Chapter 6

Participants' behaviors on power exchanges

In this chapter we look at the very important issue of participant behavior on power exchanges. We first present briefly an overview of the behavior of firms in economic theory and in electricity markets in general. The strengths and limits of these approaches for the analysis of power exchanges as marketplaces are then discussed. Trading behaviors depending on the nature of participants are analyzed, and then bidding behaviors that represent concretely how players interact on the power exchange are described. Examples of specific bidding related to marketplace design, the problem of market power and examples of arbitrage strategies based on Enron memos are presented to illustrate actual behavior in electricity markets.

6-1 Introduction to firm's behaviors

6-1-1 Introduction

The concept of a firm's behavior, also referred as conduct or strategy, has different meanings in the economic literature. This concept can be divided into two main categories. One, neoclassical theory considers profit maximization as the only possible behavior. Two, since in practice profit maximization may not be the only motivation for behavior, other types of behaviors are considered.

6-1-2 Economic theory of firm's behaviors

In most economic models the behavior of firms is limited to profit maximization. Hence in perfect competition and monopoly models, firms will produce the quantity at which marginal cost equals marginal revenue. In a perfectly competitive framework, the conduct of a firm is restricted to a minimum: in the short run the firm can only respond to market price by producing a quantity that maximizes profits and in the long run if the firm is making loses it will leave the industry. In the monopoly case, the monopolist will choose the price output combination such that marginal cost equal marginal revenue[1].

Since perfect competition and monopoly are two specific limited cases, they rarely exist in practice and the range of a firm's strategies is wider that just profit maximization. Firms can develop different strategies in imperfectly competitive markets (Scherer and Ross, 1990). Industrial organization defines several types of conduct such as product differentiation, advertising, predatory pricing, price discrimination, merger and acquisition, collusion etc. Product differentiation is one of the most studied types of behavior of a firm (Chamberlin, 1933; Bain, 1968). The objective of product differentiation is to avoid competition, by making the product special for consumers[2]. Advertising is another classical strategy of firms (Stigler, 1961). For instance advertising can be use to increase barriers to

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[1] See chapter 4

[2] This strategy can involve either change in the product characteristics or investment in advertising to change the public's perception of the product.

entry by building up consumer *loyalty* or *inertia*[3] (Kaldor, 1950). Predatory pricing is traditionally related to a strategy carried out by a dominant firm, which will fix its price below the average variable cost (Areeda and Turner, 1975). The objective of such strategy is to drive other firms out of the market. Price discrimination[4] is related to the ability of a firm to sell the same product at varying prices. Mergers and Acquisitions (M&A) are certainly the most visible part of a firm's behaviors. M&A occur for a myriad of reasons and few topics in industrial organizations arouse more passionate debate (Scherer and Ross, 1990). Reinforcement of market power, elimination of competitors, achievement of economics of scales/scopes are classically cited as some of the many objectives of M&A. Finally collusion is an attractive option for firms who are aware of each others actions. *Overt* collusion and *tacit*[5] collusion aim to reduce competition and to obtain charge higher prices than if competitive pricing is operating.

6-1-3 Why behaviours on PX cannot be directly studied

An analysis of participant behavior on a power exchange must take into account the fact that a power exchange is a fringe market, i.e. power exchange are voluntary and only represent a part of the market, i.e. day-ahead trading. For this reason the behavior of a firm on a power exchange represents only a small part of its overall strategy and overall activity. Since power exchanges are organized markets for spot trading with specific rules the behavior of firms on these markets is limited to sale and purchase bids. Hence any firm's strategies of diversification or advertising, for instance, are meaningless from the point of view of a power exchange. It does not mean that firms, which participate in trading on the power exchange, cannot have these kinds of strategies, but that due to the very specific functioning and purpose of power exchanges these strategies are not visible on power exchanges only.

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[3] *Loyalty* is defined as a rational preference, whereas *inertia* involves routine buying.

[4] See chapter 3 (section 3-3-3)

[5] *Overt* collusion is characterized by a formal agreement also called a cartel, *tacit* collusion may occur when for instance, in an oligopoly, firms followi the price fixed by a leader.

Box 6-1: Predatory pricing on power exchange

Is predatory pricing a credible strategy on a power exchange?

While most strategies considered in industrial organization are not well suited for power exchanges due to the specific nature of these markets, predatory pricing might appear to be a possible behavior of a participant. Indeed by fixing bids at very low prices on the power exchange, a firm may expect to be able to drive out others participants and then charge a higher price later.

Such strategy is not credible for three reasons. One, since most electricity contracts are traded on the OTC market on a long-term basis, only a small part of the total market is traded on the power exchange. It is therefore unlikely that a company charging a very low price will be able to cover the entire market on the power exchange. Thus, in a marginal price auction the very low bid will not determine the market-clearing price, which strongly reduce the impact of such strategy.

Two, even if a firm is able to fix the market clearing price of the power exchange below the competitive level, and thus drive out the others competitors from the PX, it will not be able to enjoy its monopoly position. Since power exchanges are voluntary markets, as soon as the firm tries to charge higher prices on the power exchange, buyers will leave the power exchange and use the bilateral market.

Three, even if a firm tries to bid at very low prices, it will always face other participants that will bid at a price of zero (see section 6-3-2). Participants who overcontract on the OTC market and know that they will not be able to consume what they contracted will try to get rid of their extra volume. Since this volumes represents a sunk cost for them they are willing to sell this electricity regardless of any cost consideration. Then, in a marginal price auction, bidding under average production costs will not be sufficient to drive out competitors because some participants bid at a price of zero.

Most strategies described above, with the exception of pricing strategies or collusion, can be easily observable from outside a company, bids on an exchange are not. For practical reasons, an analysis of a firm's behavior in an economic study is often limited by the availability of data. Indeed, strategies such as M&A or advertising are easily observable. In both cases the firms involved in these types of strategy will communicate with the outside world and the information that is published can be used for analysis. In the case of power exchanges the action of each participant is confidential and commercially sensitive. By definition, organized marketplaces provide anonymous places for trading. Anonymity allows market participants to balance their portfolio without revealing their position to the outside world. Power exchanges avoid the risk of discrimination ensuring confidentiality of each participant's trade, and in doing so ensure that realized transactions are based only on objective economic criteria.

Though for economic analysis, publication of market participants' bids and transacted volumes would strongly improve the level of transparency and understanding of the functioning of these markets, from a competition point of view, information openness is not always suitable since it may facilitate, overt or tacit, collusion. If every market participant knows the pricing strategy of every other firm, there is little opportunity for gaining market share by price-cutting. Any attempt from an individual player would be discovered by the competitor and would be met with an aggressive answer. Hence, availability of pricing information may facilitate collusion and should be discouraged.

The confidentiality of bids and realized transactions per participant does not allow direct analysis of participant's behaviors on power exchanges. However possible trading strategies can be described based on experience in the United Kingdom and in California. A first range of "classical" strategies can be identified according to the type of market participants (section 6-2) assuming that pure traders, i.e. without physical assets, large consumers and producers use power exchanges differently. A second aspect of trading strategies is related to the details of bidding behaviors (section 6-3).

6-2 Trading strategies involving a power exchange

6-2-1 Introduction

Participants on a power exchanges can use a number of different trading strategies. A first approach consists of analyzing possible strategies according to the nature of players. The first obvious category is composed of electricity producers defined as players owning production capacity and which represent the sale-side of the market. The second category includes distribution companies and large industrial consumers which constitute the demand-side of the market. Finally there are pure traders, without physical assets, these players act on both side of the market. For simplicity we will ignore here the fact that, in practice, generators may act as traders and that large consumers, distribution companies and traders may also have production assets.

6-2-2 Producers

Most producers trade in long and medium-term markets so they can plan production and maintenance plans and from time to time use a power exchange to cover specific needs. Hence, the basic use of a power exchange for a producer of electricity includes three strategies: selling additional capacity, buying when "overcontracted" on the bilateral market or facing an unexpected outage, and buying when prices on the market are lower than production cost.

The first and most common strategy on a power exchange for a producer is to sell day-ahead their available extra-production capacity. Thus producers are typical sellers which means that, in general they sell most of the time. For example, assume a power producer with a production capacity of 1000 MW that has already sold 930 MWh[6] on the bilateral market. Since the producer has some production capacity left, according to the hypothesis of profit maximization, the difference between the two values represents the volume the producer will offer to the power exchange (70MWh). The price asked (P_a) is determined by the production costs (C_p) of such extra production[7]. If the market-clearing price (MCP) is lower than P_a then the producer will not sell any volume on the power exchange. If the MCP is higher than the P_a, then the producer will sell part or all of its extra volume.

Conversely if the producer has sold more on the bilateral market than what it is able to produce, it will enter the market on the purchase side to fulfil its obligation. If the producer has no possibilities to renegotiate part of the volume it can not produce, the price it is ready to pay may be very high, to avoid imbalances charges. Such a situation may also occur when a generator faces a forced outage[8] or a change in availability which decreases its production capacity.

Table 6-1: Basic behaviors of producers on a power exchange

Strategy	**Motive**
Sell	Not fully contracted on OTC (volume available day-ahead)
Buy	Overcontracted on OTC (e.g. face unexpected outage)
Buy	MCP< production cost

A producer will buy on a power exchange when the MCP is lower than its production costs (C_p). When a producer can buy electricity on the market at a lower price than its production cost instead of producing it, it will buy electricity on the market. In such cases, a producer's profitability will be improved if it meets its contractual obligations with power sourced from the market rather than produced by its own power station. This can occur for instance when fuel costs increase.

[6] See previous chapter, table 5-3 for details

[7] In general in "imperfect markets" the relationship between the price asked and the production cost can be defined by: $(P_a) = (C_p) +$ margin

[8] A generator that does not have control over its fuel supply, e.g. wind turbine or gas-fired plant with interruptible supply, may also use power exchange to adjust its position day-ahead.

Hence, in typical bidding, a producer will place a "buy order" for low-price (lower than C_p) power while placing "sale order" for high prices (higher than C_p).

6-2-3 Large consumers

Industrial consumers and distribution companies are large consumers of electricity. While the first buy electricity on the wholesale market for industrial processes, the second buy electricity for selling on the retail market. For the purpose of this section we will consider them together as *large consumers*. As for electricity producers three basic strategies can be defined for large consumers and these form an exact symmetry of producer's strategies.

Large consumers of electricity, that have not contracted for enough electricity in advance ("undercontracted"), on the bilateral market, to meet their load, will enter the power exchange to buy the extra volumes they need. This situation occurs when the large consumer has underestimated its real consumption needs. For instance, on abnormally hot days a distribution company will need additional power to respond to an increase in demand, related to an intensive use of air conditioning. A large industrial consumer which needs to increase its level of activity for a couple of days may also use the power exchange to buy additional power.

Since the price of electricity on a power exchange is normally higher and at least more volatile than the electricity price in a long term bilateral contract, risk-adverse consumers have a great incentive to "overcontract" on the bilateral market. In doing so, they avoid the risk and uncertainty of having to buy on the power exchange's spot market[9]. Such strategy is especially relevant during the startup phase of a power exchange[10]. Large consumers will become sellers on the power exchange when they have contracted too much on the bilateral market

[9] In market characterized by a low level of liquidity, any large increase of demand might cause a great increase of price.
[10] On a mature power exchange the level of liquidity ensures that an increase of demand from one party does not affect largely the equilibrium price.

with respect to their expected consumption. Moreover, just as producers which might face forced outages of a power plant, large consumers may face forced decrease in their consumption, e.g. workers strike, forced maintenance of a factory, cancellation of a large order etc. In these cases selling on the power exchange represent a way to get rid of the extra volume contracted on the bilateral market and to avoid balancing charges.

Table 6-2: Basic behaviors of large consumers on a power exchange

Strategy	**Motive**
Buy	Undercontracted on OTC (e.g. underestimation of needs)
Sell	Overcontracted on OTC (e.g. face unexpected decrease of needs)
Sell	MCP> opportunity cost of not consuming

In the presence of high prices on the market large consumers may decide voluntary to decrease their consumption in order to sell on the power exchange. Such behavior is directly related to the elasticity of demand of each consumer. Thus when the MCP is higher than the opportunity cost of not consuming, a consumer will become a seller on the power exchange. For instance, during the Californian crisis, it was more profitable for some aluminium factories to stop their operation and sell the electricity they had contracted to the power exchange (Borenstein, 2001). Moreover, with the development of load management services, distribution companies can decrease the consumption of some of their customers, in exchange of financial counterparts, and sell the power to the exchange.

6-2-4 Traders

As for any market, electricity traders bring liquidity to the market. For instance, at one instant there might be no buyer willing to buy electricity from a generator. Traders provide liquidity by filling this gap and purchasing the electricity with the intent to sell it at a higher price later. This traditional function of trading is rather limited in electricity market because electricity cannot be stored: a trader cannot buy electricity at hour 1 and resell it at hour 12. For this reason this kind of arbitrage does not occur on power exchanges.

Table 6-3: Basic behaviors of traders on a power exchange

Strategy	Motive
Buy-Sell	Act on behalf of a large consumer
Buy	Price PX_A < Price PX_B (aim to resell on PX_B)
Sell	Price PX_A > Price PX_B (has already buy on on PX_B)
Buy	Price PX < Price OTC (aim to resell on OTC)
Sell	Price PX > Price OTC (sell OTC contract)

However two basic behaviors of traders on a power exchanges can be identified. One, they act on behalf of other market participants who asked them to sell or buy their electricity. This is the case for industrial consumers that do not want to act directly on the power exchange. There are two reasons for such a decision. The consumer or the supplier might be a too small player to act directly on the power exchange. For industrial consumers the trading of electricity does not represent their core business; therefore they do not have the expertise to participate on a power exchange nor are they willing to build their own trading floor which will involve costs they do not wish to incur. Thus such players use traders to manage their electricity portfolio. Traders act then as "aggregators" and reduce risk for their consumers[11].

[11] Assuming that the risk to a group of participants is less than the sum of the risks to each individually ,i.e. different groups might offset each other's demand variations

Traders also act as arbiters between markets[12], to do this they regularly switch position depending on the price spread between markets. Such arbitrage may be achieved between markets, e.g. OTC markets, balancing markets, power exchanges, or between countries. For instance, arbitrage can be carried out for bilateral contracts and the power exchange. A trader will buy a baseload contract for a defined period at a fix price and will resell it per hours on the power exchange expecting that the average price of the power exchange would be higher than the price paid for the bilateral contract.

Traders can also buy electricity in a cheap area and resell it on the power exchange. This type of operation is becoming increasingly important in Europe where cross-border trade is booming. For instance, a trader can buy electricity on a power exchange in Germany and resell it in the Netherlands or buy on the French bilateral market and sell on a power exchange in the United Kingdom. In doing so, the trader lowers prices in high-priced areas and increases prices in low-priced areas. This behavior augments the efficiency of these markets and in the absence of transmission constraints this behavior creates a single equilibrium price.

6-3 Bidding behaviors

6-3-1 Introduction

Bidding behavior represents concretely how players act to reach a strategy. In most academic research so far, the analysis of bidding strategies has been limited to generators in the context of power pools (Wolak, 1999). The main literature available concerns the England and Wales pool (Green and Newbery, 1992, Vickers and Yarrow, 1991) and the California power market (Puller, 2001; Harvey and Hogan, 2001; Joskow and Kahn, 2001) which have both been abolished. In the literature, the analysis of bidding behavior is mainly limited to comparison between bids and costs of power plants over time (Brealey and

[12] See Enron memo (section 6-4-3)

Lapuerta, 1997; Wolfram, 1998). In its strict definition any bid superior to cost[13] can be considered to be a strategic bid, hence, in general analysis of bidding strategy is related to market power[14]. The important differences between the power pool model and the hybrid model strongly reduce the interest of this literature[15]. Most analysis are based on oligopoly competition-game theory models assuming most of the time that a generator's optimal bidding strategy will depend on the bidding behavior of all its competitors[16]. In practice, due to the voluntary nature of power exchanges it is more likely that players are unable to anticipate accurately the behavior of competitors[17]. Participants tend to use the power exchange with respect to their position on the other markets and also to the rules governing the power exchange. The publication of the Enron memos[18] has shown that in practice, in presence of multiple markets, bidding strategies can be overly complex to take advantage of market rules and (bad) market design. Since bidding strategies on power exchanges are not publicly available information, an analysis of actual the bidding strategy of a player cannot be done. However, some well-known principles can be described as can some possible strategies related to the design of existing European power exchanges.

6-3-2 Classical bidding behaviors

Five classical bidding behaviors for power exchange participants can be identified: selling (at least) at marginal cost, buying at the "utility" value, selling at a zero price, buying at the maximum price, and simultaneous buying and selling, i.e. "double side bidding". For most of the strategies, the nature of the price formation mechanism, a uniform price auction, is fundamental.

[13] Short-term marginal costs (STMC) or long-term marginal costs (LTMC) are considered in the literature depending on the assumptions made by the authors. In the short term, the capital cost associated with delivering an additional unit is fixed. It is therefore possible to measure marginal cost excluding capital cost (STMC). In the long term, capital cost also needs to be recovered which increases marginal costs (LTMC)
[14] See 6-4-2
[15] See chapter 2
[16] See 4-4-6
[17] While in a power pool competition is restricted to main generators, in a power exchange every participants market participants may compete on both sides of the market
[18] See 6-4-3

Selling at marginal cost, or at least at marginal cost, is the first basic bidding strategy. The short-term decision rule for a generator is whether it can cover its variable costs (Lopez, 2001). Hence, if the MCP is equal or above its variable cost of producing, a producer will sell, below it will not. Producers rely on period where they will not be the marginal bidder to recover their fixed costs. Buying at the "utility" value on a power exchange is the corresponding buying strategy. The utility value is related to the value a consumer attaches to the consumption of additional power. For a large industrial consumer, for which electricity represents a large part of its costs, the utility value is the maximum price it is willing to pay for electricity. Above this price it is more profitable to not consume.

Due to the technical aspects of electricity production and peculiarities of electricity markets/marketplaces design, others bidding strategies have emerged in practice. One classical bidding behavior of a seller is to sell its electricity at a price of zero. This type of bidding has become well known since the start of organized electricity markets and is not specific to power exchanges. Such behavior has four main explanations: the existence of baseload power plants, low variable costs technology, sunk costs related to other contracts and arbitrage between non-coordinated markets. These four reasons have the same objective: to sell at any price to balance portfolio. Indeed, by bidding at a zero price, sellers maximize their chance of being matched on the power exchange. They rely on other players to determine the market price since in a uniform price auction every one receives the market-clearing price. This is related to the fact that electricity cannot be stored and the existence of baseload power plants which cannot easily reduce their level of production ("must-run"). Producers owning such types of units are almost forced to bid at a zero price[19]. This is also the case for instance, with nuclear power plants which are characterized by high fixed costs and almost insignificant variables costs (Wolfram, 1998).

[19] Note that most of capacity of these power plants are likely to be contracted on the bilateral market via long term contracts

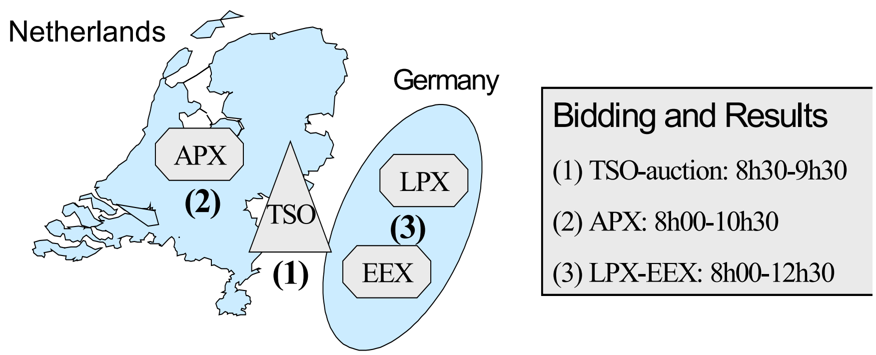
Another motivation for bidding at a price of zero is the existence of a long position on the OTC market. Take for example, a railway company facing a 50% reduction of its activity for a couple of days, e.g. due to a strike or following extraordinary storm, this company will be "overcontracted" and will need to get rid of the extra volume it bought previously on the bilateral market. In order to avoid imbalance charges this company will be willing to sell this electricity at any price, give it away. In this situation the price paid on the bilateral market does not enter into account. Hence, the most likely bidding strategy for this company is to bid at a zero price. Finally, bidding at a zero price is a necessary strategy in non-coordinated markets[20]. This strategy is illustrated in box 6-2 with an actual example. In such a marketplace design, the timing of markets creates a strong incentive to bid at a zero price regardless of any cost consideration.

[20] The issue of coordinated markets and transmission pricing is discussed in chapter 9

Box 6-2: Why bidding at zero in non-coordinated markets: the APX-LPX example

The Dutch market, importing 17% of estimated consumption, is the market most reliant on cross-border trade of all major European markets. Available interconnector capacity is auctioned separately from the power exchange. On a day-ahead basis, trading arbitrage can be done between the Dutch power exchange (APX), and the German power exchange (LPX-EEX). Since these three markets are not coordinated their timeline influences trading, and especially bidding strategies. The timeline of these markets is important since it has a practical impact on the arbitrage possibilities between the markets. The key aspects of the timing of these markets are their trading period and their closure hour. The different timings of these markets are shown below in figure 6-1.

Figure 6-1: Timing of markets



Assuming that on average electricity prices in Germany are lower than in the Netherlands, classical arbitrage behaviors consists of first buying interconnector capacity on the TSO auction from Germany to the Netherlands, second selling power on the APX and finally buying the corresponding volume on one of the German exchanges. An arbitrageur will bid as follow to maximize the probability to be matched on each market:

- (1) TSO Auction: obtain interconnector capacity
- (2) APX: selling at zero or at minimum allowed price
- (3) LPX-EEX: buying at maximum allowed price

In so doing the arbitrageur will maximize its probability of being matched on each market while receiving and paying market-clearing prices. Such behavior is the most rational in situation of uncertainty, because not being matched on one market means facing imbalance charges. For instance, if a pure trader has obtain interconnector capacity and has sold electricity on the Dutch power exchange but has not secure power on the German market it will be unable to cover its contractual commitments.

Bidding for buying at the maximum price is in many ways symmetrical to the previous strategy of selling at a zero price. First large consumers that are "undercontracted" on the bilateral market outage with respect to their day-ahead anticipated consumption or a producer facing an unforced outage, will bid at a maximum price to maximize their chance of being matched on the market. Bidding at the maximum allowed price is also a rational behavior in non-coordinated markets (box 6-2)

Buying and selling simultaneously corresponds to a "composite" strategy which take advantage of the flexibility of a player. Such strategy is simply a combination of possible behaviors as described in the previous section. Keeping in mind that day-ahead spot markets represent only a small part of the total production/consumption of players, participants that have the possibility to modify their needs at short notice can value this flexibility on the market. A "flexible" producer[21] will buy from the market if the MCP is lower than its production cost and will sell if the MCP is higher. A flexible consumer[22]will sell to the market if the spread between the MCP and the price previously negotiated on the OTC market is superior to the opportunity cost of not consuming. Since MCP is defined on a power exchange after submission of bids, each participant must take into account the different scenario within its bids. An example of possible double-side bid is provided in box 6-3.

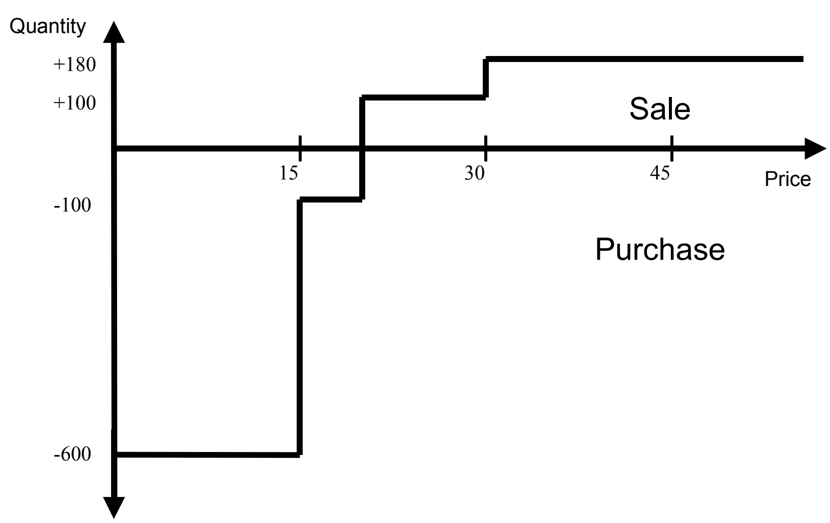
[21] For instance a generator using a gas turbine or having an option contract with a consumer that can decrease its consumption
[22] For instance large green house

Box 6-3: A simple double-side bid

A producer has two generation units with respective production capacities of 500 and 200 MW and respective linear variable costs of 15 and 20 Euro/MWh*. For hour X, this producer has contracted on the bilateral market different sale contracts for a total volume of 600 MWh at an average price of 20 Euro/MWh. Moreover, one customer of this producer has agreed to decrease its consumption up to 80 MWh for a price of 10 Euro/MWh**. Hence, if the price on the market is very high the producer can sell some extra volume on the market rather than to this customer. Base on this information the generator will bid as follow:

- If the MCP is below 15 Euro/MWh, the producer will buy totally from the market (600MWh) to cover its bilateral contracts and not use its own assets
- If the MCP is between 15 and 20 Euro/MWh, the producer will produce 500 MWh with its cheapest unit, nothing with the other one and will only buy 100 from the market
- If the MCP is between 20 and 30 Euro/MWh the producer will sell 100 MWh corresponding to the available capacity not contracted
- If the MCP is higher than 30 Euro/MWh the producer will sell 180 MWh, adding the volume not consumed by its customer***.

Graphical representation



* In this example we do not take into account any fixed cost or starting cost
**In that case the producer pay the customer for its non-consumption
*** If the MCP is 50, the producer will pay 800 Euro (80*10) to the customer and will receive 4000 (80*50) from the power exchange. The profit of this operation will be then 4000-800-1600 (production cost80*20) =1600 Euro

6-4 Examples of specific bidding on power exchange related to market/marketplace design

6-4-1 Strategies related to the regulatory framework: examples from the Dutch case

A peculiarity of the Dutch electricity market design is the obligation for parties who acquired interconnector capacity at the daily auction for importing to the Netherlands to trade the electricity through the Dutch Power Exchange (article 5.6.12.1, Dutch Grid Code[23]). The first formulation of the grid code[24] involved two possible interpretations, which in turn involved different bidding behaviors from market participants on the power exchange. The point here is how to interpret "*obliged to trade [...] through the APX*"[25]. Indeed the wording is such that it is unclear whether the related energy should be traded through (strong interpretation), or just offered on the APX (weak interpretation). Traded obviously means being matched (or sold) on the exchange; however no market participant can make sure to sell its electricity on the exchange since whether a transaction takes place or not depends on the supply and the demand of the market. Moreover, a seller should not be forced to sell below the price that it wants to charge. Secondly even if a seller bids at the minimum authorized price, a seller might not sell all its power if the MCP equals the minimum price[26]. The interpretation of this rule is problematic for these reasons.

An illustration of a first possible bidding behavior is given in box 6-2. A player who has obtained interconnector capacity and secured power from abroad will bid at the minimum authorized price to maximize its chance of being matched, expecting than the MCP will be higher or at least equal to the price of interconnector capacity plus the price of energy abroad. Now consider the case of a market participant that wants to import spot power for its own consumption or to cover any contractual agreement and not only to sell the power to the

[23] See 5-5-3

[24] *"Parties to whom import capacity has been allocated at the daily auction are obliged to trade the electricity transmitted on the Dutch side through the Amsterdam Power Exchange"*

[25] We do not discuss here the following version of the grid code which has amended this article (for more information on that, see www.nma-dte.nl/en/default.htm)

exchange. For instance, if a player is facing a forced outage in the Netherlands it might be willing to secure one day in advance the corresponding amount of power on the German market and to import it through the interconnector. This player will do so if the price of power in Germany plus the price of the interconnector is lower than its prediction for the Dutch spot price (both OTC and PX). In the absence of article 5.6.12.1, such player would not use the Dutch power exchange. However due to this specific rule the player has to "trade" on the power exchange. Depending on the interpretation of this article two different bidding behaviors may occur which we call: "self-buy" and "cap-sell".

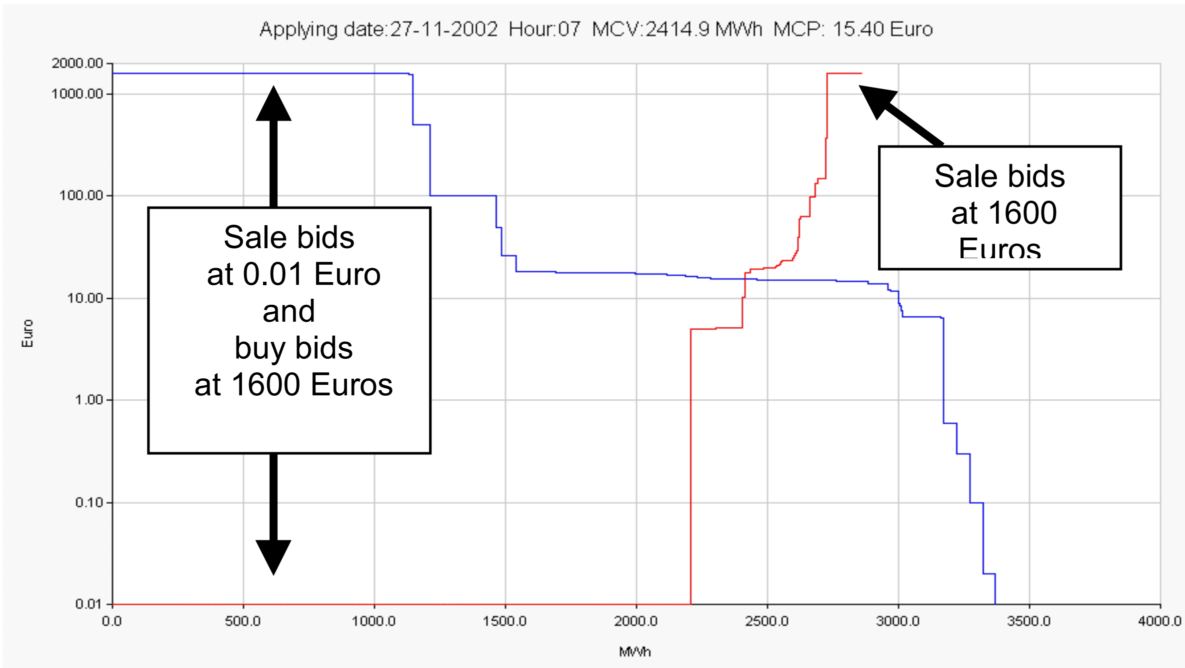
"Self-buy" behavior corresponds to the behavior of a participant which has made a "strong" interpretation of the Grid code, i.e. all volume obtained must be sold on the exchange. In order to respect the code and the desire of this player to use the electricity imported for its own needs, this player will simultaneously sell and buy back on the exchange. In other words the player will buy its own electricity on the market. In terms of bidding behaviors such strategy will involve a composite bid for selling at a low price and buying at a high price. In practice this player will make a sell bid for a quantity X of electricity at the minimum authorized price and a buy bid for the same quantity at the maximum authorized price. For every MCP between these two unlikely limits, this player will sell all its power and buy it back. In doing so, the player respect the Grid code and can use the electricity bought on the exchange for its own needs.

At the opposite a "cap-sell" corresponds to the behavior of a participant that has a "weak" interpretation of the Grid code, i.e. all volume obtained have to be offered on the exchange. In this case, a participant willing to use the interconnection capacity obtained on the daily auction for its bilateral obligation will offer the corresponding volume at the highest price possible (price cap). In doing so, it will fulfill its obligation to offer on the exchange. However since it will not be matched it will then use the obtain volume for its own need without

[26] In that case a prorata rule is used

breaking the law. The bid will only be a sale bid at the maximum authorized price.

Figure 6-1: Example of bids on the APX



Source: APX

These two examples show the influence of market design on the bidding behavior on a power exchange. Indeed "self-buy" and "cap-sell" bidding strategies appear to be especially odd strategies only from a power exchange point of view. Yet once the design of the exchange and article 5.6.12.1 are taken into account, the rationale of these strategies can be understood.

6-4-2 Strategic bidding: the issue of market power

Market power is certainly the most discussed issue in the recent literature on participant's behaviors in electricity markets and represents therefore an important concern with respect to power exchanges. Market power is defined as the ability to unilaterally manipulate prices. Both California and England and Wales have experienced such behaviors. In California, market power was presented as an important reason of the crisis (Wolak, 2002b), while in the UK it was one for the main reason for the introduction of a totally new market design (Sweeting, 2000). The case of California (box 6-4)[27] is especially interesting because economists are divided about the impact of market power when explaining the crisis. Several studies concluded that generators were able to exercise market power (Borenstein *et al*, 2002; Joskow and Kahn, 2002). However, other studies dispute these conclusions and show that such empirical studies suffer from significant shortcomings (Harvey and Hogan, 2001; Falk 1998). Likewise the Federal Energy Regulation Commission (FERC) has found strong evidences for the exercise of market power in the prices prevailing in the real-time market and in the power exchange, but faced difficulties when trying to identify the individual participants responsible of such abuse (FERC, 2003).

The introduction of competition in the electricity industry has produced multiple interdependent markets which have been described as "*an extremely complicated non-cooperative game with a very high-dimensional strategy space"* (Wolak, 1999), and it is the peculiarities of the electricity markets that make it possible for market participants to influence market prices. In oligopolistic competition theory[28], market participants can influence market functioning via two variables: price (Bertrand) and quantity (Cournot). In order to increase markets prices players can decrease supply (withholding of capacity), increase demand (market mix strategy), or sell at very high prices (strategic bidding also called economic withholding). We will now provide some illustrations of this behaviour in the context of European markets with respect to power exchanges.

Withholding capacity is certainly the most well known strategic behaviour in electricity markets that is used to abuse market power. We can identify three types of withholding capacity behaviors. One: withholding capacity can consist of decreasing supply and profiting from high prices for the rest of the production. This is the classic form of withholding capacity where a generator, by decreasing

[27] See also appendix 1

supply from one power plant, profits from high prices from other production facilities. The profitability of this strategy increases with the size of the player's market share.

Two: consists of the strategy of withholding capacity on one market to force buyers to go to other markets, where prices are usually higher. For instance, a player able to withhold enough capacity from the bilateral market may force buyers to go to the power exchange where prices are usually higher due to inefficient arbitrage mechanisms between the two markets. Furthermore by withholding capacity on both the OTC and on the power exchange a player can cause a general shortage in the market. The player acting this way would be aware of this fact and would offer electricity at an inflated price in the balancing market.

Three: the last type of capacity withholding is linked to the market for interconnection capacity. A player can buy a large amount of interconnector capacity to protect a market for cross-border trade. This generator can either decide to use this capacity while offering high prices or decide to block the capacity to make sure that no one else will use it to protect its market from others competitors. Moreover, it can be profitable for a generator to withhold output at a specific location to modify transmission constraints (Borenstein *et al*, 1996; 2000; Oren, 1997; Stoft, 1998). For instance, it may be profitable for a generator to modify its output at one node to create congestion and increase prices from transmission contracts (Joskow and Tirole, 2000).

[28] See chapter 4

Box 6-4: Strategic behavior in California's electricity wholesale industry: did it cause the crisis?

During the California electricity crisis, repeated allegations were made of strategic behavior by generators, both local and out-of-state. Detailed and elaborate investigations into the causes of the crisis followed. So far it has remained unclear if, and if so, what type of strategic behavior took place in California's electricity market and to what extent strategic behavior may have contributed to the electricity crisis. However, strong indications have been found that suggest that the following types of strategic behavior played a part in California's electricity crisis*.

Withholding capacity

The withholding of vital generation capacity in California's electricity market is said to have been one of the causes that led to and made California's energy crisis worse during the winter of 2000 and spring of 2001. During the final months of 2000 especially, strategic withholding of generation seems to have taken place (Joskow and Kahn, 2001). The unprecedented amount of power plant outages during the winter and spring of 2000-2001, at times 16,000 MW, or nearly 35% of California's total generation capacity – roughly double the typical historical forced outage rates, strongly suggests the occurrence of strategic behavior (GAO, 2000; Joskow and Kahn, 2001; Joskow, 2001). Evidence points towards privately owned out-of-state generators such as Enron and Reliant, and to some public entities. Furthermore, withholding in California's natural gas market, which supplies more than 50% of California's electricity industry, also seems to have played a role (CSA, 2001; Faruqui *et al*, 2001).

Strategic bidding

California's market structure stimulated a shift in the amount of power that was traded in the day-ahead market to the more unpredictable and volatile real-time spot market. This strongly increased the volatility of the prices in the real-time market. As California's electricity shortages became more acute, the amounts of energy traded in the day ahead market declined to the point that the California independent system operator was unable to procure enough electricity reserves in the real-time market to cover California's load. This forced the system operator to make out-of-market purchases at far higher prices, which further drove up electricity prices, resulting in vicious cycle (CSA, 2001).

* See also appendix 1.

Generators can also exploit their market power using a *mix of market strategies*. While the first kind of strategies describe above (decreasing supply) are the most obvious, increasing demand is less evident but can lead to a comparable increase in prices. Due to the confidentiality of the OTC market many players may use the power exchange price index as a reference for their bilateral contract. This relationship between the two markets can lead into specific strategies. Take for instance a player that sells part of its OTC indexed on the power exchange price. This player can take advantage of buying electricity on the power exchange to increase the price on this market because this price variation will increase its revenue on the OTC market. This strategy is profitable when the volume on the power exchange is low compared to the volume on the OTC market, when some player have a large market share in both markets, and when arbitrage between market is difficult. These three conditions are present in most European electricity markets.

Finally, the last type of strategy is to use *strategic bidding* to exploit temporary market power. The analysis of strategic bidding behaviour is mainly limited to a comparison of bids and costs of power plants over time (Brealey and Lapuerta 1997, Wolfram 1998). Hence, in its strict definition any bid superior to cost[29] can be considered to be a strategic bid. As in other electricity markets, the use of excessively high bids on the power exchange can be done in order to increase market price. For instance, for buyers that are short in the OTC market the power exchange represents the last place to buy electricity before going to the expensive (and risky) balancing market. For these players very high purchase bids may appear to be the only way to escape the balancing market. Suppliers which are aware of the tightness of the market can then bid at prices higher than the competitive level. This kind of behavior is possible due to the inelasticity of

[29] The literature, depending on the assumptions made by the authors considers short-term marginal costs (STMC) or long-term marginal costs (LTMC). In the short term, the capital costs associated with delivering an additional unit are fixed. It is therefore possible to measure marginal costs excluding capital costs (STMC). However in the long term, capital costs also need to be recovered which increases marginal costs (LTMC)

the demand in electricity markets and the low possibilities for arbitrage between markets.

Strategic bidding can also depend on the type of auctions used. With respect to power exchanges design, the choice between the different options, one-sided auctions versus two-sided auctions, marginal bid versus pay-as-bid etc,[30] can mitigate or facilitate the exercise of market power. For instance, one-sided auctions obviously facilitate the exercise of market power since they limit demand response. However for some others aspects of marketplace design, the choice between different options with respect to their impact on market power, is more controversial. This is the case for the choice between pricing rules (or auction design). Following the Californian crisis and the introduction of NETA in the UK, investigations have started to determine whether the choice between marginal bid versus pay-as-bid might have an impact on market power. While marginal pricing based on an auction is the rule in most European power exchanges but also in most electricity markets around the world (Shuttleworth and McKenzie, 2002), following the Californian crisis and the introduction of NETA investigation have started to determine whether the choice between the two systems might have an impact on market power (Kahn *et al*, 2001; Currie 2000; Bower, 2001). The starting point in the debate on the impact on market power between pay-as bid and marginal pricing auction is that marginal price auctions may facilitate the exercise of market power (Brennan, 2001). The question is whether generators should be allowed to offer different amounts of electricity at different prices rather than all of their output at a single price. The point is that if generators are allowed to offer different amounts at different prices, they have an incentive to offer a small amount of their output at a very high price. The reason for this is that if their high bid is accepted they will receive the high price for all their output while if the bid is rejected the lose involved will not be significant due to the low volume involved. In the analysis of both types of auction, no evidence emerged to support which auction design would systematically produce lower prices and thus

[30] See chapter 3

mitigate market power. However, pay-as-bid auctions appear to be less suitable in general because they may create significant entry barrier, which penalizes small players and thus may facilitate market power in the long run by deterring entry.

6-4-3 Arbitrage strategies: lessons from the Enron's memos

The publication of the Enron memos[31], written by Enron's lawyers in December 2000, has been largely represented in the press as evidences of market manipulation by market participants during the California crisis[32]. However, detailed analysis of the memos reveals that the vast majority of the strategies described were standard arbitrage strategies and at worse most of them increased market efficiency (Falk, 2002). While it is unclear whether the remaining strategies actually served to increase prices and, if yes, to what extent (Wolak, 2002; Hildebrandt, 2002), they clearly show how poor market design creates perverse incentives (Taylor and VanDoren, 2002). Since arbitrage strategies used in power exchanges at present in Europe are not directly observable, the Enron strategies are of particular interest because they provide a good illustration of sophisticated market behaviours in complex electricity markets[33].

In general, as one would expect, Enron's strategies (box 6-5) were aimed at taking advantage of price differences between markets or in time. This is the normal behaviour of traders in any market who try buy low in one place, or at a given time, and sell high in another place, or a another time. Such behaviour increases market efficiency because it reallocates goods from places where they are plentiful to places where they are scarce. For instance "Ricochet" and "Fat Boy" were two strategies used by Enron to exploit prices discrepancies between the real-time market and the day-ahead market. However other strategies such

[31] The first is from the law firm Stoel Rives and is the most complete. The second is from the law firm Brobeck and explains the first memo. They are both available at www.ferc.gov

[32] Los Angeles Times, May7/2002; USA Today, May 7/2002; St. Petersburg Times, May 8/2002;

[33] See appendix 1 for a description of California's market design and discussion

as "Load Shift", "Death Star", and "Wheel Out", though it is unlikely that they had a significant effect on efficiency, clearly show how Enron took advantage of specific weakness in market design.

Box 6-5: The principal Enron's strategies

"Fat Boy":
Arbitrage between Real-time and Day-ahead markets by overstating load in the real-time market.

"Export of California power":
Arbitrage between location by buying in California day-ahead and selling outside California when prices outside California exceed the price cap of the day-ahead market.

"Death Star":
Arbitrage between transmission pricing system by simultaneously scheduling a transaction from A to B and from B to A.

"Load Shift":
Artificially creating congestion and get paid for relieving it.

"Get Shorty":
Arbitrage between Real-time and Day-ahead markets by selling ancillary services in the day-ahead market and buying them back in the real time market.

"Wheel Out":
Scheduling transactions on a transmission line already out or full and receiving payment for being rejected.

"Ricochet":
Arbitrage between Real-time and Day-ahead markets by buying power from the PX exporting it to a party in neighbouring countries and importing it back to sell the energy to the ISO market where no price caps are in place.

Several of Enron's strategies had the objective to take advantage of or avoiding the price cap that applied to transactions within the California market and arbitrage the spread between the PX's market and the ISO's market. California imposed day-ahead price caps of $250 to mitigate price spikes and abuse of market power, but prices were not capped in neighbouring countries. For instance, on December 5, 2000 prices increased to $1200 per MWh in the Pacific Northwest while they were limited to $250 in California. In such a situation it was rational for any market participant to buy as much as possible in California and sell it in the Pacific Northwest. This strategy was called "Export of California power". It has been argued that such a strategy exacerbated the supply shortage in California. This is true, however this is a simple rational arbitrage strategy, i.e. when prices outside California are above the price cap, there is no reason to sell power in California. In this case the design of the market was directly responsible for decreasing available generation in California.

The "Ricochet" strategy described in Enron's memo goes further. Since, no price caps were in place in the ISO real time market and because this market was crucial to system reliability, Enron traders were buying power from the PX exporting it to a party in a neighbouring State and importing it back to sell to the ISO market. Again this strategy is a classical arbitrage strategy aiming to take advantage of the spread between the PX and the ISO market. In a well-designed market such strategy would not have been profitable because the ISO price and the PX price should be equal or at least very close. However the existence of a price cap in the day-ahead market and not in the real time market made such strategy interesting when Enron estimated that the market clearing price on the real-time market would be higher than the price cap on the day-ahead market.

In the real-time market, participants wishing to supply generation had to claim a corresponding load. When Enron expected that prices in the real-time market would be higher than in the day-ahead market, they voluntarily overstated their load. If their expectation were correct they received the ISO real-time price. This strategy called "Fat boy", or "increasing" load into the real-time market, is illustrated in the memo as follows: *"Enron will submit a day-ahead schedule showing 1000 MW of generation scheduled for delivery to Enron Energy Services. The ISO receives the schedule, which says "1000 MW of generation"* *and "1000 MW of load" […] In real-time, Enron sends 1000 MW of generation, but Enron Energy Services only draws 500 MW. The ISO's meter shows that Enron made a net contribution to the grid of 500MW, and so the ISO pays Enron 500 times the Dec[34] prices".* Again, in a well-designed market such a strategy would not have been profitable because the ISO price and the PX price would be equal or at least very close.

Besides strategies aimed at arbitrage of the spread between the PX's market and the ISO's market, several strategies described in the memos took direct advantage of the inefficient transmission pricing system of the California market design. For instance, the idea of the "Load shift" strategy was to create artificially congestion and to get paid for relieving it. For this purpose they would schedule moving power through a congested interconnector. Then, in real-time Enron would cancel the transaction and receive money from the ISO which would pay Enron for relieving congestion. The arbitrage opportunity existed because congestion payments for relieving congestion could exceed electricity prices. According to the Enron memo, this strategy produced about $30 millions of profits in 2000 which shows that it was particularly profitable to do this. It is unclear to what extent such a strategy influences market prices. On one hand, this strategy potentially increased prices in the day-ahead market by raising congestion prices. On the other this strategy can not affect real time prices because they are determined only after a company has restated the loads correctly (Falk, 2002). Hence, in a well-designed market such strategy would not have been a problem because players facing high prices in the day-ahead-market would have buy power in the real-time market. However, the market design did not allow investor-owned utilities to do this because they were required to buy on the power exchange.

The description of the "Death Star" strategy is different and contradictory between the two memos. According to the first memo, the "Death Star" strategy

[34] Real-time price for contribution to grid

allowed Enron *"to get paid for moving energy to relieve congestion without actually moving any energy or relieving any congestion"* while according to the second memo *"congestion was relieved and energy did flow through otherwise under-utilised paths".* In fact "Death Star" is a generic name for a whole types of strategies. These strategies are the most disparaged because they aim to capture congestion payments from imaginary transactions (McCullough, 2002). In the first memo, the "Death Star" strategy is described as follows: assuming that congestion was anticipated from California-Oregon-Border (COB) to Lake Mead, Enron's trader would scheduled a transaction from Lake Mead to COB and collect congestion payments because the energy travel in the opposite direction of congestion. Second, Enron buys transmission in the congested direction (from COB to Lake Mead) which net the transaction. The ISO could not see that the same energy was exported and imported simultaneously because the transmission line from COB to Lake Mead is outside the ISO's control area. This strategy was profitable due to different system for transmission pricing depending on the direction: *"Enron is not subject to payment of congestion charges because transmission charges for the COB to Lake Mead line are assessed based on imbedded costs".* Hence, this strategy was made directly possible due to two design problems. One, the ISO's control area is limited and thus it is unaware of what happen outside its area. Two congestion charges were not priced consistently.

The "Wheel out" strategy is certainly one of the simplest strategies used by Enron for taking advantage of bad market design with respect to transmission pricing: because a first-come first-served system was applied for transmission capacity rather than a bidding process, Enron scheduled transaction on transmission lines which were out or already full. This scheduling was rejected by the ISO and Enron received payments for not being allowed to move power through this interconnection when in fact they had never attempt to send any energy.

In conclusion, the recent publication of the Enron memos shows how market/marketplace design can influence behaviours of market participants. However it is worth noting that the vast majority of the strategies were, one available to all markets participants, two, that most of them were standard arbitrage strategies as opposed with abuse of market power that would not have been profitable in a well-designed market, and three, these strategies were known to the market monitoring committees of the CAISO and the power exchange well before the publication of the memos (Wolak, 2002). Two important aspects are at the centre of most strategies in this example: separation between real-time market and power exchanges, and inefficient transmission pricing mechanisms. Whatever the impact of the Enron strategies had on the market, they shed light on some examples of market intelligence and shows how sophisticated trading strategies can be to take advantage of market design, i.e. of unclear or poor market/marketplace rules.

Finally, the Enron memos illustrate one, how the complexity of electricity markets result in sophisticated market behaviours, and two, how players may take advantage of bad rules and poor market design. In a European market where the power exchanges and other markets have been designed separately, one can reasonably assume a similar set of complex arbitrage trading strategies will take place using power exchanges.

6-5 Conclusion

In conclusion, attention in this chapter was focused on how market participants use power exchanges. A typology of strategies according to the nature of players and different types of bidding behaviors was defined to help us understand the diversity and complexity of behaviors on power exchanges. This chapter shows that the nature of electricity markets and market design involves market participants using complex strategies. These strategies are largely influenced by market/marketplace design. A major concern is the several opportunities for the exercise of market power by market participants. Moreover, an analysis of

Enron's memos has showed how the complexity of electricity markets results in sophisticated market behaviors with respect to arbitrage strategies between markets. Unfortunately, in Europe these strategies cannot be directly observed, though the results of these behaviors on competition can be analyzed through analyzing market structure and outcomes of these markets.