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Trading in Electricity Markets.  
Implications for Stability”**

Valeria Termini and Laura Cavallo

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Valeria Termini, *National School of Public Administration (SSPA)  
and University of Rome Tor Vergata*

Laura Cavallo, *Department of Economic Affairs, Prime Minister's Office (Rome)*

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# **“Spot, Bilateral and Futures Trading in Electricity Markets. Implications for Stability”**

## **Summary**

The design of wholesale electricity markets in the transition towards liberalization presents significant differences from country to country. Some spot markets have imposed the concentration of transactions to ensure market liquidity. Other markets are based on bilateral trading. The debate about the optimal trading mechanism mainly concentrates on how to deal with the trade off between the liquidity of the market and the stability of the system. The solution chosen by some market is a mandatory pool with a regulated market for electricity derivatives, that allows to hedge price volatility and to mitigate market power. This paper investigates whether, in the presence of a futures market, spot and bilateral trading can operate together and what are possible outcomes in terms of liquidity of the spot market and stability of the system. The paper extends existing literature on the role of futures market on the behavior of spot market prices, developing a multi-period model in which electricity consumers can choose whether to trade on the spot market or negotiate bilateral contracts. Results suggest that a spot market with futures contracts and a market for bilateral contracts are not necessarily alternative ways to manage stability problems, but may co-exist with positive and synergic outcomes on price behaviors and market power.

**Keywords:** Derivatives, Electricity, Market power, Hedging

**JEL Classification:** G18, L94, Q41, Q48

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*Address for correspondence:*

Valeria Termini  
SSPA  
Via dei Robilant 11  
00194 Roma  
Italy  
E-mail: [termini@sspa.rupa.it](mailto:termini@sspa.rupa.it)

## 1. Introduction

Electricity spot markets play an important role in the liberalization of electricity industry. The advantages of wholesale markets are well-known: they promote price transparency, efficient price signals and competition, with positive outcomes on both consumers and firms. Compared with long-term bilateral contracts, spot markets provide both consumers and generators with greater flexibility in their trading decisions, since traders can adjust their trading programs until the day before the trade, on the “day-ahead” market. However, all expected benefits of spot market crucially depends on the liquidity of the pool. The liquidity of the pool is negatively affected by volatility risk. The non-storability of electricity makes electricity prices particularly exposed to fuel price volatility and to surges caused by temporary imbalances between the demand and supply of electricity. Furthermore, the hourly auction mechanism, chosen by most electricity markets, enables strategic behaviors and increases price volatility. In order to give market participants the possibility to hedge the volatility of electricity prices, many spot markets have introduced a market for derivatives instruments. Existing literature have investigated the role of futures market on the behavior of market prices and on the possibility to exercise market power (Wolak, 2000, Liski and Montero, 2004, Green 1999, Powell 1993 and others).

The models used by this literature share the common hypothesis that the spot market is compulsory. The implicit assumption is that a mandatory pool with a hedging tools market can be an alternative to a market based on bilateral trading (NETA).

This paper investigates the possible outcomes, in terms of liquidity of the spot market and stability of the system, of a structure in which the two trading mechanisms operate together. Our paper extends existing models to a setting where bilateral transactions are permitted in addition to the centralized hourly auction market, where the system marginal

price is determined (as is the case of Italy and NordPool, for example)<sup>1</sup>. This extension gives a role to market demand that can choose whether to buy electricity on the spot market or through bilateral contracts.

The model also extends a previous analysis of the authors (Cavallo, Termini, 2003) to a multi-period setting in which the price of bilateral contracts is no more exogenous and fixed by the regulator, but is determined in the model. The presence of a long-term bilateral contract market may further contribute to mitigate market power but the problem of such a system is how to ensure market liquidity. The aim of our simple model is to examine the impact of futures market on the price and on the liquidity of a non-compulsory electricity market.

In summary, the model investigates the possibility and the consequences of giving a role to the demand side of the market; the impact of an electricity futures market on the liquidity of the spot market and the stability of prices in a non-compulsory market.

The idea of the paper arises from studies on the opportunity to introduce a futures market of electricity in the Italian power exchange, but could apply to any country with similar institutional features<sup>2</sup>.

We argue that a regulated electricity derivatives market can increase the liquidity of spot market with no need to impose centralized trading. Results evidence that derivative and physical electricity transactions may present synergies and that, even in the presence of a dominant operator, they can have a positive impact on the spot price.

The paper is organized as follows. Section 2 provides a brief description of the electricity industry in Italy, and of the Italian spot market. Section 3 summarizes the theoretical literature dealing with the impact of electricity derivatives on the spot market. Section 4 develops a theoretical two-period model of the behavior of electricity consumers

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<sup>1</sup> Other examples of non-compulsory pool are: the APX (Netherland), EEX (Germany) and Powernext (France). Examples of compulsory pools are the Californian Pool, the new Australian market and the English Pool before the introduction of NETA.

<sup>2</sup> Actually, the only assumptions made about the institutional framework are the existence of a bilateral OTC market and of a futures market for the commodity.

and generators in the presence of a spot market, a long-period bilateral market and a futures market. Section 5 concludes and discusses results and some policy implications.

## 2. Electricity markets in Italy

Italy responded to the 1996 European Directive with Legislative Decree 79/1999, which, reflecting the guidelines calling for the unbundling of generation, transmission and distribution functions, shaped the future development of the sector and provided for competition in production and supply. On the production side, deadlines were set for reducing Enel's monopoly share of electricity generating capacity: from 77.8% in 1999 to a maximum of 50% in 2003 (Enel, the state-owned monopoly producer since 1964, was required to divest 15 GW of generating capacity by 2002. In 2003 ENEL generation accounted for 46.4% of national production, plus 2.9% by ENEL Green Power spa<sup>3</sup>). On the demand side, large customers (consuming more than 30 GWh per year in 1999 and more than 9 GWh per year in 2003, with associations of buyers also being allowed) were considered "eligible clients", free to choose from whom to buy, while small and domestic consumers were to remain the captive market of local distributors. After July 2004 the market was opened to all non domestic consumers. In 2005 60 % of all potential eligible consumers (accounting for 129 TWh of the market demand over a potential demand by eligible consumers of 215 TWh) was acquiring on the liberalized market ; by July 2007 eligibility will be extended to the domestic sector. Finally, as regards high-voltage transmission, dispatching activities (undertaken by the new State owned grid company GRTN) were separated from ownership of the assets (in TERNA, controlled by ENEL) in order to enable non discriminatory access to the transmission network. In 2005 the two companies were merged in a new transmission company -TERNA, controlled by the Treasury owned Cassa Depositi e Prestiti spa-; limits on the share of stocks of the new transmission company (20%) and on voting rights (5%) held by the generating companies (including ENEL) are expected to guarantee non discriminatory access.

New institutions were created to permit implementation of this program: the Electricity and Gas Authority (AEEG) in 1997 and three new Treasury-owned companies: the national grid operator (GRTN - Gestore della Rete di Trasmissione Nazionale) in 1999, the single buyer (AU - Acquirente Unico) in 1999 and, lastly, the electricity market operator (GME - Gestore del Mercato Elettrico) in 2000.

The three companies were given different objectives. Security and the physical stability of the system is entrusted to the national grid operator, while short-run and long-run efficiency, to be reached through price signals, is the objective of the electricity market operator. The latter runs five different markets : two energy markets -i.e. the day-ahead energy market (MGP) and the adjustment market (MA) and three Ancillary Services Markets (MSD), where Terna spa procures the resources required for the dispatching service (i.e. the congestion management, reserve and real-time balancing markets). Moreover, GME organizes the platforms for environmental markets: Green Certificates (CV) to incentives electricity generation from renewable and Energy Efficiency Certificates (TEE); in 2006 a platform for an organized market of Emission Trading Certificates (ETS) should be launched. Generators' offers are selected in the hourly auction of the day-ahead market according to economic order, after a check of network compatibility by the national grid operator, which examines whether the unconstrained schedule of supply and demand faces transmission constraints. The accepted demand and supply offers determine the Pool price at the margin – i.e. the System Marginal Price (SMP), which will be the electricity price for all the generating plants called upon to produce in that hour. Should network congestion arise, the country would be divided into up to 5 zones; accordingly, different zonal prices should give producers price signals for efficiently allocating new generating plants, thus promoting long-term efficiency. A transitional solution is envisaged for large consumers buying electricity in the pool: a uniform

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<sup>3</sup> See major producers's share of net power generation in Italy in Chart 3, Appendix.

System Marginal Price for buyers, should ensure a smooth two-year “adjustment period”, even in the presence of different zonal prices for producers.

Pool transactions are not compulsory and bilateral contracts are admitted. At the time the Italian power exchange started operating, bilateral trading was subject to authorization by the Electricity and Gas Authority, according to criteria intended to ensure competitive conditions and the security of the system. As the market become more developed, this constraint was removed and, currently, bilateral trading are admitted to all eligible consumers provided that trades are consistent with transmission constraints. In the same period the Italian energy authority (AEEG) introduced some measures to avoid market power and abnormal price increases<sup>4</sup>. The Authority rules included the monitoring of specific market power indicators. If these indicators reveal the presence of non - competitive behaviors, the responsible generator will not receive the pool marginal price but the bid he submitted for the electricity produced by each of his power plants. In the next 30 days, the same generator has to sell all its output on the power exchange at a constant price.

Data in the Appendix outline the structure of the Italian electricity industry. Table 1 shows the size of the market and the breakdown of supply between imports and internal production. Figure 2 illustrates the capacity balance at the peak in 2003 and 2004, in order to reveal the reserve capacity of the system. As a result of GRTN's activities to increase the security of the Italian power system, the reserve margin increased from 2 to 12 % upon the summer peak load. Figure 3 illustrates the structure of the industry. Figure 4 compares the composition of electricity generation by source in Italy with that in the major European countries. It reveals two critical points for the Italian electricity industry deriving from the large proportion of thermal power used (about 79%): the high cost of generating electricity due to oil-related inputs and the high price volatility which producers have to face.



### **3. The role of derivatives in electricity spot markets; a short review of the relevant literature**

The literature addressing the impact of electricity liberalization shows that the physical characteristics of electricity and the typically non-competitive structure of the market make spot-market prices very volatile and susceptible to market power problems. This paper extends existing literature by examining the impact of a regulated futures market for electricity on the liquidity and the stability of the spot market in a market where trades are not concentrated on the wholesale spot market and consumers and generator can enter into private bilateral contracts. Our conjecture is that the presence of regulated and standardized electricity derivatives can help to address both volatility and liquidity problems raised from theoretical debate with no need to move to a compulsory market or to replace centralized power markets with bilateral trading (as happened with NETA).

One of the conclusion of this debate (Joskow, 2001; Wolak, 2000; Bushnell, 2001; et al) is that in a non-competitive industry most of the demand for electricity should be met by long-term contracts, and only a small part should be channeled to the spot market and be fully exposed to price volatility. However, the efficiency of the spot market and its capacity to give price signals to long-term contracting cannot be guaranteed when this market handles only a small fraction of transactions. Electricity derivatives offer to traders a way of entering in spot-market positions protecting them from price volatility.

Since the early 1990s an interesting body of literature has developed on this issue and on the impact of financial derivatives on spot-market equilibrium. There are two strands to this literature. The first dating from the introduction of the Pool in England and Wales and Nord Pool in Scandinavia focuses on UK experience and mainly deals with the ability of derivatives contracts to mitigate market power in monopolistic/oligopolistic market structures.

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<sup>4</sup> See [www.autorita.energia.it](http://www.autorita.energia.it)

The second strand focuses on US experience and mainly deals with the stability of the system and the contribution of derivatives to the stability of the wholesale electricity spot market.

The first strand demonstrates that in the presence of hedging contracts, dominant operators lose their incentive to exercise market power over spot-market prices. The behavior of electricity generators, facing an extremely inelastic demand, is analyzed by modeling the spot-market equilibrium either with supply functions (Green and Newbery, 1992; Newbery, 1995, 1998)<sup>5</sup> or with multi-unit simultaneous auctions (von der Fehr and Harbord, 1992). In a simultaneous auction system the dominant generator can exercise market power either by reducing supply or, given the system marginal price (SMP)<sup>6</sup> mechanism, by differentiating between the bid prices of different generating units in accordance with a profit-maximizing strategy. In fact, with the SMP mechanism, all dispatched units are paid at the market-clearing price, which is equal to the price bid by the most expensive unit among those selected to supply electricity. The dominant operator thus has an incentive to offer a price higher than the marginal cost for some units. The risk of losing market share — since these units will not be called upon to supply electricity — will be more than compensated by the higher profits that can be obtained from the other units called into operation (Green e Newbery 1992).

The main finding of this strand of the literature is that dominant operators who hedge their positions on the spot market will lose the incentive to raise prices above marginal costs<sup>7</sup>. Allaz and Vila (1993) show that sequential markets may lead to even less market power than one-shot markets. Wolfram (1999) indicates the existence of financial contracts as one of the possible explanations for observed price-cost markups not being as high as most theoretical

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<sup>5</sup> The supply function used is the one proposed by Klemperer and Meyer, 1989. Different degrees of competition can be modeled using conjectural specifications (Bertrand or Cournot conjectures). The Cournot specification lies at one extreme of the supply function models.

<sup>6</sup> The units called upon to supply electricity on the spot market are selected on the basis of the prices at which they are willing to supply electricity, ranked by the auctioneer to construct a market supply curve, consistently with the transmission network constraints evidenced by the national transmission network operator.

<sup>7</sup> If generators sell their output forward, the extra-profits obtainable on the spot market are offset by the losses on the derivatives market. The spot price affects their net profits only for the fraction of electricity not covered by derivatives contracts

models would predict. Financial derivatives also help to push prices closer to marginal cost by making the generating market more contestable. The hedging strategy allows generators to practice an aggressive price policy on the spot market and to counter the threat of new entrants. With limited capacity, if potential entrants could compete with the incumbents in the contract market, entrants would be covered from the post-entry price risk (Newbery, 1998). The possibility of using “Contracts for Differences” (CfDs) permits both future incomes and future costs to be insured, providing new entrants with a solid financial structure that facilitates the financing of investments in new generating units (Green 1999). Some negative aspects of financial derivatives also emerges. Newbery (1998) indicates that if the industry has enough total capacity, the incumbents can easily deter entry, by using contract cover as an instrument for dumping. Gans, Price and Woods (1998) demonstrate that in a dynamic setting, by lowering electricity prices and hence the profits of individual generators, CfDs could make entry unattractive, with the risk of having higher prices in the long run. One of the main conclusions of the relevant literature is that the effects of derivatives on the spot-market price depend crucially on the level of hedging by the dominant generator. In the case of full contracting the price would be equal to the marginal cost. This finding gives a critical role to the quantity of electricity that the generator is willing to sell forward. Both theoretical arguments and empirical evidence support the hypothesis that generators hedge most of their output through derivatives contracts. If consumers are more risk averse than generators, the latter can have an incentive to sell derivatives contracts in pursuit of the risk premium. Also, generators can use derivatives as a commitment device to prevent new entries or regulatory intervention. In an oligopoly, firms can sign derivatives contracts to increase their market share. Some empirical evidence supports the hypothesis that generators cover most of their output in the derivatives market <sup>8</sup>.

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<sup>8</sup> Green, 1999, gives evidence regarding the electricity supply industry in England and Wales.

The second strand of the literature on electricity derivatives focuses on the effect of these contracts on the stability of the system. A common assumption of this literature is that all electricity transactions pass through the spot market. The experience of California, where distributors were prevented from hedging on the financial market by a strict regulatory framework, has been a catalyst for studies on this issue. Wolak (2000), Joskow (2001) and Green (2001) indicate that the use of derivatives would have helped to curb price surges and allowed distribution companies to hedge against the volatility of wholesale prices. The studies of the Californian experience reveal two additional critical points. First, the absence of a strategic role for the buyer (see, among others, Bushnell 2001).<sup>9</sup> The low elasticity of the demand and the large number of buyers (in particular small buyers) does not facilitate strategic behaviors.<sup>10</sup> Second, the risk implicit in concentrating a large volume of transactions on the day-ahead market in non-competitive situations, as evidenced by Joskow (2001). The need for imminent consumption heightens the market power of the dominant operator: in this situation, any irregularity in the quantity of electricity offered on the market can lead to price surges, with highly destabilizing effects on the system. Joskow's proposal is to ensure that a large fraction of retail transactions be met by long-term bilateral contracts, and that only a small fraction be fully exposed to the price volatility of the spot market. Bilateral contracts should increase the stability of the system by fixing the long-run price of electricity. However, such contracts are not transparent and, on their own, do not give market operators the same flexibility of spot-market transactions, where both generators and consumers can modify their decisions to sell or to buy electricity until the "day-ahead". There thus seems to be a hard-to-resolve trade-off between the liquidity of the spot market and the stability of the system. This

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<sup>9</sup> All the theoretical studies on the topic concentrate on the behavior of generators.

<sup>10</sup> The presence of asymmetric regulation (as in the Californian case) may further insulate consumers from price signals. In the presence of asymmetric regulation, the distributors buy electricity on the spot market at wholesale market prices and sell it to consumers at regulated prices. In most countries, as California, regulated prices are fixed for a period of about four years (in some cases, as in the UK, the formula may include a generating cost pass-through). If retail prices are fixed prices, consumers are not exposed to the risk of market price volatility, but at the same time they do not receive information on the behavior of market prices.

gives rise to a vicious circle, since liquidity is a necessary condition for the efficiency of the spot market. This is confirmed by international experiences with liberalization: one of the main obstacles to the full development of electricity spot markets is their lack of liquidity. This paper develops a simple theoretical model of spot and futures prices that extends existing models giving consumers and generators the choice to trade on the spot market as well as on an OTC bilateral contract market. This extension allows to address both liquidity and stability problems and to give a role to the demand.

## **4. The model**

### *4.1 The role of demand in spot-market transactions*

In the first part of the analysis we model the behavior of electricity consumers. In order to simplify the analysis and to treat consumers as a homogenous class with the same preferences, we decide not to consider the demand coming from the single buyer and to assume that all the demand comes from industrial end-users. This assumption is not too far from the initial conditions of the Italian market, where the large part of the demand come from industrial end-users. At the time the spot electricity market begun operating, only big industrial end-users where allowed to trade directly on the spot markets. The Single Buyer (Acquirente Unico, AU) could purchase electricity from the spot market for all other consumers. By July 2007 all consumer could buy electricity on the spot market with no need to pass through the Single Buyer.<sup>11</sup> ..As discussed above, most of the literature on electricity spot markets analyses the supply side of the market, taking demand as given. In this paper, by allowing electricity consumers to choose the fractions of electricity they want to buy on the

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<sup>11</sup>The Law no. 239/2004 (the so called “Marzano law,” from the name of the Production Activities Minister), implementing the EU Directive n. 2003/55/EC, opened the market to all non-domestic consumers starting from July 2004. From 2007 the market will be extended to domestic consumers.

spot market and through bilateral contracts, we give an active role to demand. In order to examine the effect of a futures market on electricity buyers' behavior, we compare consumers' optimizing choices in the absence and in the presence of a futures market. Industrial end users tend to be risk averse. We assume they have an exponential utility function, and we model their behavior using a two-period mean variance utility function. Since we are mainly concerned with the share of electricity the consumer will buy on the spot market and not with the total amount of resources they are willing to spend in electricity, we assume total quantity in the two period as fixed at  $q_1$  and  $q_2$ . We assume that bilateral contract last two years (each period correspond to one year). The quantity of bilateral contract will be decided in period 1 and, for simplicity, it will be consumed in equal amount  $q_{BC}$ , in period 1 and 2 (the total quantity is  $2q_{BC}$ ). Assuming additive utility function, the objective function of electricity consumers is:

$$\text{Max } E[U(W_1, W_2)] = E[U(W_1)] + \rho E[U(W_2)] \quad (1)$$

Since prices in period 2 are the only source of uncertainty, and being  $\lambda$  the factor of risk aversion, we can write equation 1 in mean-variance terms as:

$$\text{Max } E(U)/q_{BC} = U(W_1) + \rho[E(W_2) - \frac{\lambda}{2} \text{Var}(W_2)] \quad (2)$$

$$q_{T,t} = q_{ts} + q_{BC} \\ t = 1, 2$$

Where  $\rho$  is the intertemporal discount factor,

$$W_t = - [p_{st}q_{st} + (p_{BC} + TC_{BC})q_{BC}] \quad (3)$$

$$E(W_2) = - [E p_{s2} q_{s2} + (p_{BC} + TC_{BC})q_{BC}] \quad (4)$$

$$\text{Var}(W_2) = (q_{s2})^2 \text{Var}(p_s) \quad (5)$$

$W$  is negative as it corresponds to the total cost of buying electricity. In our assumption, the demand for electricity comes entirely from industrial end-users, who use electricity as an input in their productive process. We model their behavior with mean-variance utility (see also

Powell, 1993) mainly to take in account their aversion to price risk, but their optimization choice is more similar to that of a producer whose main concern is that of minimizing costs subject to the total quantity of production they want to supply. Consequently, as evidenced in eq. 2, their maximization process is not conditioned to a budget constraint but to a sort of production constraints. Since the two inputs are perfect substitutes (actually, they are exactly the same good!), total production depends on the total quantity of inputs, which is the sum of the quantity of energy bought on the two markets<sup>12</sup>.

$q_{st}$  is the fraction of electricity purchased on the spot market in the two periods,  $p_{st}$  is the spot-market price,  $p_{BC}$  is the price of bilateral contracts.  $TC_{BC}$  are transaction costs of bilateral contracts, represented by the lower flexibility of bilateral contracts compared to the spot market (net of any advantages obtainable)<sup>13</sup>. On the Italian market

Maximizing the utility function with respect to  $q_{BC}$  and substituting, we can write the optimal share of the demand for bilateral contract in each period and for spot market transactions in the two periods as:

$$q_{BC} = q_1 + b[p_{s1} + \rho E p_{s2} - (1+\rho)(p_{BC} + TC_{BC})] \quad (6)$$

$$q_{s1} = b[-p_{s1} - \rho E p_{s2} + (1+\rho)(p_{BC} + TC_{BC})] \quad (7)$$

$$q_{s2} = q_2 - q_1 + b[(1+\rho)(p_{BC} + TC_{BC}) - p_{s1} - \rho E p_{s2}] \quad (8)$$

$$b = \frac{1}{\lambda[Var(p_s)]} \quad (9)$$

Not surprisingly, the quantity of electricity that consumers are willing to buy on spot market depends on the difference between the total cost of buying electricity on the spot market ( $p_{s1} + \rho E p_{s2}$ ) and the total cost of buying it through bilateral contracts  $(1+\rho) p_{BC}$ , to an extent that varies with the degree of risk aversion and the volatility of spot prices. The flexibility offered by spot-market transactions could increase consumers' willingness to buy

<sup>12</sup> For simplicity, we assume a linear production function with slope 1.

<sup>13</sup> For simplicity, we assume that the costs of flexibility are fixed and exogenous. A future extension of this work could model these cost and deepen the analysis of their impact on consumer choice.

electricity on the spot market. In the limit, when the total price of the spot market corresponds exactly to the price of bilateral contracts, they will still use the spot market in an extent that increase with the cost of the lack of flexibility<sup>14</sup>.

Results indicate that the demand of spot transactions is negatively correlated with risk aversion and price volatility. This suggests that futures contracts may have a positive impact on the liquidity of the spot market by making it possible to hedge against the risk of price fluctuations. This hypothesis is further examined by modeling consumers' behavior in the presence of a futures market. We assume that this is a regulated financial market, with a clearinghouse that provides a system of guarantees that mitigates counterpart credit risk. Futures contracts are financially settled, and this allows for a diverse universe of buyers and sellers that not necessarily have to belong to the electricity market. However, the strong assumption that we make here, that will be further discussed below, is that generators and buyers would use this market only for hedging purposes. This implies that generators are mainly sellers of futures contracts, and consumers are buyer.

Futures Exchange provides standardized futures contracts with different maturities (weekly, monthly) on on-peak and off-peak electricity transactions based on the daily price for each day of the month. If the futures price for a unit of electricity at time  $t$  is  $F_t$ , the pay-off of futures contract bought at time  $t$  with maturity  $T$  is  $(F_T - F_t)$ . The wealth of a consumer hedging his spot-market position with a long positions of  $x$  futures contracts with maturity one year is:

$$W_2 = - [q_{s2} p_{s2} + (p_{BC} + TC_{BC})] + x(F_2 - F_1) \quad (10)$$

According with standard assumptions, the relationship between spot and futures prices at time  $t$  can be written as:

$$F_{t,T} = p_{st} B(r, \tau) \quad (11)$$

Where  $B(r, \tau)$  is the relation between the spot and the futures price, expressed as a function of  $r$ , the market risk-free rate, and  $\tau = T - t$  is the time to maturity of the futures contract. Financial theory suggests several forms to describe the exact relationship between the spot and the futures price<sup>15</sup>. Whatever the form assumed, this relationship is positive. Since this is the only

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<sup>14</sup> Starting from the 31<sup>st</sup> of December 2004, operators can adjust their bilateral position through the PAB (Platform of Bilateral Adjustment for the demand) at the cost of 0,01 € for each MWh traded. This system can increase the flexibility of bilateral market, and the cost of utilizing the system is a proxy for the cost of flexibility.

<sup>15</sup> As observed by Geman (2001), the relationship generally assumed to describe this relationship for the commodities market (the usual form is:  $F(t, T) = S(t)e^{(r-y)(T-t)}$  where  $r$  is the risk-free rate and  $y$  the convenience yield given by the difference between the positive return from owning the commodity and the cost of storage  $s$



condition necessary for our results to be valid, and we are not concerned with the form assumed by this relationship, we chose to simplify the notation indicating this relationship with  $B(r, \tau)$

$$E(W_2) = -[p_{BC}q_{BC} + q_{s2}Ep_{s2}] + x(EF_2 - F_1) \quad (12)$$

$$Var(W_2) = (q_{s2})^2Var(p_s) + x^2Var(F) - 2xq_{s2}Cov(p_s, F) \quad (13)$$

The buyer will obtain a positive result from the futures market if  $(F_2 - F_1) > 0$ .

In the presence of a futures market, the buyer's optimal choice for the quantity of electricity to buy on the spot market in the two periods becomes:

$$q_{s1} = -\frac{p_{s1} + \rho Ep_{s2} - (1 + \rho)p_{BC} - (1 + \rho)TC_{BC}}{\lambda\rho[Var(p_s)]} + x\frac{Cov(p_s, F)}{Var(p_s)} \quad (14)$$

$$q_{s2} = q_2 - q_1 + \frac{p_{s1} + \rho p_{s2} - (1 + \rho)p_{BC} - (1 + \rho)TC_{BC}}{\lambda\rho[Var(p_s)]} + x\frac{Cov(p_s, F)}{Var(p_s)} \quad (15)$$

The first part of these expressions is identical to Equation 7 and 8, obtained in the absence of a futures market. The difference lies in the last term. Since the correlation between future and spot price is positive and  $x > 0$  (the assumption is that the buyer operates in the futures market to hedge its position on the spot market) the sign of this term is always positive. This means that the presence of a futures market increase the willingness of electricity consumers to buy electricity on the spot market thus contributing to the liquidity of the spot wholesale market. The higher the quantity of electricity hedged with futures contract ( $x$ ), the higher will be the effect on the liquidity of the spot market.

It follows that:

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relationship) does not hold perfectly in the case of electricity and in general of power, because of non-storability, which also invalidates the non-arbitrage argument. For our purposes however, the exact relationship between the

*Proposition I - If a risk-averse consumer is allowed to decide whether to buy electricity on the spot market or through bilateral contracts, the presence of a futures market increases the fraction of demand that passes through the spot market.*

This proposition points to a positive role for consumers' choices in the market.

As a corollary, the size of the futures market's impact on the optimal choice of spot transactions depends on the correlation between the spot price and the futures price. The higher this correlation, the greater will be the ability of a futures market to increase spot-market liquidity.

If we simultaneously determine the first-order condition that identifies the buyers' choice of  $x$ , we obtain:

$$x = \frac{E(F_2) - F_1 + \lambda q_{s2} Cov(p_s, F)}{\lambda Var(F)} \quad (16)$$

As expected, the demand for futures contracts as the preference for spot market transactions, depends positively on the correlation between the spot market and the futures market. Therefore, a high correlation between futures and spot market has a positive impact not only on the liquidity of the spot-market but also on that of the derivatives market, with synergic effects between the spot and futures markets. The demand for hedging tools is also positively affected by the correlation of the price of these instruments with the price of bilateral contracts.

Another interesting result emerges from the analysis<sup>16</sup>. If spot trading is compulsory and derivatives are the only instruments available to hedge volatility risk, the cost of hedging could become so high to compensate the potential benefits of hedging instruments on the level

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spot and the futures price is not essential. The only necessary assumption for our results to be valid is that relationship to be positive. We than decided to indicate this relationship with the term:  $B(r, \tau)$ .

<sup>16</sup> We thank an anonymous referee for useful suggestions that help us to derive this further implication of the model.

of spot prices. In the limit, the spot price plus the cost of hedging could overcome the spot price in the absence of a futures market. This problem is more relevant in electricity market: as the underlying asset of electricity futures is a physical good, the elasticity of the demand of hedging to its cost is lower than in financial markets.

The hypothesis assumed in this paper, that spot market is not compulsory, gives consumers an alternative to the futures market: as the cost of hedging become too high, they can move to bilateral contracts. This contributes to increase the elasticity of the demand for hedging instruments and to mitigate the cost of hedging.

This lead to:

*Proposition 2: the possibility for strategic consumer to move to bilateral contract as the cost of hedging becomes too high contribute to mitigate the demand for futures instrument reducing the pressures on their prices.*

Expression 16 evidence that an increase in the cost of hedging, which may be represented by an increase in  $F_1$ , reduces the demand for futures contracts ( $x$ ) that, in turn (eq. 14), reduces the quantity of electricity the consumer is willing to buy on the spot market and increase the demand for bilateral contract.

#### 4.2 The electricity spot market: the generator's behavior

The second step of the analysis is to model the behavior of the supply side of the market. Consistently with the Italian case, we assume a market in which there are few operators (actually, there is still one dominant operator) that are likely to act cooperatively. For simplicity, we specify the hypothesis of two generators acting cooperatively assuming one monopoly generator. In that case we can model the generator as a quantity or price setter. Let us assume a risk-neutral generator<sup>17</sup> with a generic cost function  $C(q)$  and marginal costs

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<sup>17</sup> The hypothesis of risk-averse generators leads to the same conclusions and is provided in an Appendix available from the authors upon request.

$c(q)$ . Both buyers and the generator can cover their spot-market positions through futures contracts.

The objective function for a generator who face a fraction  $q_{st}$  of its total capacity  $q_T$  through the spot market and the residual  $q_{BC}$  through bilateral contracts, and opens a short position on the futures market to cover its positions on the spot market can be written as:

$$\pi = \pi_1 + \rho\pi_2 \quad (17)$$

where

$$\pi_1 = p_{s1}q_{s1} + p_{BC}q_{BC} - c(q_1) \quad (18)$$

$$\pi_2 = p_{s2}q_{s2} + p_{BC}q_{BC} - x(F_2 - F_1) - c(q_2) \quad (19)$$

$$q_1 = q_{s1} + q_{BC}, \quad q_2 = q_{s2} + q_{BC},$$

On the Italian electricity spot market it is possible to hedge via ‘‘Contracts for Differences’’ or CfDs. In our model we always refer to a regulated futures market, in the hope that a regulated market could be introduced as soon as the market will be more mature. The reference to a futures market rather than CfDs does not substantially change the analytical structure and results of the model. However the presence of a regulated market can have a significant impact on the liquidity of the market because of standardized contracts and of a clearing house which guarantees the participants from counterparty risk. These characteristics help to attract non-electricity (speculative) traders.

In the first stage, the generator sign bilateral contracts with the buyer.

In Stage II, trade occurs in the pool, and the net result of futures trade will be revealed.

The model described by expressions 17 to 19 will be analysed working backwards, considering the stage-two pool market behaviour and then looking at the bilateral contract and hedging contract market behaviour according with the predicted stage-two behaviour.

We assume that the demand of electricity needed to close the model depends on actual and expected prices as follows:

$$q_{TI} = f(p_{BC}^-, p_{s1}^-, E p_{s2}^+) \quad (20)$$

$$q_{BC} = g(p_{BC}^-, p_{s1}^+, E p_{s2}^+) \quad (21)$$

$$q_{s1} = q_{T1} - q_{BC}$$

$$q_{T2} = h(p_{s2}^-) \quad (22)$$

$$q_{s2} = q_{T2} - q_{BC}$$

The assumptions on the signs of the relationships between prices and quantities can be clarified as follows. According with intertemporal preferences, we assume that the demand for electricity in period 1 is positively correlated with the expected price of electricity on the spot market in period 2. The total demand of electricity in period 1 is decreasing in prices of electricity in both markets. Since cross-elasticity between the two alternative and substituting markets is negative, the demand of electricity in market  $j$  ( $j= BC, s1$ ) is negatively correlated with the price of electricity in the same market but positively related with the price of electricity in the other market. In period 2 the decisions of period 1 are taken, and the total demand of electricity to buy on the spot market depends (negatively) only on the spot price in period 2.

Expressing the demands indicated in expressions 20 to 22 in linear form and rearranging, we obtain the inverse demand functions (of prices as a function of quantities), that may be written as<sup>18</sup>:

$$p_{s1} = A - b q_{s1} + b' q_{BC} + b'' E p_{s2} \quad (23)$$

$$p_{BC} = C + c q_{s1} - c' q_{BC} + c'' E p_{s2} \quad (24)$$

$$p_{s2} = D - d q_{s2} - d'' q_{BC} \quad (25)$$

Replacing the inverse demand function and futures price in the model (expressions 17 to 19), the profit of the generator at time 2 will be:

$$\pi_2 = (D - d q_{s2} - d'' q_{BC}) q_{s2} + p_{BC} q_{BC} - x [(D - d q_{s2} - d'' q_{BC}) B - F_1] - k (q_{s2} + q_{BC}) \quad (26)$$

The relevant first order condition may be written as:

$$q_{s2} = (p_{s2} - k) / d + x B \quad (27)$$

substituting, we get the optimal spot quantity and price in period 2:

$$q_{s2}^* = (D - k + xdB - d''q_{BC})/2d \quad (28)$$

$$p_{s2}^* = (D + k - xdB - d''q_{BC})/2 \quad (29)$$

Eq. 27 has the following implications:

*If a generator with a generic cost function offers a quantity of electricity on the futures market close to the amount sold on the spot market, the spot price of electricity converge to marginal cost.*

We can now solve the stage I of the problem.

We maximize the intertemporal profit of generator substituting the inverse demand function in period 1 and optimal spot prices in period 2.

The optimal spot and bilateral transaction can be written as:

$$q_{s1}^* = (p_{s1} - k)/b + (1 + \rho)(c/b)q_{BC} \quad (30)$$

$$q_{BC}^* = Z - z(p_{s1} - k) + z'p_{BC} + z''xB \quad (31)$$

Using these quantities we can write the optimal spot price as a function of the mark-up in period 1, the price of bilateral contracts and the quantity of futures contracts:

$$p_{s2}^* = (1/2)[D - d''Z + k + d''z(p_{s1} - k) - d''z'p_{BC} - (d + d''z'')xB] \quad (32)$$

Eq. 27 indicates that the optimal share of electricity sold on the spot market is a positive function of  $x$ , the quantity of futures contracts that the generator is willing to sell to hedge the quantity  $q_{s2}$  sold on the spot market<sup>19</sup>. The results have several implications:

1. *Futures trading contributes to mitigate market power.*

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<sup>18</sup> More details about demand function and calculations are in an appendix available from the authors.

<sup>19</sup> A similar conclusion was obtained by Powell (1933), Green (1999), et al. in the case of all transactions passing through the spot market.

Eq. (27) shows that a generator who hedges its spot market position with future contracts would lose incentives to drive the spot price above marginal cost. As suggested by the literature on the role of financial contracts, the generator expects that any profit obtainable on the spot market by driving the price up will be offset by a loss on the futures market, and prefers to adopt a more aggressive strategy in the spot market.

2. *The possibility for strategic consumers to purchase electricity through bilateral contracts further reduces generator's incentive to raise spot market price.* Equations 29 and 32 show that both bilateral contract market and futures market contribute to low spot market prices.
3. *Futures trading increases the quantity of bilateral contracts bid by generators favoring effective consumer choice.* Eq. 31 evidences a positive impact of futures trading on the optimal quantity of bilateral transaction.
4. *Futures trading contributes reducing the price level both directly and indirectly,* as a consequence of points 2 and 3 (directly, as shown by eq. 32; indirectly, by increasing bilateral transaction (point 3) that in turn will have a negative impact on prices (eq. 29).

In the Italian market the Authority declared that the rules to avoid market power and abnormal price increases<sup>20</sup> will become as less constraining as the CdF contracts will be more developed<sup>21</sup>. Our model provides an analytical support to the intuition behind the Authority provision. As soon as hedging tools will be more developed (read: when the quantity of electricity hedged,  $x$ , will be closer to the quantity traded on the spot market,  $q_{st}$ ) the spot

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<sup>20</sup> At the beginning: bilateral negotiation had to be submitted and approved by the Authority. Recently: a generator that offers a quantity of electricity lower than its total capacity will not receive on these quantity the spot price but the bid submitted.

<sup>21</sup> Press releases, [www.autorita.energia.it](http://www.autorita.energia.it)

price will tend to the bid submitted and will be closer to marginal price with no need for an exogenous regulatory intervention.

## **5. Concluding comments: policy implications and market design**

Results obtained have several policy implications and yield some interesting suggestions about the design of competitive electricity markets in the transition towards complete liberalization. The first implication (*Proposition 1*) regards the dilemma: compulsory pool or consumers' choice. Some spot markets have imposed the concentration of transactions to ensure market liquidity (the Californian Pool, the new Australian market and the English Pool before the introduction of NETA). UK market replaced a mandatory pool with a market based on bilateral trading (NETA). This paper shows that in the presence of a regulated market for electricity derivatives, the two trading mechanism can operate together with positive outcomes both on the liquidity of the spot market and on the stability of the system. This result supports the decision of the Italian regulator not to impose the concentration of transactions on the electricity spot market provided the launch of the wholesale spot market will be accompanied by that of a futures market.

The consumer's choice between spot market and bilateral contracts increases the price elasticity of demand, reducing generators' incentive to exercise market power. Since the effect of a futures market on liquidity depends on the correlation between spot and futures prices, electricity index prices have to be highly representative of spot-market behavior. Liquidity problems may appear to be transferred from the spot market to the futures market. However, our results suggest that a high correlation between spot and futures prices also has positive effects on the liquidity of futures markets, with synergic effects between spot and futures transactions.



Other interesting policy implications emerge from the second part of the analysis. The conclusions emerging from the analysis of generator's behavior indicate that if consumers are free to choose among spot transactions and bilateral contracts and generators hedge their spot-market supply, spot market prices will be mitigated. It follows that there would be no need to impose exogenous limits to the fraction of demand that passes through the spot market (as suggested by Joskow, 2001 et. al.) in order to mitigate the effects of market power on spot prices and ensure the stability of the system. The advantages of this result, in terms of spot-market liquidity and efficiency, are evident.

Furthermore, this result supports the need for a regulatory intervention to mitigate market power at least in the transition towards liberalization. In contrast with the regulatory mechanism used in other countries (capping market prices), the intervention of Italian regulator has a limited and indirect impact on market mechanisms. Moreover, regulatory intervention is triggered only when spot-market prices are not competitive. Otherwise, the regulatory intervention would not be operating, and the threat of a regulatory intervention would only act as a disciplining device.

As in Powell (1993), Green (1999) and others, the attractive results of this paper depend crucially on the assumption that generators and consumers are willing to hedge their spot-market positions (the best results are obtained when generators fully hedge their positions). As shown in Section 3, many arguments are used to support the hypothesis that generators hedge most of their output through derivatives contracts. Here, the increase in the spot-market demand price-elasticity produced by giving a strategic role to demand and generators' desire to prevent regulatory intervention by committing themselves to keeping prices low would be an additional incentive for them to sell derivatives contracts (Wolak, 2000). A final suggestion of this study is that a regulated market for financial derivatives should be introduced, in addition to OTC transactions. In a regulated market the financial authority oversees transactions and the clearing-house guarantees participants from

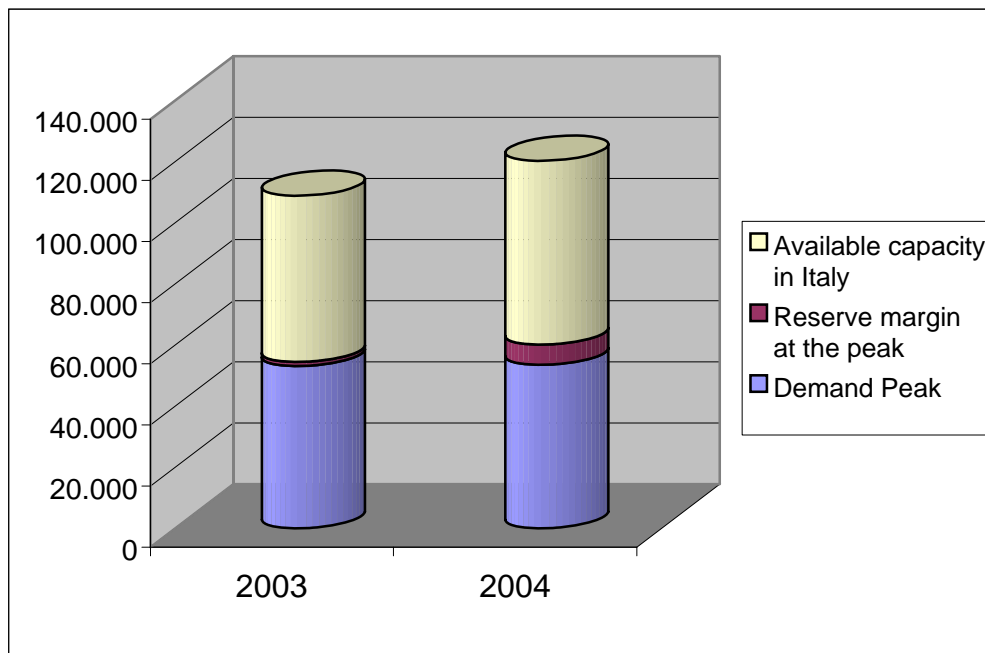
counterparty risk, thereby reducing the risk of systemic crises. Furthermore, standardized futures contracts may attract non-electricity speculative traders increasing market liquidity.

Table 1 – Electricity Balance in Italy (2005)

	Gwh
Gross Production	303.670
Auxiliary Services of Production	13.064
Net Production	290.607
Net Imports	49.160
Pumping Consumption	(9.320)
<b>Energy supplied</b>	<b>330.440</b>
Captive Market	153.000
Free Market	135.500
Autoproducer Consumption	21.300
<b>Total Consumption</b>	<b>309.800</b>
Losses	(20.640)
<b>Energy supplied</b>	<b>330.440</b>

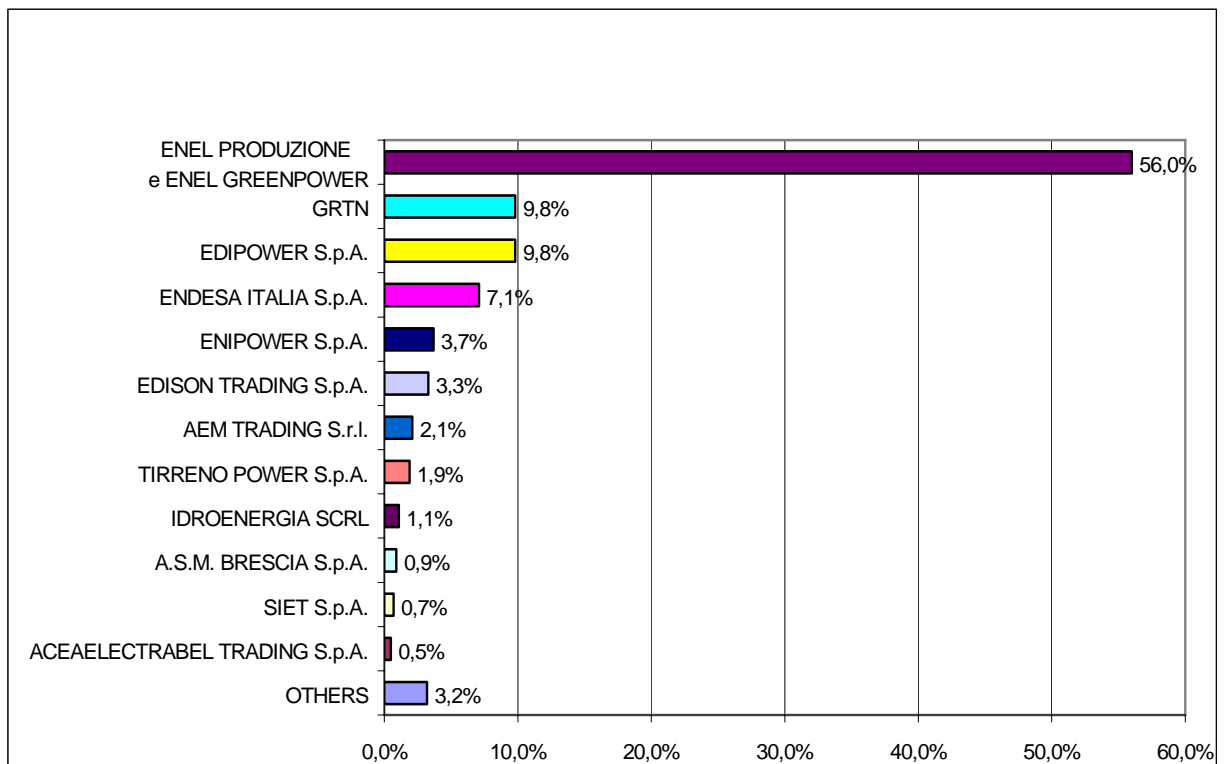
Source: AEEG, September 2006.

Figure 2 – Capacity balance at peak time



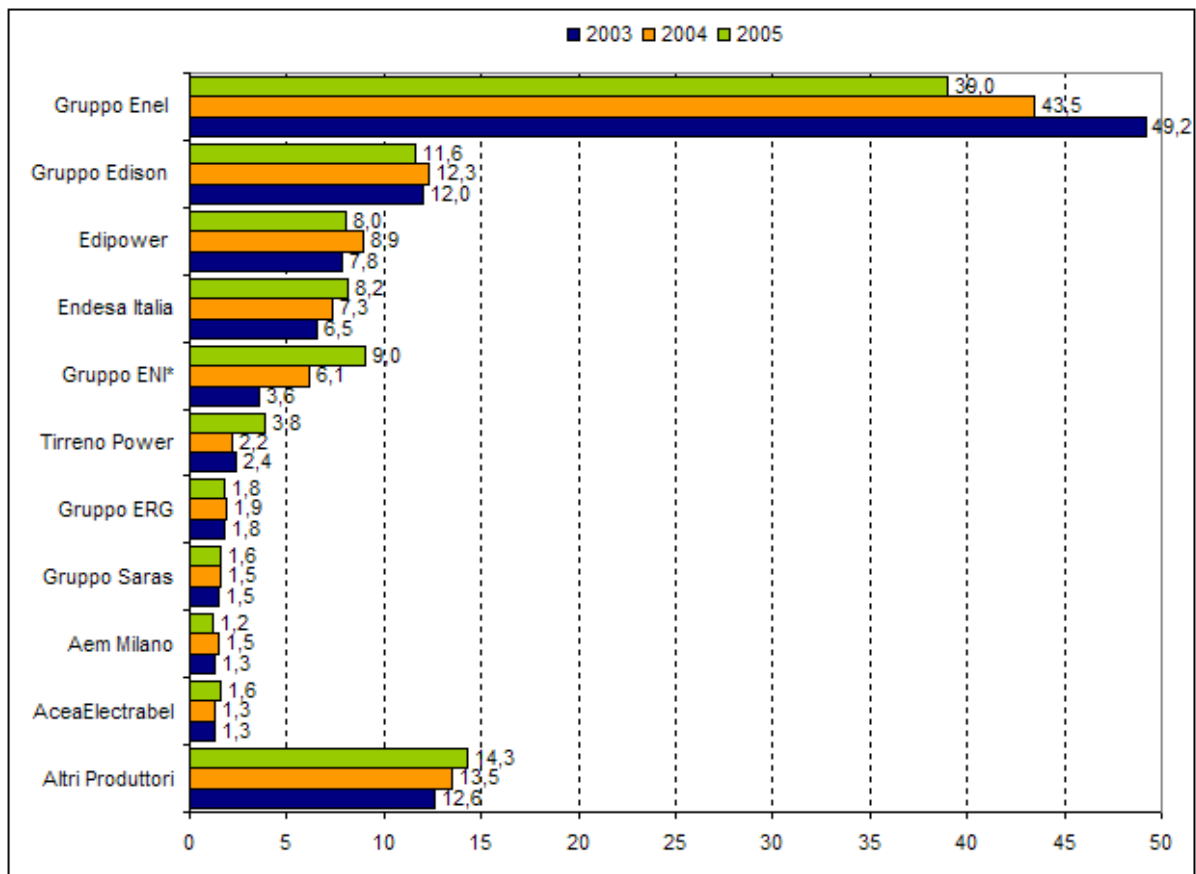
Source: GRTN

Figure 3 a – Italian Electricity producers. Market share (2004)



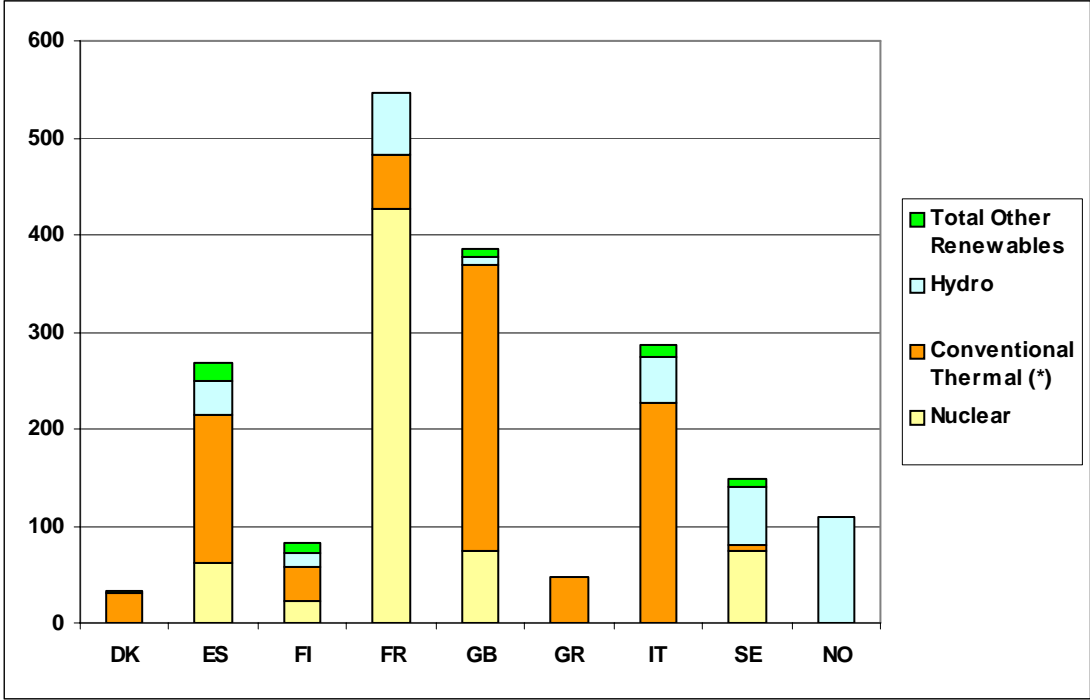
Source: AEEG estimates on company figures.

Figure 3 b - Electricity producers. Share of gross production



Source: AEEG 2006

Figure 4 – Net Electricity Generation in major countries in Europe by source (2004)



(\*) Conventional Thermal include OCGT

(\*\*) France 2004: "Other renewables" are included in "Conventional Thermal"

Source: EURELECTRIC

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	1997	1998	1999	2000	2001	2002	2003	2004	2005
A) Produzione lorda	251.462,6	259.786,0	265.656,6	276.629,1	278.994,6	284.401,2	293.865,1	303.321,1	303.671,9
B) Consumi dei servizi ausiliari	12.174,0	12.843,0	12.920,0	13.336,4	13.029,3	13.618,5	13.681,8	13.298,5	13.064,0
C) Produzione netta (A-B)	239.288,0	246.943,0	252.736,7	263.292,7	265.965,3	270.782,7	280.183,2	290.022,6	290.607,9
D) Destinata ai pompaggi	6.728,0	8.358,0	8.903,0	9.129,5	9.511,0	10.653,6	10.492,4	10.300,3	9.319,4
E) Produzione destinata al consumo (C-D)	232.560,0	238.585,0	243.833,7	254.163,2	256.454,3	260.129,1	269.690,8	279.722,3	281.288,5
F) Ricevuta da fornitori esteri	39.827,0	41.633,0	42.538,0	44.831,0	48.926,6	51.519,1	51.485,9	46.425,7	50.264,0
G) Ceduta a clienti esteri	995,0	901,0	528,0	484,0	549,3	922,3	518,3	790,8	1.109,5
H) RICHIESTA (E+F-G)	271.392,0	279.317,0	285.843,7	298.510,2	304.831,6	310.725,9		325.357,2	330.443,0
I) Perdite di rete	17.718,0	18.508,0	18.559,5	19.190,7	19.339,5	19.766,4	20.869,8	20.867,6	20.626,2
L) CONSUMI (H-I)	253.674,0	260.809,0	267.284,2	279.319,5	285.492,1	290.959,5	299.788,6	304.489,6	309.816,8



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