption locations owing to the *regulations* (environment) and for *technical* reasons (HEP stations have to be sited at dams, thermal power stations have to be sited on water courses because of the need for cooling water). The *pooling* of reserve capacity is another reason for providing a transmission network.

The difference in scale between the production and consumption units is a *fundamental difference in relation to telecommunication and provides a totally different reason for the existence of the network* (1). In this last sector, the network is an essential element of the service.

The transmission and distribution of electricity are generally regarded as natural monopolies because it is not practicable to build multiple networks, in contrast to the telecom sector where the network segment has also been opened up to competition. In principle, if multiple networks are constructed, that also diminishes the network advantages. In the telecommunication sector this problem was overcome by expanding the mutual links between the networks of the various operators. One of the points demonstrated in this section is that such interlinking of electricity networks could cause stability problems.

As already stated, transporting electricity entails *transport losses*. In other words, if electricity is transported from a producer to a consumer, a quantity of electricity will be lost in the process. That loss has to be made up in one way or another (2).

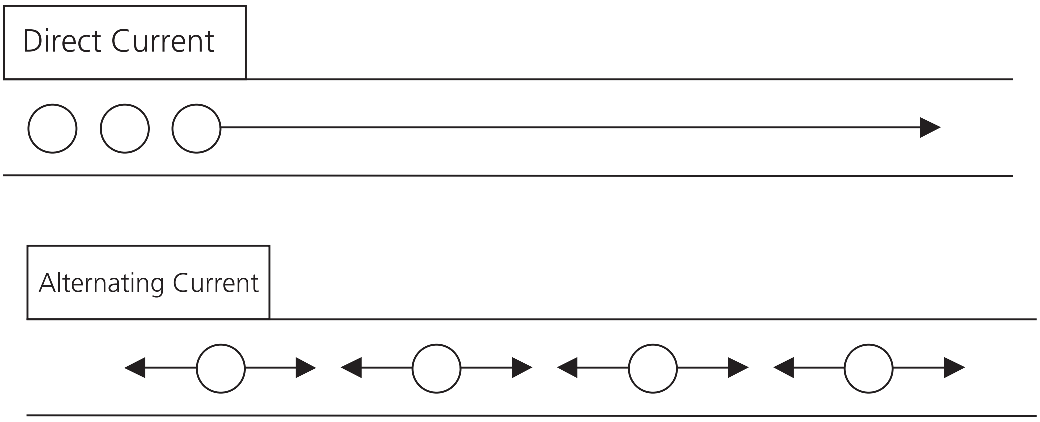
In order to limit the loss, alternating current is used (see box 5).

(1) This could change if the fuel cell makes a breakthrough in the future, because then it would be possible to produce on a smaller scale, and less account would have to be taken of the existing negative externalities. A transmission network can in such a case only be justified for swapping surpluses.

(2) In order to obtain a quantity of energy Q, the producer has to produce a quantity Q + V, where V represents the losses.

Box 5 – Network losses

Physics states that electricity consists of a stream of moving negative charges, the electrons. They produce either continuous movement (direct current) or oscillating movement (alternating current) within a conductor.



In the case of direct current, the charges therefore move from left to right. In the case of alternating current, the charges oscillate. The speed of oscillation is called the frequency. This frequency is an essential parameter of the system and must be constantly maintained at the right level.

However, in both cases electrical energy is converted into heat, and energy is therefore lost (this is called the Joule effect). This is due to friction between electrons within the conductor.

Physics demonstrates that this loss is proportional to the square of the strength of the current and the resistance of the wire. That resistance is in turn proportional to the length of the wire and in inverse proportion to its diameter.

The loss therefore increases the further the electricity is transported (length of the cable) and the stronger the current. If the current is doubled in strength, the loss actually increases by a factor of four.

In the case of transport over very great distances (i.e. transmission) the loss is great owing to the length of the wire. If the current is very strong, that causes the loss to increase sharply.

In comparison with direct current circuits, however, alternating current circuits have one very favourable characteristic, namely that the strength of the current – and therefore the loss - can be reduced by increasing the voltage (using transformers). That is why the transmission network transporting electricity over great distances operates at high voltage (in excess of 30 kilovolts). The distribution network, which transports electricity over shorter distances, operates at medium and low voltage (less than 30 kilovolts).

It is in order to minimise the loss that electricity systems are usually alternating current systems[(1)].

(1) In this connection, see the debate between two well-known physicists, namely Edison and Tesla. The former was in favour of direct current (with the negative characteristic of increasing lossens) while the latter advocated alternating current (where high voltages could be dangerous). In the end, Tesla seems to have got it right.

TABLE 4 TRANSMISSION AND DISTRIBUTION LOSSES
(In GWh)

	1992	2000	2001	2002
Demanded power	67,439	82,848	83,571	84,206
Transmission and distribution losses	3,568	3,682	3,755	3,768
Net Consumption	63,871	79,166	79,816	80,438
Losses (in p.c.)	5.3	4.4	4.5	4.5

Source : FPE, Annuaire Statistique 2002.

At first sight, the loss appears relatively small, but it does imply a substantial quantity. For example, we can assess it at the average spot price on APX (30 euro/MWh in 2002, 46 euro/MWh in 2003). The lower price gives a total of 113 million euro, the higher price 173 million euro.

Transport losses are essentially transport costs which the consumer should therefore pay. However, for that purpose it would be necessary to be able to count the cost of transport between two points. That is impossible owing to another physical characteristic of electric current, namely *Kirchhoff's laws* (see box 6). Those laws imply that at a junction in a network, incoming current cannot be made to flow through one particular outgoing line, but automatically distributes itself among all the outgoing lines. This has a number of far-reaching implications for the electricity network.

- It is *not possible to define a path* along which the current is transported. *Nor is there any direct link between producer and consumer.*
- Overloading of a line within the network is difficult to manage and requires intervention by the producers[1].
  This operational management of the maximum line capacity is nevertheless of vital importance. If a line is overloaded, it may fail so that neighbouring lines also become overloaded and are in turn liable to fail, and so on. In other words if overloading is not rectified, the whole system may fail. Moreover, the maximum load for a line depends on the outside temperature.
  Furthermore, overloading of certain lines creates "market segments" within which certain players can acquire a dominant position[2]. One example is the limited capacity for mutual links at the Belgian/French border.
- Any change to an incoming current can produce an effect capable of being felt hundreds of kilometres away by the network (known as the loop flows)[3].
  The possibility of these currents means that the expansion of capacity within the network requires close examination. For instance, an increase in capacity at the border between France and Belgium may have an impact on the load on transmission lines at the Belgian coast.

It must also be said that the volatility of demand requires the installation of adequate reserve transmission capacity. This has to be financed by differential pricing between peak and off-peak network use[4].

Finally, the construction of high voltage lines often gives rise to considerable opposition, so that it is subject to strict regulation. As a result, their construction is also associated with long lead times. This problem is even more acute in the case of international transmission, because there are more parties involved, although the transmission manager's income is less uncertain than that of the producers, so that future investment in the network is more or less guaranteed.

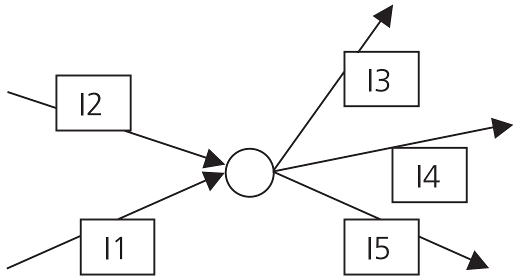
Transport losses also occur in *telecommunication networks*. "Repeaters" have to be installed at regular intervals in order to strengthen signals that have become weak. However, the telecom operator can resolve that problem without the intervention of other parties.

The problem of overloading is also not unique to the electricity network, and arises in telecommunication networks as well. However, Kirchhoff's laws do not apply to the latter; instead, the junctions are intelligent switching

(1) Production is reduced on one side and increased on the other in order to reduce the traffic via the line. This has to be done within a relatively short space of time.
(2) In the single European market in electricity, the limited capacity for interlinking national networks creates national markets within which the historical producers retain a dominant position.
(3) In Belgium these loop flows can be very substantial (up to one-third of transmission capacity with France) and may even cause problems. See for example "La Belgique craint les 'flux fantômes' d'électricité" in L'Echo, 30.09.2003 en "Elia wapent zich tegen stroompannes" in De Standaard, 12.06.2002.
(4) This is the tariff component that gives rise to a difference between peak and off-peak prices, just as in the telecommunication sector.

Box 6 – Kirchhoff's laws

Kirchhoff's laws relate to incoming and outgoing currents at a junction in the network.



A current is represented by I, and consists of moving charges. The first of Kirchhoff's laws states that no charge can be lost at a junction, and that the incoming and outgoing currents must therefore be equal.

I1 + I2 = I3 + I4 + I5

The second of Kirchhoff's laws states how the incoming current is distributed over the outgoing currents. This distribution depends on the resistance of the outgoing cables.

There is therefore no possibility of directing the current to a particular junction. The incoming current distributes itself according to fixed rules across all outgoing lines.

points which can direct an incoming signal via a specified outgoing line. Here it is therefore possible to determine a communication path linking two parties.

Owing to the possibility of directing the signal, overloaded lines can also be avoided and traffic can be diverted via less busy lines.

Moreover, the impact of overloading of a telecom line is far smaller. In the case of an overloaded line, the user has to try again later; an overloaded electricity line can cause the whole system to fail via cascade effects.

In the liberalised telecommunication sector, multiple communication networks are licensed (Belgacom network, Telenet, mobile telephony, etc.)(1). These networks are much easier to interlink than electricity networks. It can therefore be said that, if electricity networks are interlinked, the reliability of the entire system depends on the weakest network (as a result of the cascade effects). Telecommunication networks are far more independent of one another, even if they are interlinked.

The multifunctionality of the telecommunication network has already been mentioned (transmission of data and images as well as sound). Multifunctionality spreads the infrastructure costs over a larger volume, reducing the average costs.

New technologies (multiplexers and advanced modems) make it possible to handle this increased volume with no significant increase in costs.

In telecommunications, economies have of scale have therefore declined as a result of technological progress. Moreover, economies of scale do not lead to a monopoly unless the most efficient level of production (lowest point on the average cost curve) exceeds the market, in other words the economies of scale have to be related to the market size. In the telecommunication sector the market has expanded enormously, particularly with the advent of the Internet.

(1) However, the historical operator retains an advantage because over the years his network has become more widespread and has a greater number of connections (network advantage implies that the benefits to a user increase the greater the number of connections).

2.6 Regulator

It is the regulator's job to supervise the monopoly segments (transmission, distribution), including the tariffs set for their services.

The regulator must also monitor competition in the segments open to competition. However, that task is performed jointly with the existing competition authorities.

The telecommunication sector also has a regulator of that type[(1)].

Although some areas are exempt, the regulator has an influence on all parts of the electricity sector. However, side effects must be avoided somehow. Frequently changing regulations will further exacerbate the uncertainty and discourage essential investment.

Also, owing to non-uniformity, market operation may be disrupted in the competing segments. A specific case in point is the variation in the regulations on nuclear plants in Europe, which distort competition, especially in the base-load segment of production, since the costs of nuclear power stations are considerably lower than those of other types of plant, as has been explained (see above and below). The selective banning of this primary energy source therefore confers an advantage on the remaining nuclear power producers. It therefore seems absolutely essential to address this issue uniformly throughout Europe.

2.7 Coordination with a view to reliability

2.7.1 Need for coordination

The individual problems in the sub-segments require the enforced coordination of all elements in order to install a reliable system.

In the case of a vertically integrated operator, that function was an internal matter. However, when competition was introduced that function was "externalised" in a new body, the independent system operator.

In a liberalised market, the coordination of the various segments is left to the price mechanism. Owing to the special characteristics of electricity production and the mutual interaction, however, that market mechanism is not sufficient and has to be supplemented by a coordinating function.

The independent system operator looks after the stability of the network and is responsible in particular for:

1. The continuous coordination of demand and supply, or what is known as frequency control.
2. Compensating for network losses.
3. The loading of high voltage lines.
4. The monitoring of unidentified currents.

All this comes under the heading of "ancillary services". They are entrusted to an independent body because the intervention of multiple parties is necessary to resolve any problems.

The preceding sections have repeatedly stressed the need for a *continuous balance between demand and supply.* If there is a sudden change in demand (which tends to be the rule rather than the exception, given the volatility of demand), the system operator records a fall in the frequency on the network. In order to avoid a total blackout, he therefore has to increase production (as demand is inelastic).

Since there is no connection at all between consumer and producer, the system operator cannot directly indicate which producer supplyies the customer whose consumption has increased. He therefore has to call on the cheapest producer.

In practice, this means that the system operator must have information on such factors as the offered prices of the producers, any parts of the network which may be overloaded, etc.

He can only obtain that information from the various producers and from the owner of the transmission network. Mechanisms must therefore be provided for exchanging this information.

The problem of the *network* loss is comparable. The system operator also has to increase production to compensate for the loss, and to do so he has to call on other players.

In the event of *overloading*, there is too much current flowing along the line. According to Kirchhoff's laws, that current cannot be diverted to other lines. This problem can only be resolved by reducing production at one end of the line and increasing it at the other. Here, too, it is necessary to call on the electricity producers and, in the longer term, on the owner of the transmission capacity to increase the capacity of the network.

(1) For Belgium this is the Belgian Institute for Post and Telecommunication, the BIPT.

It is therefore the responsibility of the system operator to ensure the reliability of the system [1]. However, to do so he has to call on other participants.

As we have said, mechanisms are needed for these interactions between the participants and the system operator. Either that is a market where the system operator can buy electricity, or the system operator concludes contracts with particular producers.

There is an essential *difference here in relation to the telecommunication sector*. The network manager in that sector can take charge of the stability of his network with total autonomy and does not need to call on any other players.

The system operator takes charge of the operational management of the transmission network. However, the breaking up of the electricity sector also gives rise to coordination problems in other segments, including distribution. Take the case of a consumer changing supplier. The new supplier and the consumer agree on a price for future supplies. However, for invoicing purposes the supplier also needs to know the quantity of electricity consumed, but it is the distributor who has that information.

The distributor can make that information available to the supplier so long as he knows who the supplier is. The distributor therefore needs to know the supplier for each customer in his region, purely so that the supplier can invoice the customer. The distributor has no functional need for that information. In the event of a change of supplier, both the new and the old supplier therefore have to be informed, as well as the distributor.

To prevent distortion of competition in the production segment, it is possible to enact legislation requiring strict segregation between electricity production and transport. However, at the same time it has become apparent that such a split makes it difficult to coordinate the system as a whole. Consequently, liberalisation can only be considered after examining to what extent the split:

1. does not endanger the reliability of the system; it is the system operator's job to guarantee that reliability. However, as demonstrated above, he is dependent on other parties in that respect.
2. entails additional expense (e.g. exchange of information). The operational management of the network is not new, and was already present in the old system. However, splitting the sector into various segments increases the need to exchange information.

2.7.2 Organisation of the markets

Within a vertically integrated operation, coordination between the various segments is an internal matter. However, the introduction of competition into certain sub-segments means that coordination is effected via a market mechanism. One has the choice among bilateral contracts between a consumer and a producer or the creation of an electricity exchange. Bilateral contracts fix a future price and quantity and as such reduce uncertainly. They are often used by big industrial consumers. On an exchange the price is determinated by the equilibrum between offer and demand and as such is very volatile. The exchange price is know to all participants, so it is more transparent than contracts (where the price is confidential), As such exchanges have a pricesignalling goal. Most countries opt for a combination of contracts and an exchange [2].The costs incurred in concluding contracts or in the creation and the operation of an exchange are part of the fore-mentioned transaction cocts.

In summary the market mechanism can be:

– Bilateral contracts that are extremely flexible
– An electricity exchange. However, owing to the complexity of electricity production, and more particularly the sometimes protracted start-up times for power stations, multiple submarkets exist on an exchange:
  - a market where potential customers and producers can submit bids up to 24 hours before the actual time of supply (*"day-ahead" market*);
  - a *fine-tuning* market where corrections can be made until a few hours before the time of supply;
  - a *real-time* market where equilibrium is guaranteed at the time of supply;
  - *financial markets* where price risks can be hedged.

  The necessity and the operation of these submarkets are the subject of the following paragraphs.

2.7.2.1 Day-ahead market

In order to give all participants (demanders, suppliers and the network operator) an initial indication of demand for the next day, a so-called day-ahead market is organised. Here, all bidders can submit offers for their estimated production or consumption for each hour of the next day. The bids must be submitted at least 24 hours beforehand.

(1) The (N-1) rule is often applied to maintain system stability. This means that the system must continue to function properly following the failure of any random element. The system operator conducts checks at regular intervals to see whether this rule is still respected.

(2) On Nordpool, the electricity market for the Scandinavian countries, roughly 1/3 of all consumption is traded on the spot market, the rest being determined in bilateral contracts (see Bergman L. (2002)). On the Dutch exchange, APX, the corresponding figure was only 11 p.c. in 2003, while on the French market, Powernext, it was 5 p.c. in the same year (see CREG (2004)).

The day is divided up into 24 hours in view of the high intra-day volatility of demand for electricity.

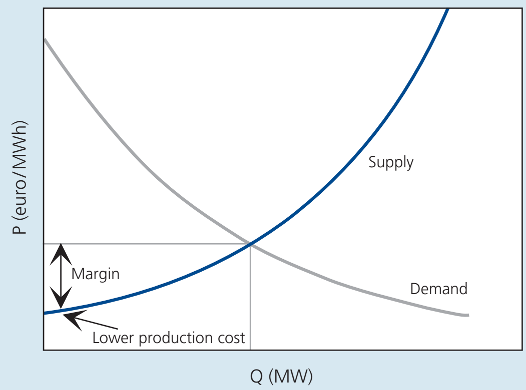
Buyers therefore all indicate their demand curve for each hour of the next day. For an illustration, see table 5 below.

If the price for the first 6 hours of the day is below 40 euro/MWh, then 50 MWh will be bought in. If the price is between 40 and 60 euro/MWh the quantity is reduced to 20 MWh.

Every producer makes an offer like this, and the quantity to be supplied will be greater the higher the price.

Next, the market authority will aggregate the individual demand and supply curves of all participants. This results in a single demand curve and a single supply curve for each hour of the next day, with an equilibrium price per hour (see chart 7).

CHART 7 AGGREGATED DEMAND AND AGGREGATED SUPPLY, EQUILIBRIUM PRICE PER HOUR FOR THE NEXT DAY.



Despite the variation in electricity production techniques, there is thus only one equilibrium price per hour (see chart 7). The market price is therefore the price of the most expensive power station that has to be brought in to meet the demand. This naturally means that all cheaper power stations can make an additional margin.

Chart 3 showed that the average costs of a nuclear power station in Finland come to roughly 24 euro/MWh. The minimum production costs for a CCGT power station total 32 euro/MWh (in both cases, for production of 8,000 hours per annum, excluding CO_2 costs, and with the price of natural gas remaining constant). As a result, as soon as the nuclear capacity is insufficient to meet demand[(1)], a nuclear power station will make a margin of at least 8 euro/MWh.

However, for completeness it must be pointed out that this applies only to offers on the market (where the price is determined on the basis of the mechanism described above). However, a producer can also conclude bilateral contracts with a buyer, specifying a lower price. In that case, the margin is lower but the nuclear producer undoubtedly has a competitive advantage[(2)].

Finally, it should be pointed out that this day-ahead information gives the network manager some warning of potential congestion problems during particular hours on the next day[(3)].

2.7.2.2 Fine-tuning market

On the day-ahead market, prices are set on the basis of the estimates of the individual producers and consumers 24 hours before the actual time of supply. Since the actual amounts supplied will depend on numerous parameters, including the temperature on the next day, fuel costs, etc., they seldom tally with the estimates. At best, they are a good approximation.

As a result, participants can adjust their predictions as their information becomes more accurate. For that purpose, they can submit offers on the fine-tuning market until a few hours before the actual start time.

TABLE 5 INDIVIDUAL DEMAND CURVE FOR EACH HOUR OF THE FOLLOWING DAY

Hour		Price (in €/MWh)				
from	to	<40	40	60	200	2,000
1	6	50	20	10	0	–20
7	24	60	25	11	0	–

(1) Table 3 shows that, for Belgium, the nuclear power stations have a capacity of 5.7 GW, and chart 7 shows that the minimum load is 6 GW, So nuclear producers realise a margin. This undoubtedly also applies to all nuclear power stations within a unified European market.

(2) In the scenario with no nuclear power, this competitive advantage disappears, but the cost to the buyer increases to the level of the CCGT power station. Ceteris paribus, this means that the price would rise by almost 33 p.c. in any case.

(3) Provided this information also contains data on network junctions where the supplier will inject current into the network and where the consumer will extract this current, and on the quantities supplied via bilateral contracts.

2.7.2.3 Real-time market

Pricing on the day-ahead market and on the fine-tuning market is based on estimates of future production and consumption. Those markets therefore guarantee that the *estimated* demand is in equilibrium with the estimated supply.

However, section 2.2 showed that it is crucial for the *actual* demand and the actual supply to be in equilibrium at all times. If that condition is not met, the result could be a total black-out.

As stated earlier, the independent system operator is responsible for achieving that balance. For that purpose, he can call on the real-time market where he is the sole buyer.

That real-time market can also be used to redispatch production in the event of congestion problems.

2.7.2.4 Financial market

Apart from these markets for the physical supply of electricity, "derivative" markets have been set up to give participants the opportunity to hedge the highly volatile price of electricity, and to provide them with information on future movements in prices.

These are financial markets because the transactions are not accompanied by any physical supply of electric current. These derivative instruments are not unique to the electricity sector, but also exist for other commodities, so they will only be discussed briefly here.

By way of explanation, we shall first define a *forward*. It is a contract for the physical supply of electricity. This contract states the price and quantity of electricity which a producer will supply to a consumer at a particular point in time in the future. These are therefore customised contracts, concluded between two parties. Both buyer and seller are sure of a fixed price and a fixed quantity for the future.

Future contracts are similar, except that they relate to a standardised quantity of a standardised commodity. Standardisation makes futures more flexible and more liquid. The liquidity is increased even more by the establishment of a "clearing house" that acts as the counterparty for each transaction (1). This guaranteed counterparty reduces the risk of non-payment of the contract, and as such increases de liquidity of the market.

Future contracts are seldom accompanied by physical supply. After expiry of the contract on the due date, the parties exchange between themselves the difference between the price on the physical market and the price fixed in the contract.

Apart from buyers and sellers, there are also speculators and arbitragists on the futures market. The price of the future is determined by the demand and supply relating to a future with fixed parameters. Models for the determination of the price of a future establish a link between the future value and the expected price of electricity. Thus, the future price contains information on the expected price of electricity. In that way, futures therefore represent an important aid not only for buyers but also for producers and investors in production capacity. However, in this connection it must be pointed out that :

1. the term of a future is limited (on the Scandinavian electricity exchange, Nordpool, it is 3 years maximum), while it takes many years to build a power station (2).
2. the models for determining the prices of futures are based on the assumption that the underlying product can be stored for a particular period of time (namely until the due date of the contract). That assumption does not apply to electricity production (3).

While a future contract entails an obligation on both buyer and seller, an *option contract* confers a right on one of the two parties. If the seller has the *right* (but not the obligation) to supply a given quantity of electricity at a specified price on a specified future date, that is called a put option. If the buyer has the right to buy a specified quantity of electricity at a specified price in the future, that is a call option. It is therefore an asymmetrical contract ; one party has an obligation, the other party has a right to exercise an option.

Conclusion

The liberalisation of the electricity sector is motivated by the effort to increase efficiency, and is meant to bring down prices. At least, that is what the theoretical, perfect competition model predicts. The successful deregulation of the telecommunication sector is usually cited in support of this

(1) In order to limit the risk for the clearing house, each market participant will be asked to pay a margin that corresponds to his outstanding positions with the clearing house. This margin is adjusted daily, a process known as "marking to market".

(2) AMPERE (2000) quotes a construction time of 24 to 30 months for a CCGT, and 3 to 5 years for a nuclear power station.

(3) This assumption is presumably more valid in countries where electricity is generated mainly by HEP stations, at least for the producer/owner of those power stations, and not for the other producers or for consumers.

paradigm, as there is no denying that the liberalisation of that sector has led to lower prices and better quality.

However, this article has emphasised that, apart from the analogies, there are also substantial differences between the two sectors. They are comparable as regards both the network structure and a number of technological developments which have reduced the scale effects. However, on the other hand there are major differences in the complexity and implementation of the liberalisation. Not only does the electricity sector have more sub-segments, for technical reasons it is also far more difficult, and considerably trickier, to coordinate the sub-segments.

As regards the implementation of liberalisation, it was pointed out that the production and supply of electricity have been liberalised while the transmission and distribution monopolies remain. In contrast, in the telecommunication sector, it was specifically in the network infrastructure that competition was introduced. The argument that both segments (production of electricity and the communication infrastructure) had long been seen as (natural) monopolies and that the economies of scale were being diminished by technological changes appears open to criticism. In the telecommunication sector, technological advances were in fact accompanied by an enormous expansion in demand. The larger market combined with smaller scale networks makes it possible to have a greater number of network operators. Such an expansion in demand is not occurring in the electricity sector, however ; on the contrary. As a result of environmental considerations, efforts are instead being made to limit electricity consumption.

The electricity sector consists of various sub-segments, namely production, transmission, distribution and sale. Competition is being introduced into production and sale. Transmission and distribution remain monopolies. The discussion of the specific characteristics and problems of the various segments showed that two points must be borne in mind if it is decided to deregulate the sector :

1. Breaking up the previously vertically integrated operation may entail additional costs – transaction costs – especially if it requires coordination between the segments or if information needs to be exchanged on a large scale.
2. If the introduction of competition in some segments is to have a beneficial influence on prices, then one should aim to meet the conditions of the theoretical model. According to the basic assumptions of the perfect competition model, no individual producer or consumer can influence the price, producers and consumers have perfect information, the product being traded is homogeneous and the producers are free to enter or leave the market.

It is also clear that the specific characteristics of the sector hamper competition.

The physical characteristics of electricity networks require demand and supply to be in equilibrium at all times ; if they are not, then the whole system fails. In combination with the high volatility of demand for electricity, this imposes very specific requirements on the production facilities. Thus, there must always be sufficient reserve capacity available to cope with peak demand. That reserve capacity is very expensive since it will potentially be used for just a few hours each year. During those peak periods, it is therefore power stations with low fixed costs that will be used. During periods of low demand, the fixed costs are spread over a large number of hours' production and the power stations with high fixed costs are the most efficient. In practice, this means that during periods of low demand nuclear power stations and (accumulation) HEP stations are used ; during peak periods, gas and coal-fired power stations are used. This means large variations in costs and hence differences in price between peak and off-peak periods.

The high fixed costs of "off-peak" capacity also imply the existence of economies of scale, limiting competition in this segment. Competition among different producers can be more or less ruled out owing to the economies of scale (1) and for safety reasons, too, in the case of nuclear power stations. This fact is clearly at odds with the assumption of *free access*.

Competition is therefore confined to the capacity which is used during peak periods. Producers with mixed production facilities (off-peak and peak capacity) have a significant advantage because, owing to the single market price, they make a margin on their "off-peak capacity". That enables them *to influence the price and access* (cross-subsidies between cheaper and more expensive production methods) ; these producers are therefore not price-takers.

Overloading of certain parts of the network (e.g. the limited capacity for interlinking on the European market) creates *an access barrier*.

The difference between peak and off-peak periods and the capacity used imply that electricity is not homogeneous. In fact, there is a product for every hour of the day, as is evident from the way in which electricity exchanges are organised in practice.

(1) In the context of the Belgian market, with nuclear capacity of 5.8 GW and a base load of 6 GW, these economies of scale lead to a dominant position. That is not the case in the context of the European market. Owing to interconnection problems, the European market currently only exists in theory. For obvious reasons, however, it is not a good idea to have competition between nuclear producers.

Furthermore, variations in regulations between countries, particularly as regards nuclear power stations and the application of the Kyoto protocol, contribute towards *distortion of competition*.

The need for reserve capacity makes it necessary for the free market to give signals in time for the construction of future capacity. Both the classical theory of the net present value of an investment and the more recent theory of real options reveal a negative correlation between investment and uncertainty. It is therefore far from certain that the free market mechanism will generate the stimulus required to provide reserve capacity. In the initial phase of liberalisation, the surplus capacity which exists almost everywhere is dismantled; however, there is no guarantee that this dismantling will not ultimately result in a shortage of capacity with higher consumer prices and additional margins for producers.

The typical characteristics of the electricity network make it necessary to have a system coordinator and a large-scale exchange of information between participants. That contributes towards the transaction costs mentioned earlier.

Interaction between network limitations and the production segment can create local *market power*. That is currently already the case in the European market, where capacity for interconnections is inadequate.

It is therefore not clear that the fall in price brought about by deregulation will be permanent. In the initial phase, the introduction of competition may certainly have a favourable impact due to the reduction of excess capacity, but the increased transaction costs and the impediments to competition resulting from the specific characteristics of the sector may ultimately lead to a attenuation of this benefit or to a compensatory movement. Finally, there are *elements unconnected with deregulation* which could have an adverse effect on prices, such as the tariff charged for CO_2 emissions and the dismantling of nuclear power stations. In addition, these last two elements increase demand for natural gas, thus pushing up its price.

In view of the intermediate character of electricity consumption, this will have repercussions on all other sectors of the economy. If the operators in the various European regions are subject to different rules, the competitiveness can be affected. A uniform policy within the EU is therefore a prerequisite.

Finally, it should be mentioned that the heaviest costs entailed in electricity production stem from the fact that current cannot be stored and from the volatility of demand, which necessitates substantial reserve capacity to cope with peaks. In order to keep costs to a minimum (including the environmental costs), it is therefore necessary to even out peaks in consumption; it is not consumption itself that has to be reduced, it is the peaks that need to be lowered. Finding ways of storing electricity is another possible solution, though it is probably not feasible in the short term.

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