Chapter 3
Theory of market design for electricity

The introduction of market mechanisms in the electricity industry has shown the need for designing these markets. This issue is very recent since the creation of “markets” for electricity is a recent phenomenon. The key idea is that there is no universal ideal solution but that both academic work and practical experiences gleaned from earlier stages should be incorporated into each new market’s design. However, experience has shown that some models are more suitable than others for achieving efficient electricity markets. This chapter will first introduce the concept of market design and make the distinction between the three levels of market design: industry structures, wholesale market design and marketplace design. Hence, the different possible industry structures are presented in the following section. The different design controversies concerning wholesale market design will be analyze in the third section. Finally the chapter is concluded with different possibilities relative to the design of electricity marketplaces.

3-1 The issue of market design

3-1-1 Terminology

Markets exist wherever buyers and sellers interact to buy or sell a product at a mutually agreed price. The Oxford dictionary of Economics defines a market as *"A place or institution in which buyers and sellers of a good or asset meet"*. However, the everyday sense of the word "market" also tends to include market participants, market conditions, legal framework, geographical area etc. Secondly, in practice, electricity markets comprise a sequence of overlapping markets (Stoft, 2002). Hence, a necessary step for the analysis is to define the meaning of the word "market" and other related terms with respect to their use in European electricity markets.

First, for the purpose of this work we will exclude from the definition of the word "market" generators, traders, distribution companies, and regulators. Generators, traders, distribution companies are "markets participants" while regulators, and laws and legal aspects constitute, the "market's legal framework". Second since power exchanges are markets for wholesale electricity, the retail market is excluded from our definition of a market. Hence, following the Oxford dictionary of Economics, in our analysis the word market will refer to all places or institutions in which buyers and sellers of wholesale electricity contracts meet to ratify. This includes both financial and physical contracts. Moreover these contracts can be traded on over-the-counter markets (hereafter OTC or bilateral contracts) and organized markets such as power exchanges or power pools. The rules of functioning of the market are defined by trading arrangements, e.g. NETA in the United Kingdom, which define the rules and legal agreements between players, places and institutions.

"Physical" contracts refers to contracts which involve physical delivery of power while financial contracts do not involve physical delivery, and are only used to hedge. An important characteristics of existing wholesale markets is the combination of market with physical existence (organized markets) and market without a physical existence (OTC). Markets with a physical existence or organized markets will be called marketplaces. Marketplaces have trading rules which cover the method of setting the price, the characteristic of the traded product, arrangements for delivery, settlements terms, obligations of the buyers and sellers, and a neutral organization running the marketplace (Hunt, 2002). In this section we present standards definitions of important concepts and the definitions which will be used for this work (box 3-1).

Box 3-1: Market terminology *(Oxford Dictionnary definition in Italic)*

Market:
"A place or institution in which buyers and sellers of a good or asset meet". All places or institutions in which buyers and sellers of wholesale electricity contracts meet. The market includes all organized markets, i.e. power exchanges, power pool, balancing markets and OTC markets, i.e. all type of bilateral transaction, where contracts for wholesale electricity are traded.

Marketplace or organized market:
A third party which facilitate the transaction between a seller and a buyer. Marketplaces have trading rules, which cover price setting, delivery, clearing, type of product, timing etc. For instance power exchanges and power pools.

Bilateral markets or Over The Counter (OTC):
"A market in securities not regulated by a stock exchange". Markets which are not regulated by an organized market authority. These markets involve a direct transaction between a buyer and a seller.

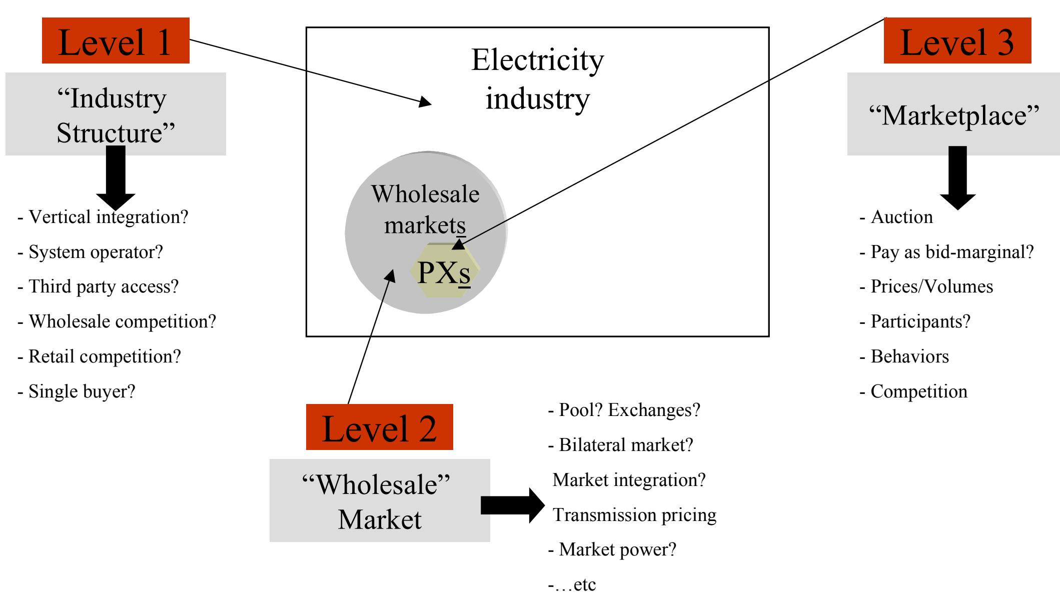
Spot market:
"A market for goods, securities, or currencies for immediate delivery or in some case a short time is allowed for delivery." In Europe, the spot market for wholesale electricity refers to the day-ahead market. In the US the spot market is the real time market. In this thesis the spot market includes all transactions day-ahead for delivery the following day. These transactions can be realized through a marketplace and/or bilaterally.

Market = Wholesale market = Marketplace + OTC
Power exchanges are one type of marketplace

3-1-2 The three levels of market design

The issue of market design is akin to the main research topic of industrial organization in which the goal is how best to organize markets. The first question for introducing competition in the electricity sector is to define which activity should be organized based on market mechanisms and competition and which activity should stay a monopoly and be regulated. In the electricity industry, market design or market architecture is a confusing notion which can refer to different types of design. For instance, for some authors market design refers to the whole value chain of the electricity industry from generation to final load, including both wholesale and retail electricity markets (Hunt and Shuttleworth, 1996). For other authors, market design refers only to the wholesale market and includes short-term spot markets, bilateral transactions, transmission congestion contracts, networks access charges etc (Hogan, 1992, 1993, 1998; Walton and Tabors, 1996; Chao and Peck, 1996). Finally in the literature, market design can refer to the detailed functioning of a marketplace such as the type of auction, the format of bids, the rules governing the marketplace (Wilson, 1997; McAfee, 1998; Green, 1998; Klemperer, 1999). We identify three different levels of design: industry structure, wholesale market and marketplace (figure 3-1).

Figure 3-1: The three level of "market" design



The first level is about the way to organize the industry as a whole, i.e. from the production of electricity to final consumption. Should players be allowed to be vertically integrated (VanDoren, 1998)? Is an independent system operator necessary (Cameron and Cramton, 1999)? Is there third party access to the network (Deng *et al*, 2000; Brunekreeft, 2001)? If yes, what are the rules? Who should be allowed to participate in the market? What is the extent of competition (wholesale/retail)? Which part of the industry should be regulated (Borenstein and Bushnell, 2000)? Which part of the industry should be open to competition (Newbery, 2001)? Obviously this level of market design should be the first to be addressed to open the electricity industry to competition and to define the basic design characteristics of the market (Gilbert and Kahn, 1996).

The second level of market design concerns the wholesale market. In practice, many states both in the US and in Europe have decided first to create a wholesale market and postpone the creation of a retail market too later stage (Bergman *and al*, 1999). Such approach allows competition between generators and offer choice for large consumers and distribution companies while sale of electricity to small consumers is still subject to regulation. In contrast to the first level of market design defined above where a large consensus can be found, the design of wholesale markets is at the center of many controversies. Do we need an organized market or should the trading be organized bilaterally (Hogan, 1994; Gilbert *et al*, 1996)? If a marketplace is suitable should it be compulsory or voluntary? Who should run the marketplace? Should the marketplace define zonal prices or locational prices (Stoft, 1998)? What kind of technical aspects must be taken into account during the design of the market (Hogan, 1998)? To what extent should governments design wholesale trading arrangement? At this level the critical activity is the one provided by the transmission system operator (Hogan, 2002; Stoft, 2002). The answers to these questions differ widely between countries, raising the question of whether an ideal solution exists.

Finally, the third level of market design is about the detailed functioning of the market and especially the rules of the marketplace. Should prices be determined by a pay-as-bid auction or by a marginal price auction (Garcia-Diaz, 2000; Federico and Rahman, 2001; Kahn and al, 2001)? Should the auction be a two-sided auction or only one sided (Green and Newbery, 1992)? Who should be allowed to participate to the auction? What should be the characteristics of the bids, e.g. only price-quantity or also start up costs, transmissions constraints and others technical aspects? What should be the timing of the market? How will the results of the market be transferred to physical delivery?

The first level of market design has mainly been defined by the electricity Directive in Europe and by the FERC in the US. At this level the possible choices are relatively limited and a large consensus can be found. This model consists of a separate transmission company, competing generation, third party access and an independent regulatory body (Littlechild, 2001). In this thesis little attention is given to the above, however to be complete we briefly present the four possible global architectures for the electricity industry (3-2). Subsequently, the second and third levels of market design, concerning respectively the wholesale market (section 3-3) and the design of the marketplace (section and 3-4), which are fundamentally relevant for the purpose of this thesis, will be analyzed.

3-2 Industry structure

3-2-1 Introduction

The central institutional part of public utility regulation is to find the best possible mix of inevitably imperfect regulation and inevitably imperfect competition (Kahn, 1995). Governments and regulators have started to liberalize their electricity markets in a large number of countries around the world. The main motivation is to increase the efficiency of their electricity industry by introducing market mechanisms. Such decisions involve important choices concerning the industry structure. Hunt and Shuttleworth (1996) have defined four basic industry models.

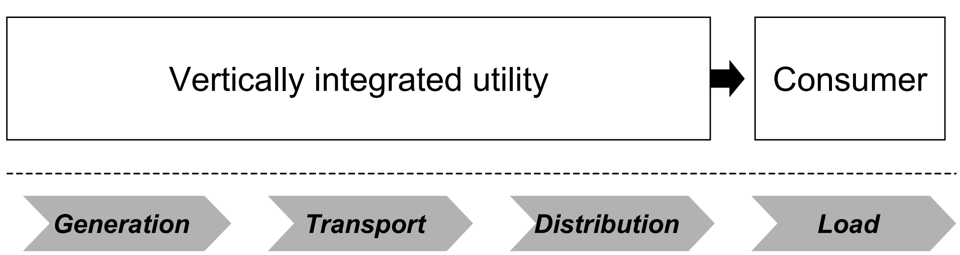
- Model 1: Monopoly
- Model 2: Purchasing agency
- Model 3: Wholesale competition
- Model 4: Retail competition

Every existing model can be seen as an extension of the four models. These models take into account two aspects, the level of competition and the nature of ownership. The four models are particularly useful for defining the general framework of the industry and for this reason we briefly present the four models[1].

3-2-2 Model 1: Monopoly

The first model is a classical, vertically integrated, monopoly without any competition. One company generates electricity, operates the transmission and distribution functions and finally is responsible for retailing to the end consumers. Hence, there is no competition. The monopolistic company is responsible for its area, which can be a city, a specific region or even a country. This model is the original one for most of the electricity industry worldwide, and thus represents the genuine starting point for any reform.

Figure 3-2 Monopoly

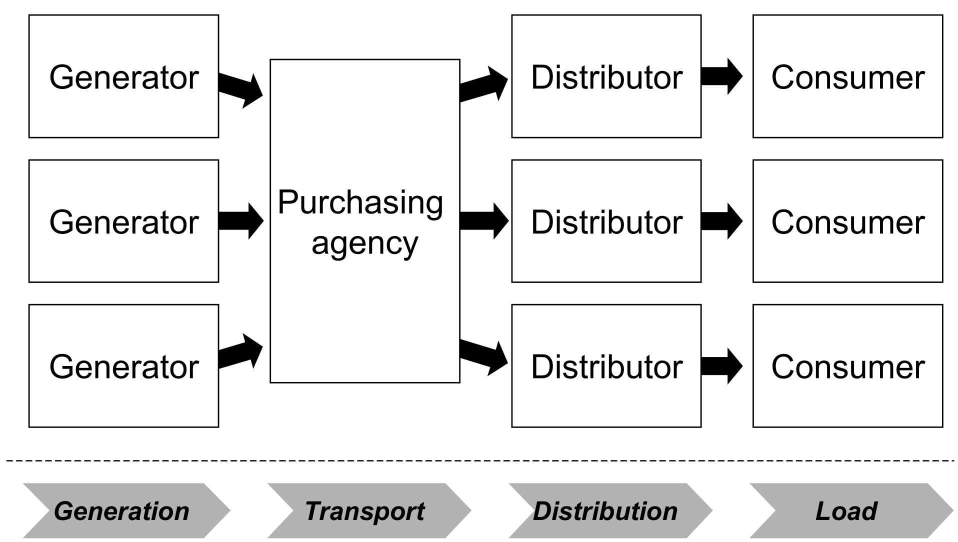


[1] For detailed descriptions see: Hunt and Shuttleworth (1996) and Hunt (2002)

3-2-3 Model 2: purchasing agency

In the purchasing agency or single buyer model, a nominated authority acts on behalf of all registered consumers. This authority negotiates with generators to buy energy and services. This model allows competition in generation. Generators compete to supply the nominated authority. In turn, the purchasing agency sells to distribution companies at a preset tariff. At the retail level small consumers do not have a choice of suppliers and retail prices are regulated, which means that distribution companies still have a monopoly over small en users. The interest of this model is that it realizes competition in generation and facilitates negotiation for consumers. One important characteristic of this model is that it is easy to introduce it. The main disadvantage of this model is that the authority represents a monopoly which is not subject to market forces (Murray, 1998).

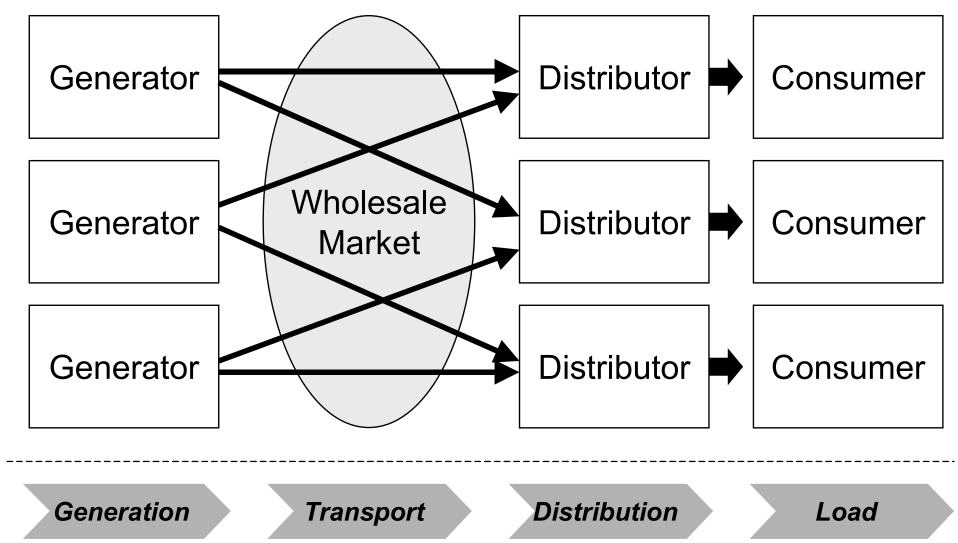
Figure 3-3 Purchasing agency



3-2-4 Model 3: Wholesale competition

The main difference between model 2 and model 3 is that in model 3 distribution companies and large consumers do not have to use any particular purchase agency but can choose their suppliers. At the same time generators are not forced to sell to the purchase agency and this gives them access to alternative buyers. This model allows real competition in production, which represents the most important part of the costs of electricity. This model expands the level of competition widely in comparison to model 2. The model makes the market more dynamic and closer to classical commodities markets by allowing more buyers to participate within the market. The advantage of this model is that it represents a serious step to full competition without disrupting the retail market. The problem with this model is the definition of what is the minimum size required to participate to the market and the combination of a free market at the wholesale level and a regulated market at the retail level[2].

Figure 3-4: Wholesale competition

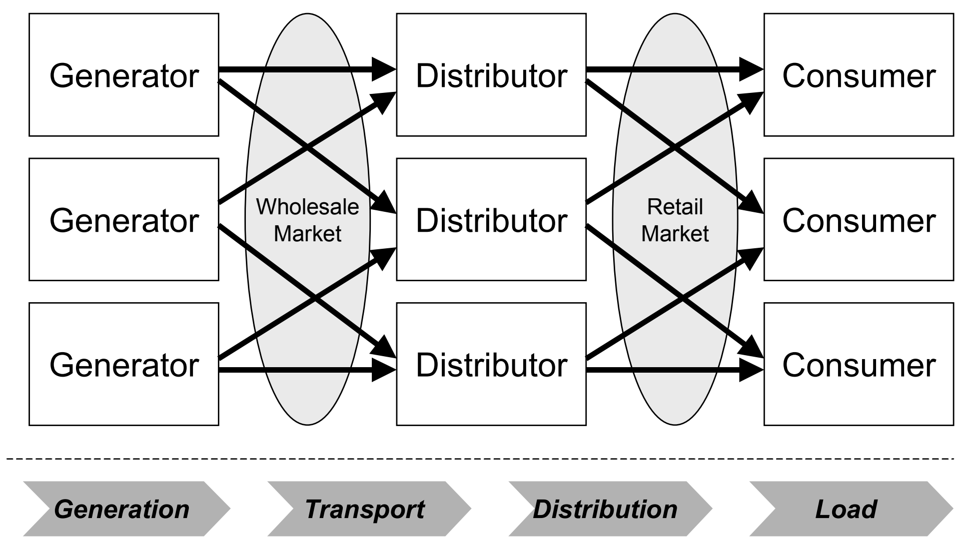


[2] On this aspect see appendix 1 about the Californian crisis

3-2-5 Model 4: Retail competition

In the retail competition model, the functioning of the wholesale market is the same as in model 3, the difference is that end-users at the retail level can choose between different kinds of suppliers. Such model requires the development of settlement process, meter reading, billing mechanisms and the education of final consumers. The main idea of this model is to allow consumers to have choice in their consumption of electricity as they have for any other goods. The problem with this model is that without any strong regulation, distribution companies may charge very high prices, or not serve, for example customers in isolated areas.

Figure 3-5: Retail competition



3-3 Wholesale market

3-3-1 Introduction

Wholesale market design is central to the introduction of competition in the electricity industry. Controversy has surrounded the subject in the US since the beginning of the liberalization process (Stoft, 2002), yet in Europe it has been widely overlooked. Though third party access to the network is definitely a necessary condition for competition, the major issues concern the role of the system operator and the existence of transmission constraints (Hogan, 1992). The design of the wholesale market also has to take into account the potential gains in longer-run efficiencies with the transaction costs associated with new rules and institutions for implementing decentralized operations and investments decisions (Joskow, 1998). At the wholesale level, two major issues exist (Stoft, 2002). The first one concerns the nature of the product traded, i.e. electricity is a sequence of products for energy and transport or electricity is a bundled service. When electricity is seen as a sequence of product, transmission constraints are ignored while these constraints are taken into account when electricity is seen as a bundled product. The second issue concerns the level of centralization of trading.

Many of the controversies surrounding the design of wholesale electricity markets relate to the technical vulnerability of electricity coordination and the existence of transmission constraints (Joskow and Schmalensee, 1983). The need for continuous synchronization between production and consumption on the entire network requires control in real time. Hence, these features must be taken into account when creating electricity markets and the main discussion point is how the different market design deal with these constraints

The existence of a system operator is a common feature of any electricity market and the extent of its role concerning market organization is at the center of the controversy surrounding wholesale market design. The larger system operator’s role is the smaller is the role for privates parties.

“One side fears the inefficiency and market power abuses of privates parties playing social roles. The other side fears the inefficiency of nonprofit organizations but also covets the central market role played by the system operator” (Stoft, 2002)

An essential condition for the development of competition is free access to transmission (Einhorn, 1994). In Europe the EU Directive insists on the necessity of third party access (TPA), and thus to comply with this transport and energy have been separated. Energy is open to competition while transport is regulated. In the US, such a separation is not the rule (Kwoka, 1996).

Once a choice has been made to create an industry structure allowing wholesale competition, i.e. model 3 or model 4, the second aspect of market design is to define the architecture of the market (Wilson, 1998). At the wholesale level, economists and practitioners are still debating what kind of wholesale market design is the most efficient. Three approaches can be defined concerning wholesale market organization. The first one ignores transmission constraints and is a highly centralized system around a mandatory *poolco*, e.g. England and Wales before New Electricity Trading Arrangement. The second one also ignores transmission constraints but is a totally decentralized system based on *bilateral contracts* without organized marketplace for trading, e.g. the state of Texas USA. The last one integrates transmission constraints through *locational pricing,* e.g. PJM[3].

Table 3-1: The three models

	Bundled Product	Centralized market
Poolco	No	Yes
Bilateral market	No	No
Locational pricing	Yes	Yes

Whereas economics shows that if everything is perfect and complete the three models can provide the same results (Wilson, 1999); an analysis of the different

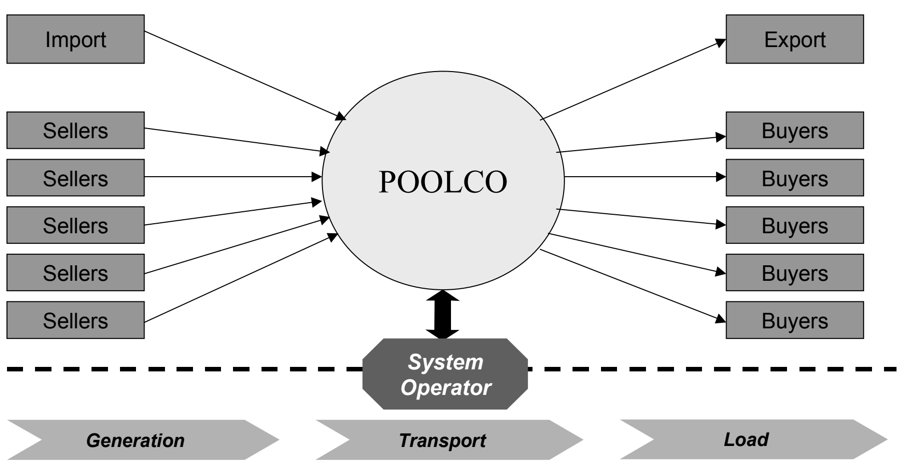
[3] See chapter 9

models allow a comparison of the strengths and weaknesses of each model and explains why some models might be preferable to others.

3-3-2 The poolco model

The reference model for wholesale market design is the poolco model which was first developed by W.Hogan in the nineties (Hogan, 1993). The poolco model is based more on engineering principles than market principles (Green, 1998). This concept has been presented as one of the best market designs for providing competitive electricity markets in many states in the US, e.g. The New England Power pool, The New York Power Pool and the Australian's Victoria pool. This model was also applied in the UK before the New Trading Arrangements (NETA). The poolco model is a general framework. Application of this model in practice can differ in details regarding, for instance, operational practices, pricing mechanisms, dispatch system etc. For the purpose of this thesis we only consider the major feature of a "mandatory" poolco model as opposed to the voluntary bilateral markets described below. Mandatory participation means that all generators have to sell their output to the poolco and that all consumers must purchase their electricity from it.

Figure 3-6: poolco model



The principles of the poolco model are relatively simples. A set of rules defining the way electricity can be trade are defined in the model (Budhraja *et al*, 1994). Each supplier submits bids to the poolco for a different time increment (mostly hours) for generation capacity that they can make available for each bid period. The price offered by the bidders reflect the level of price they are willing to accept for each hour. The poolco performs a price-based merit order dispatch which means that it dispatches to all supplier from lowest to highest bid (Garber *et al*, 1994). The last accepted bid for a given period determines the single market-clearing price. In other words, each dispatched unit receives the market clearing price which is set by the bid price of the marginal unit required to meet demand for each time interval.

In the simplest version of the poolco model transmission constraints are ignored (Hogan, 1993). A single price is set for the whole market. Hence, the same energy price applies irrespective of the physical location of generators. The TSO use a separate operational study to identify the network constraints based on the first results of the auction. When transmission constraints make it impossible to realize the first results of the pool, the system operator requires one or more generators to increase their production while others decrease their production. The additional costs are shared between all producers.

The important characteristic of the poolco is that it uses multipart bids which cover all important aspects of generator's operating costs and physical constraints. Hence, the poolco model also takes into account several technical characteristics, which are concerned initially with the physics of getting the system dispatched. This implies side payments. The poolco provides many services implicit in the economic dispatch. For instance, the poolco provides backup supplies, reactive power and spinning reserves. Every half-hour, customers pay and generators receive the short-run marginal-cost (SRMC) price for the total quantity of energy supplied in the half-hour. Generators report many details of their costs to the poolco. All this information is computed ahead of time and determines the level of price and the level of side payments with respect to technical constraints such as startup cost, ramp-rate limit etc.

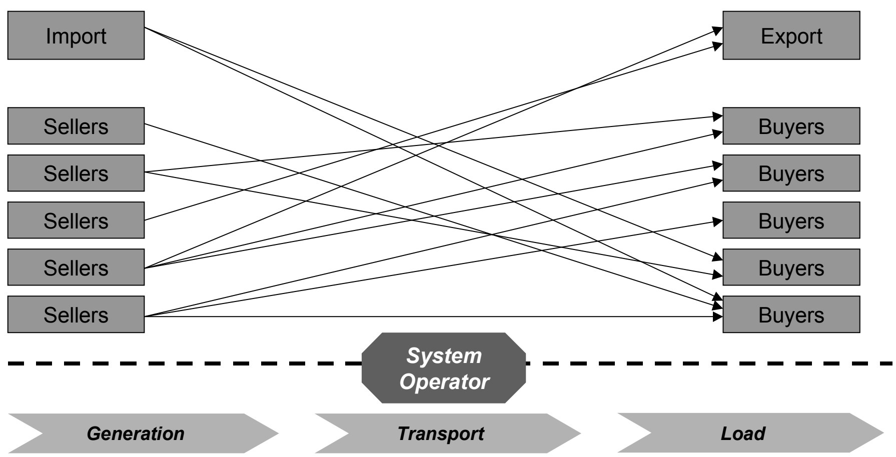
A crucial feature of the poolco model is that contracts do not play a direct part in the dispatch of power plants. Hence, financial contracts as opposed to physical contracts are used for hedging the price of the poolco. This is because in a mandatory poolco no generator can guarantee to be dispatch and that the central merit order dispatch does not involve financial penalties over and above the revenues lost due to not generating.

One of the main concerns with the poolco model is a lack of transparency. The price setting system is overly complex since it requires the submission of several parameters (Sweeting, 2000). This calculation methodology makes it difficult for players to understand how prices are determined and this then represents a true barrier to entry (Green, 1998). Moreover, side payments reward generators for making their plants available and not operating them. Hence, the existence of complex rules coupled with the repetition of the auction daily may allow generators to manipulate the market. Indeed, the complexity of poolco's bidding and price determining mechanisms make it extremely difficult to understand the relationship between price bids and available capacity submitted by generators and the actual prices. This aspect is a major concern with respect to market power.

3-3-3 The bilateral model

Bilateral trade or Over the Counter (OTC) can either be financial or physical, with the latter including actual physical delivery. Pure bilateral trade refers to direct transactions between a buyer and a seller without using any intermediaries. Hence, trading mainly takes place over the telephone without any intermediary. However, in practice, bilateral trade can also be done using a broker or bulletin board. As with stocks, brokers do not trade as a principal, but put buyers and sellers in touch with one another. For instance, a generator who has found a buyer for a part of its production may ask a broker to find it a possible buyer for the rest of the production. If the broker finds a buyer, the broker will charge a commission for this service related to the value of the transaction. Bulletin boards are mainly Internet websites where players post their offers for buying or selling electricity and define some aspects of the offer like for instance, location and duration. These offers are made available to others market parties. If a party is interested, the bulletin board will bring the two players together. Hence, a bulletin board is just a different type of brokerage. The bilateral market is then a mixture of direct transaction, brokerage and bulletin board. From a market design point of view, with the exception of bulletin boards, bilateral markets need little attention.

Figure 3-7: The bilateral model



An important characteristic of bilateral markets is that the type of contracts negotiated are totally flexible and can be tailor-made to fit the needs of each particular consumer since the consumers can specify any term they desire, examples:

- A contract signed on the 25-11-N for 50 MWh for one year baseload starting on the 01-01-N+1 at a fixed price of 20 Euro/MWh for physical delivery on the Spanish Hub

- A contract signed on 5-06-N for 10 MWh for peakload period in November N at a price based on the average price of October N for physical delivery in Germany
- A contract signed on the 2-07-N for 25 MWh for hours 10 to 15 for the 5-07-N at a price indexed based on the UK spot prices of gas.

The above are an examples of possible tailor-made contracts, nevertheless some standard contracts are also traded[4]. These contracts are listed in box 3-1.

Box 3-1: Standards bilateral contracts

***Base load**:*
Supply for all hours for every day of the traded period.

***Peak hours**:*
Supply between hour 9 and hour 24 (from 08:00 until 00:00) for every working day of a selected period.

***Weekend**:*
Supply during all of the hours in Saturday and Sunday.

***Nights**:*
Supply between hour 1 and hour 8 (from 00:00 until 08:00) of the weekdays.

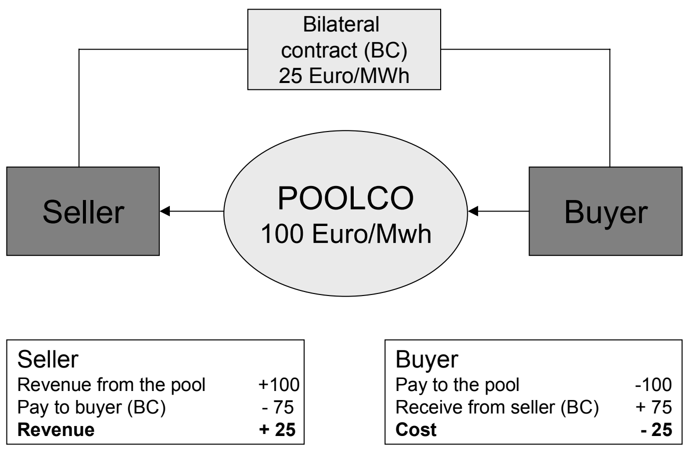
***Off-peak**:*
Combination of nights and weekends plus peak hours on bank holidays.

Of the five profiles, the first two are the most commonly traded and concentrate almost all of the market liquidity, base load being the most traded. It is often argued that in contrast to organized markets, bilateral markets give buyers and sellers broader flexibility concerning the prices and others terms of the contract because in organized markets participants can only buy and sell the product that are traded on the market. This view is incorrect. Even with the existence of a mandatory pool players can always make financial bilateral contracts. These

[4] See "Efet Standart contract", available at http://www.efet.org

contracts called Contracts for Difference (CfD) in the UK can be use between a supplier and consumer to serve the same purpose as physical bilateral contracts, i.e. responding to the specific needs of a consumer while hedging against spot prices volatility. This point is illustrated in figure 3-8.

Figure 3-8: Bilateral contracts under the poolco model



In this example, a buyer and a seller have contracted bilaterally for a price of 25 Euro/MWh. The market price determined by the poolco is higher than the agreed price hence the seller pays the difference to the buyer.

An advantage of the bilateral market is that it offers fewer opportunities for sellers to take advantages of shortages by temporally withholding capacity. If a player in an organized market withholds part of its capacity it can take advantage of the increase in price for its other units. In the bilateral model, since contracts run for longer periods, withholding capacity during period of shortage will not affect the prices of most contracts and therefore will not be a profitable strategy. Second, transactions on the bilateral market are negotiated and buyers can compare the prices of different suppliers. In contrast, some players may find a way to manipulate the market-clearing price by gaming their bids in an organized market (Joskow and Kahn, 2001; Sheffrin, 2001).

Four majors concerns about the bilateral market are price discovery[5], price discrimination, liquidity and transaction costs. Since transactions in the bilateral market are done by definition between two parties, others parties can not know what the market price for power is at any hour of the day. This lack of transparency is a serious problem for consumers who can not then compare the offer made by producers to any solid benchmark. Price discovery is also very important for investment decisions and especially for entry. In theory, high prices will attract new investments. In the absence of such a signal competition might be restricted by deterring entry and a too low level of investment is likely to occur reinforcing the market power of the incumbents.

Price discrimination is directly related to price discovery. In a world of imperfect competition, price discrimination is a common business practice. For instance, price differences result from negotiations, various bargaining powers and various levels of access to information. Electricity markets are particularly vulnerable to such practices because the number of sellers is limited, the customers can easily be divided into groups and arbitrages are restricted. The bilateral model allows producers to price discriminate between customers, in others words to sell electricity to different customers at varying prices. For this reason sellers are reluctant to reveal the price of their deal, whatever the level of the price. A generator selling electricity at a high price to a specific customer does not want its competitors to know about this since a competitor will certainly propose a cheaper contract to this customer. If a generator is selling at a particularly low price to a specific customer it does not want its other customer to know this, fearing that they will ask for a decrease in price for their actual contracts. Even large customers are reluctant to reveal the price of their contracts. If they have managed to negotiate a cheap contract they might do not want their competitors

[5] Price discovery is related to the concept of efficient market, originally developed by Fama (1970). In this approach an "efficient" market will discover a price that reflects the impact of available information on supply and demand.

to know this. Such price discrimination is not possible with an organized market since every participant receives and is aware of the market-clearing price.

Liquidity is related to the volume of trade in a power product. At this point the advantage of tailor-made contracts becomes a disadvantage. The range of contracts makes it difficult for customers to resell their contract or parts of them because the tailor-made specific terms make it difficult to find another buyer willing to take on such a contract. Hence the diversity of contract types may hamper the development of a liquid market, and this is necessary to permit buyers and sellers to adjust their portfolios. Such a variety of contracts means that there will be an equal variety of prices.

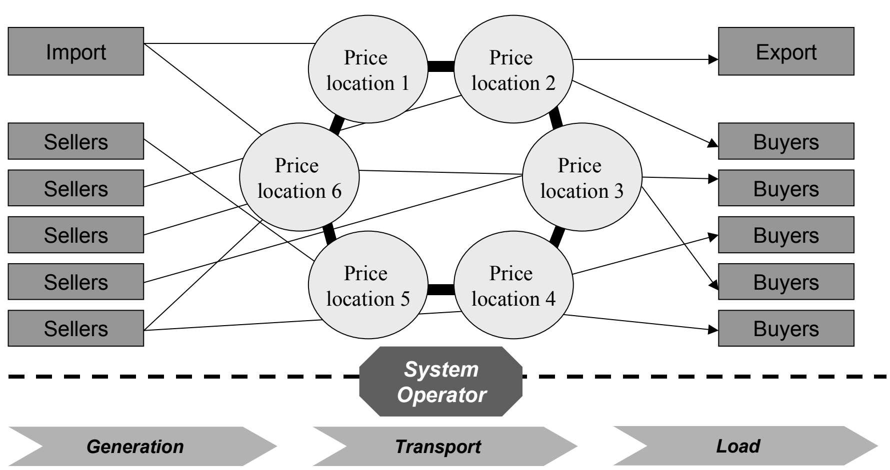
Finally, transaction costs are an important weakness of purely bilateral markets. Bilateral transactions require an actor first to find a counterpart, this involves search costs. Second, once a counterpart is found price determination and the exact terms of the contracts has to be negotiated. This is a costly process that requires time and expertise. While such costs can be justified and considered as marginal when the negotiations concern a large contract, such costs may be prohibitive for very small contracts, e.g. short term trading. Hence, a pure bilateral model does not favor short-term trading which is essential for market players to adjust their portfolio.

3-3-4 Locational pricing

Economic theory suggests applying of locational pricing in presence of transmission constraints, (Schweppe *et al*, 1988; Chao and Peck, 1996; Stoft, 1998; Johnsen *et al*, 1999). The locational pricing approach in contrast to the poolco model and the bilateral model, takes into account transmission constraints. This approach regroups nodal and zonal pricing (Harvey and Hogan, 2000). Broadly speaking, zonal pricing is a simplification of nodal pricing. In nodal pricing a different price is set for each node while in zonal pricing several nodes are aggregated to form a zone[6]. The key idea of the locational pricing approach is that the cost of delivering electricity varies around the system due to physical flows. Hence, each constrained location should have its own price that reflects transmission constraints. This approach prices generation and transmission simultaneously. All generators are scheduled and dispatched through a single market, which makes participation mandatory. The transmission system operator runs such a market directly.

In this model, the price of electricity is set for defined locations (zones or nodes) which have different energy prices. Separate locations are defined depending upon transmission constraints. Within a location the assumption is made that there are no transmission constraints, this permits any generator in the location to be used freely (Hsu, 1997). The level of interconnection capacity limits the trading possibilities between locations. The great interest of this approach is that it highlights the importance of transmission. Hence, when price differentials between two locations are important, this approach give clear incentives regarding where to invest and whether it is more efficient to invest in the transmission network or in generation capacity (Ilic *et al,* 1997).

Figure 3-9: Locational pricing



[6] See chapter 9

Prices for electricity are set for each location of the grid in the locational approach. A number of cases, taking into account increasing number of parameters are described in box 3-3.

Box 3-3: Locational pricing

Case 1: Base case

When there is enough generation and no transmission losses or transmission constraints, there is a single price (P_1) at each location for each time period:

$$P_1 = Mc$$

Where Mc is the marginal cost of the most expensive plant in operation.

Case 2: Generation shortage

In presence of generation shortage, the price P_1 has to increase in order to decrease demand. This increase of price (S) is necessary to avoid blackout:

$$P_2 = Mc + S$$

Where S can be interpreted as the scarcity rents that pay for the fixed costs of generation.

Case 3: Transmission losses

Due to transmissions losses, supplying 1 MWh requires a generator to produce slightly more than 1 MWh:

$$P_3 = (Mc + S)(1+Ml)$$

Where Ml are marginal losses.

Case 4: Transmissions Constraints

Due to transmission constraints, the price at a congested location has to be increased to discourage consumption and encourage production. The magnitude of the adjustment is called the "shadow price" of the constraint. The objective of this adjustment is that the grid supply shall at no point exceed transmission capacity.

$$P_4 = (Mc + S)(1+Ml) + Sp$$

Where Sp is the shadow price of the constraint.

P_4 is called locational price and can be considered to be the "ideal" price of electricity since it takes into account the major characteristics of electricity.

Source: IEA, Competition in electricity markets, 2001

In the locational approach energy and transport are bundled while in the poolco model and in the bilateral model transport is separated from energy. On one hand this approach appears to be simpler because traders do not have to deal with two products. On the other hand the calculation of transport charges is left totally to the system operator, which decreases transparency. In a manner similar to the poolco model, participants in the market have to submit complex bids including technical features of power plants. Hence, such an approach shares the criticism of the poolco model for this point. Moreover the problem with the locational approach is that it introduces additional complexity in terms of feasibility. The role of the system operator is very large and this requires an extremely high level of cooperation in multi-countries markets (Hogan, 1995).

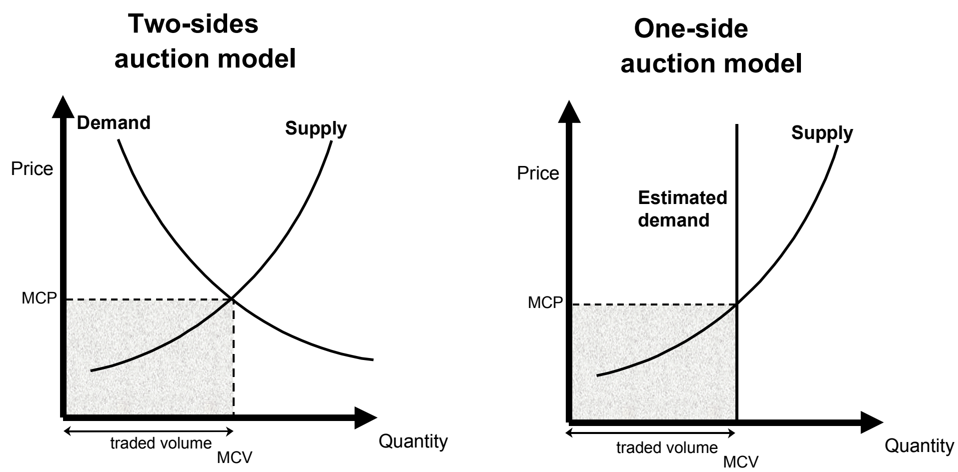
The TSO collects supply and demand bids and then computes all the bids taking into account technical aspects and transmission constraints to set the price at each location. In an unconstrained network, locational pricing will define only one price and the outcome of this system will be comparable to the poolco model (Oren, 1997). This approach is therefore suitable for weak networks subject to important constraints. Moreover such system is able to deal with loop flows, which are a fundamental characteristic of meshed networks (Stoft, 2002). While the poolco model and the bilateral model work poorly when transmission capacity is tight (McGuire, 1996), the locational model provides an efficient price mechanisms.

3-4 Marketplace design

3-4-1 One-side auctions vs two-side auctions

A first characteristic of a marketplace is the nature of supply and demand bids. One-side auctions refer to marketplaces where only supply is based on bids and demand is estimated (Bunn and Day, 2001; Green, 1998). Two-sided auctions allow both supply and demand to be based on bids from participants (Wolak, 1997). Commodities markets are usually organized according to a two-sided auction. In short, the marketplace aggregates supply and demand bids and the intersection of the two curves defines the market price[7]. However, in electricity markets demand participation may be difficult to obtain from a practical point of view. Most consumers of electricity have a low level of responsiveness to price increases. For this reason some marketplace use estimates of demand rather than bids from consumers. This was formally the case in the UK pool. The pool estimated demand for each period based on historical records and this then allowed a pool price to be determined.

Figure 3-10 Two-side auction and one-side auction model



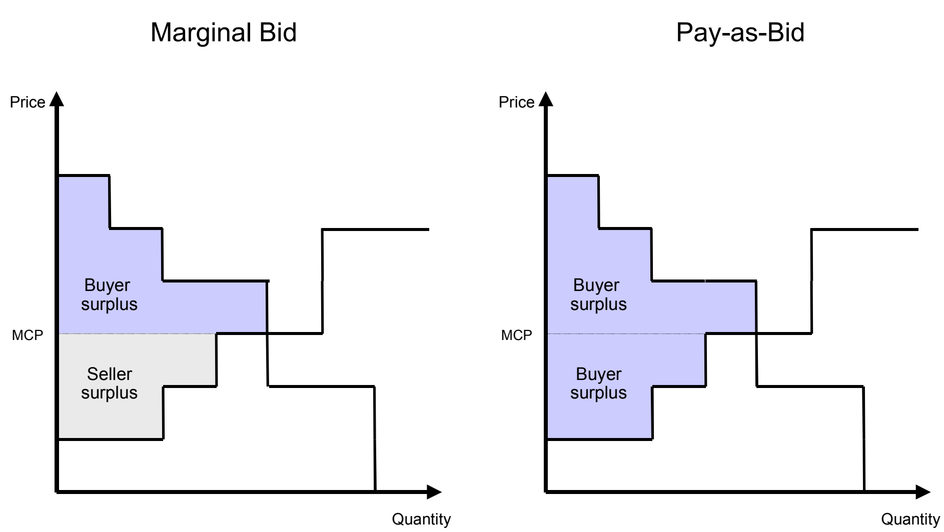
One-sided auctions are obviously not an ideal mechanism for determining optimal market prices. Their only justification is practical, when introducing market mechanisms, in particular during the start-up phase, they can be a good way to determine a market price, however a lack of direct demand participation strongly limits the value of this.

[7] See chapter 5

3-4-2 Marginal bid vs pay-as-bid

The controversy over marginal bid pricing and pay-as-bid pricing centers on the distribution of surplus and was first addressed in the United States with the treasury auction (Friedman, 1960). Both from a theoretical and from an empirical point of view, definitive ranking of the marginal bid and pay-as-bid auction is still an open question (Ausubel and Cramton, 1998; Fabra *et al*, 2002). In marginal bid pricing, all suppliers get paid the price of the marginal bid. Hence, all suppliers who bid lower prices get an extra profit called a surplus. In the same way all consumers who bid higher prices pay a lower price than the one they were willing to pay, this is called the consumer surplus (figure 3-11). From a consumer point of view it might appear unfair that a supplier who is willing to supply at a price of 15 Euro/MWh receives the market-clearing price which can be 40 Euro/MWh, and because of this it has been suggested that pay-as-bid methodology, previously experimented with in the U.S. Treasury's auction experiment (Malvey and Archibald, 1996; Reinhart and Belzer, 1996), should be implemented in electricity markets to increase the consumer surplus and eliminate these "unfair profits" (Federico and Rahman, 2001; Kahn *et al*, 2001). In a pay-as-bid auction, suppliers get paid the price they bid.

Figure 3-11: Distribution of surplus (assuming same bidding behaviors)



In a pay-as-bid auctions, if a low cost power plant (coal for instance) bids its marginal cost of 15 Euro/MWh it would be paid 15 Euro while in a marginal price auction (or single price auction) it would be paid the market clearing price which can only be equal to or higher than this amount. Hence from a generator point of view the pay-as-bid auction appears to be less attractive while in theory it allows consumers to pay the right price. However in a pay-as-bid auctions in an imperfect market generators have a strong incentive to increase the level of their bids in order to ensure a minimum level of profit. Hence, instead of bidding their marginal costs, suppliers will tend to bid what they think will be the market-clearing price (Stoft, 2002). Such behavior will lead to an increase in bids and will distort the system.

Moreover marginal costs for some technology, and especially for baseload plant, are almost zero (nuclear for instance). If players bid their true marginal costs they will not be able to recover their fixed costs. This will deter entry and involve less investment in baseload power plants thus reducing the overall efficiency of the system (Vasquez *et al*, 2000). It can also be argued that from a suppliers' point of view that pay-as-bid can also be implemented in the other way, i.e. consumers have to pay the price they were willing to pay. Moreover pay-as-bid reduce transparency by creating many prices instead of one price in the marginal price system. Finally, Gilbert *et al* (2002) have shown that in some cases marginal price auctions are superior to pay-as-bid auctions in mitigating market power as they allow competitive arbitrageurs to outbid generators where generators may otherwise secure interconnector capacity that amplifies their market power. Thus for all these reasons, marginal price appears as more suitable than pay-as-bid (Hunt, 2001).

3-4-3 Type of bids

One of important criteria for designing a marketplace is to define the nature of the bids (Shuttleworth and McKenzie, 2002). One approach considers simple bids, which only define price and quantity regardless of any technical constraint. A second approach takes into account price and quantity and technical features like start up costs, transmission constraints and unit commitment (von der Fehr and Harbord, 1998). Generally the first category is associated with power exchanges while the second is associated with power pools. The greatest advantage of the first approach is that it facilitates trading and transparency by making the system simple. Moreover, in such a system, players without assets can also participate in the marketplace. Hence, it makes it possible for traders and large consumers to participate in the market. This approach ignores the technical aspects and leaves total responsibility of physical constraints to the network operator. For this reason, this approach is more likely to be applied in areas where transmission constraints are low and the generation structure is flexible. For instance, within a country that has a dense network with low constraints.

The complex bid approach aims to take into account the technical features of electricity production (Wilson, 1998). Hence, the auction is constrained by the physics of the system to avoid overloading of lines, certain combinations of bids can be accepted while others must be rejected to ensure technical feasibility. For instance, if a generator can not suddenly stop producing electricity, which is the case with nuclear power plants, it should not be matched on one hour if it is not matched the following hour. The ramping rate constraint allows taking such aspect into account.

In conclusion, from both a theoretical and practical point of view, the choice between complex bids and simple bids is still an open question. On one hand complex bids take into account technical constraints which facilitate technical operation but hamper trading. On the other hand simple bids avoid complexity which strongly facilitates trading but overlooks physical constraints.

3-4-4 Day-ahead vs real-time

Day-ahead markets and real time markets are often confused since they are often regrouped under the term “spot market” (Stoft, 2002). For this work, as defined in box 3-1, we define the spot market as the day-ahead market, which can be organized bilaterally or/and on a marketplace. The real time market refers to real power balancing by the system operator. Due to the high transaction cost involved in bilateral day-ahead trading, the day-ahead market is usually organized on a marketplace. The real-time market or balancing market is always an organized market because it requires real time operation from the system operator to balance the system.

Since electricity consumption is difficult to predict and consumers can better estimate their consumption one day in advance than one year in advance the day-ahead market allows participants to adjust their portfolio one day before delivery. When they are organized on marketplaces, day ahead markets take the form of either power exchanges or power pool. Day-ahead markets contain four stages. One, participants submit bids. Two the marketplace determined the market price by accepting and rejecting bids. Three, transactions are settled. Four the results are transferred to the system operator in order to ensure physical delivery.

The real-time market is used to price deviations in supply and demand from contract specifications. These deviations, intentional or unintentional, must be corrected by the system operator to ensure physical delivery. The real time market is used to price these deviations and to keep the system in balance, the system operator needs to be able to call in extra production at very short notice, that is why the real time market must be centralized. Bilateral markets are too slow to handle very short term operations. Moreover beyond balancing the real time market provides two mains others ancillary services one, transmission security and two, efficient dispatch. In a vertically integrated monopoly (model 1), the division in charge of system operation used to have direct control of power plants allowing it directly to increase or reduce the output of a unit. In a market environment with unbundling the system operator must rely on real time prices.

In conclusion, day-ahead marketplaces and real-time marketplaces serve different purposes and are complementary. They represent the two main kinds of organized marketplaces in electricity. Their functioning is quite different and they should not be confused. In this thesis we will focus our attention on day-ahead marketplaces.

3-5 Conclusion

In this chapter, we have introduced the concept of market design by differentiating three levels of market design. Interestingly, it appears that only the general level of market design, i.e. industry structure, has been addressed by the Directive and that the two others levels, i.e. wholesale market design and marketplace design, have not been considered. Subsequently we have presented an overview of the different alternatives for wholesale market design. The main principles of three major models were analyzed for this purpose. Finally, we have discussed different issues related to marketplace design, which represent an important aspect of wholesale market design. This differentiation allows us to categorize electricity power exchange into marketplaces that are part of wholesale market design. In the next chapter we will present how competition in these marketplaces can be analyzed using economic theory and pertinent electricity market literature.