OPTIONS AND FUTURES CONTRACTS IN ELECTRICITY FOR ARGENTINA*

by Osvaldo E. Baccino

The reorganisation process that took place in the electricity sector in Argentina in the nineties implied an increasing degree of decentralisation and privatisation in the market. Pari passu, there came up a growing need to improve the conditions of optimisation through time. More flexibility was introduced by new clauses in forward contracts and by gradual changes in the admission of participants in the wholesale market. However, these modifications were not sufficient to satisfy a demand for efficient hedging from agents who trade in a market with large size transaction. The newer risk-sharing clauses included in the forward contract were still rigid.

This paper aims to examine the conditions of the electricity market in the mid-1990’s for the establishing of an option and futures market on electricity¹. Then, the evolution of spot prices in the following years was analysed to see if the conclusions arrived at before, were still holding. The analysis was mainly based on the spot price evolution and in the evaluation of equivalent contracts to some already existing. The equivalent contracts are synthetic transactions consisting of individual option contracts, both call and put, which reproduce the original contract and reflect explicitly the cost of hedging.

The outcome gives some answers to the following issues:

(a) Is the electricity market functioning of Argentina compatible with option and futures market based on that commodity?

(b) If option and futures were introduced, how would present trade appears in value terms? How big are costs of hedging? Actual electric forward contracts, in the wholesale market, are presumably valuing risks in an inefficient way because of the lack of an appropriate instrument to hedge against price volatility. How measuring the hedging costs of the existing forward contracts?

Nowadays there is a broad experience in the world about the functioning of risk-sharing instruments, both on financial and physical assets. Moreover, there is important evidence regarding establishing energy futures markets. Nevertheless, the conditions of generation and provision of electricity depend heavily on the particular organisation of the system. The organisation differs from country to country, and the market behaviour is at the end constrained by the local system. Under these circumstances, the questions outlined above are always up to date.

Deregulation causes more flexible trading

In many countries, the tendency to consider explicitly time in the transactions for energy products aimed to establishing a futures market. This was first verified in the case of petroleum and natural gas. The New York Mercantile Exchange, one of the world largest exchanges of futures, launched a heating oil futures contract in 1978 and option contracts on crude oil futures in 1986. The experience in electricity is more recent; it is being carried out mainly in the second half of the 1990's. In many places, this process took different forms, such as the introduction of new types of limited-risk-contracts or a direct evolution towards futures and derivative markets. In Europe, the profound reorganisations of the electric sector, like in the United Kingdom, Norway, Sweden, Netherlands, and so on, had impact in the modalities of trading². Nonetheless, in certain cases the process went farther up to definitely establishing some futures markets for the electricity as it happened in the U.S.A. with the NYMEX.
Another world centre of oil futures trading is the International Petroleum Exchange (IPE) in London. Gas oil futures trading started in April 1981. However, even when Great Britain succeeded in establishing one of the most important markets for energy futures of the world, the development in the electricity trade did not end in a futures market. In the UK there was an important experience with the contracts for differences. They were of different classes, such as one-way or two-way; with maximum-take clause or minimum-take clause. The latter refer to the number of exercises of options involved in the contract. The electricity forward agreement (EFA) is an over-the-counter scheme to trade standardised two-way contracts for differences.

The evolution toward the establishment of an electricity futures market seem to have different forms according to countries. Each experience looks different from the other, owing to the diverse systems of operation of the electricity sector under the prevailing regulatory scheme.

Option and futures contracts

There are many ways of introducing risk-sharing instruments in the electricity trade, but it is important to make clear the final goals where the actions should be aimed at. Those goals are the establishing of an organised exchange for option and futures trading. Therefore, it is convenient to refresh some characteristics of these instruments. The formulas for evaluation of option contracts to be used in this work are the usual ones developed by Black and Scholes (1973). See also Galitz (1994).

A futures contract is an agreement between two parties by which one is committed to buy (or sell) a given quantity of a commodity at a given price at a future date. The futures contract is settled every day and is rewritten at a new future price. As a consequence of that the daily change in price is debited or credited on the accounts of both buyer and seller. This is called a margin deposit. If the futures contract appreciates on the day, the difference in price is credited on the buyer's account while this difference is simultaneously debited on the seller's account. The change in the futures prices are cumulative with the corresponding sign. At the expiration of the contract the futures price always equals the current spot price of the commodity. Then the operation is settled at the spot price plus the balance on account of both parties. If both buyer and seller wait until expiration they will have paid and received the futures price agreed at the beginning. During the life of the futures contract any party can cancel it by selling or rebuying the futures for the same quantity of commodity at the ruling futures price. The balance on his account then reflects the gain or loss of the cancellation.

An option contract is an agreement to buy or sell a given quantity of a commodity at a given price (strike) at a future date. The holder has the right to exercise the option under the terms of the contract according to his convenience. For the sake of simplification only European option contracts will be considered. These contracts can only be exercised at maturity date. At the beginning of the contract the value of the option must be paid by the holder to the writer or seller of the contract.

There are different ways to explain the value of an option. One of them, can be derived from the properties of the log-normal function underlying in the Black & Scholes approach. The price of an option contract can be understood, in intuitive terms, as follows: the value of a call option \( w^C \) equals the present value of the difference between the expected market price of the underlying commodity and the strike price at expiration, multiplied by the probability that the spot price of the commodity exceeds to the strike price.

\[
w^C = \text{Prob}[P_T > K] \cdot e^{-r\Delta t} \cdot [E(P_T|P_t > K) - K]
\]  

(1)
where \( P \) is the commodity price; \( K \) is the strike or exercise price; \( r \) is the riskless rate of interest; and \( E \) is the symbol for mathematical expectation. The value of a put option, \( w_P \), equals the present value of the difference between the price of exercise and the expected price of the commodity at maturity, multiplied by the probability that the price of the commodity is lower to the strike price at expiration time.

\[
w^P = \text{Prob}[ P_t < K] \cdot e^{-r\Delta t} \cdot (K - E[P_t \mid P_t < K])
\]  

(2)

Hedging can be made by just buying or selling option contracts, or combined with transactions in futures and cash operations.

An electric option market should trade with options on electricity futures instead of the physical commodity. The underlying asset is an electricity futures contract. The evaluation model has to be adapted to these conditions.

In the B&S approach the stochastic behaviour of commodity prices follows a Markov process where only the present value is relevant for predicting the future. The Markov property in the stochastic behaviour of prices is consistent with the weak form of market efficiency. Within the present study this assumption will be maintained. Most of the interest in testing whether market efficiency hypothesis is applicable derives more frequently in the analysis of other markets such as the stock prices, where uncertain changes effect investor's decisions. By the way, as far as the electricity market in Argentina is concerned, there is no futures prices data, therefore the only possibility is the calculation of futures prices based on the study of spot prices of electrical energy.

Before explaining the treatment of option pricing applied to the electricity market of Argentina, it is convenient to have in mind some basic relationships between the price of the commodity and the price of futures contract on that commodity as follows from the usual literature on the subject. For particular aspects of derivatives pricing and its relationship with Black and Scholes model, see, R. McDonald and D. Siegel (1984), G. Barone-Adesi and Robert E. Whaley (1987), Lawrence Galitz (1994), and John Hull (1999)

The arbitrage relationship between futures prices \( F_t \), and spot price \( P_t \) can be described as

\[
F_t = P_t e^{rs} - \rho(s)
\]  

(3)

where \( s = T-t \), \( T \) is the expiration date of the futures contract, \( r \) is the rate of interest and is the rate of convenience yield. Therefore, the convenience yield rate explains the difference between today's value of electricity spot price and the present value of the electricity futures price. In the equation (3) the periodic cy is summed over the life of the contract up to expiration. The existing cyclicity of the electricity markets makes the cumulative cy a function of time, which is denoted as \( \rho(T-t) = \int_c^T cy(t) dt \). Given the date of maturity \( T \), \( t \) defines the starting point to sum convenience yield rates.

Let the spot price of electricity \( P_t \) follow a log-normal diffusion process with a known variance rate.

\[
dP/P = \mu dt + \sigma dz.
\]  

(4)

Since the futures price \( F \) is a function of spot price and of time, and according to Ito's Lemma,
\[ dF = \left[ (\partial F / \partial P) \mu P + (\partial F / \partial t) + 0.5 \left( \partial^2 F / \partial P^2 \right) \sigma^2 P^2 \right] dt + (\partial F / \partial P) \sigma P dz \]  

(5)

By taking derivatives from equation (3) and substituting them with (3) into (5), and dividing both sides by \( F \),

\[ \frac{dF}{F} = [\mu - r + (\partial P / \partial t)] dt + \sigma dz \]

(6)

The underlying asset, that is, the futures price, analogously to the spot price, follows a diffusion process affected by similar underlying source of uncertainty. The rate of return provided by \( F \) in a short segment of time is described by equation (6), where \( F \) is the price of the futures, the expression between brackets is a drift term including the expected rate of return plus the marginal convenience yield rate minus the interest rate, and \( z \) is a Wiener process. On the other hand, the change in the futures price, that is, \( dF \) follows an Ito process.

In view of predictable seasonal behaviour in the spot price of electricity in Argentina, it seemed more reasonable to consider as volatility the random variation in returns. The cyclicity makes the cumulative convenience yield for a given life of a futures contract to change with changes in \( t \).

\[ (t) = \int_1^{t+k} \text{cy}(t) dt \]

(7)

where \( k \) is the time length of the futures contract. Here, \( k \) is assumed to be invariant, so \( F \) denotes the futures price with term \( k \). The monthly change in the cumulative convenience yield between \( t-1 \) and \( t \) is denoted as \( \Delta P = \rho(t) - \rho(t-1) \). Therefore, the return rate on futures equals the return rate measured by spot prices minus the sum of convenience yield during the life of the contract.

\[ \ln(F_t / F_{t-1}) = \ln(P_t / P_{t-1}) - [\Delta P] \]

(8)

The interest adjustment affects in the same manner both numerator and denominator, then it is cancelled in equation (8). If \( f = \ln(F_t / F_{t-1}) \) and \( p = \ln(P_t / P_{t-1}) \), the relationship between their variances is the following:

\[ \text{Var}(f) = \text{Var}(p) - 2\text{Cov}(p, \Delta p) + \text{Var}(\Delta p) \]

(9)

If the sum of convenience yield for a contract term of \( k \) is constant through time,

\( \Delta p = 0 \), then \( \text{Var}(f) = \text{Var}(p) \). This is the usual case conceived in the financial market with constant exponents in equation (3) where the volatility of futures coincides with the volatility of spot prices\(^5\). If \( \Delta p \) is positive or negative, or changing the sign with cyclical movement, the variance of futures prices will differ from that of the spot price. Here plays an important role the covariance. The existence of a cycle excludes the possibility that the \( \text{Cov}(p, \Delta p) \) be zero. The relationship between the variances of \( f \) and \( p \) depends on the particular phase of the cyclical movement and the shape of the convenience yield function. The findings of Fama and French (1988) and Serletis and Hullemen (1994) regarding the relative variation of spot and futures prices concerning convenience yield and inventory levels for commodities like metals and oil products, are very helpful to understand the case of electricity. Even when in the electric market there is no room for storage and inventories. Nevertheless, it is very important the role of convenience yield, and the cycle of electric prices can be explained by periodical abundance and shortage of inputs and characteristics of the demand for energy.
The electricity market

Nowadays, the typical instrument of trade with electricity at wholesale level is the forward contract, so it was before and it continued being after taking place the reorganization of the sector. The forward contract is an agreement between a buyer and a seller of power to trade a given quantity of physical commodity at a future date at a fixed price.

At the moment of the reorganisation of the electricity sector, prevailed long term forward contracts. Later, some gradual flexibility was introduced by allowing to purchase energy through forward contracts with shorter terms and including clauses with bands of variation in the levels of the spot prices. At maturity the spot price was accepted if it was within the agreed band. These ways of dealing allowed to put some limits to the risk of fluctuation in the spot price. However, the ability to manage risk was still very constrained. The economic agent was forced to find a counterpart with opposite needs with whom to share the risk under the shape of a particular forward contract. A forward contract cannot be transferred as it can happen with a futures contract (see Black, 1976). Whether it should be replaced by another contract, then it would have to be dissolved by agreement and a new contract should be created.

If a futures market were available, a broad range of trade could be conceived. The futures market allows the participant to go long or short, that is, changing positions, by buying or selling futures contracts at any time. At the end, the ultimate buyers and sellers of electricity will trade the physical commodities, but in between, a large number of transactions in futures will take place. These operations allow the participant to benefit from managing their risks with the possibility of sharing them with other parties with inverse risk profiles. On the other hand, trade in options, either call or put, allows hedging against certain price movements, while the holder may take advantage of favourable movements in the spot market.

It is convenient to aim to an organized market, where the underlying asset for an electricity option should be a futures contract. This gives much more flexibility to transactions since deliveries can be easily compensated. An organised market for futures, as opposed to "over-the-counter" trade, provides safer and cheaper costs of transactions. This results in making risk-sharing instruments liquid and accepting a larger volume of transactions.

Now, the Wholesale Market of Electricity (MEM) channels the purchasing and selling of electricity among generators in the market, distributors and big users for the sale of energy in blocks. Power is traded in the spot market, and mainly upon the basis of forward contracts. By means of this instrument the supply of energy for a period is accorded, either upon the basis of a scheduled time curve or by committing the supply of the whole demand. As mentioned above, the agreements have caps and floors with respect to energy prices. The contract also includes the conditions of providing contingent power backing. This service consists of the guaranteeing the availability of supply in case of unforeseen interruption of delivery due to failing equipment. This service naturally has a price.

In Argentina there is an important spot market, where electricity is continuously traded. The electricity that is not provided from own equipment because it was not dispatched by the Grid Administrator (CAMMESA) must be bought in the spot market to honour the forward contracts. The dispatching of electricity is carried out upon the basis of the order of merit of costs of the generating teams whatever the existence of forward contracts. Finally the enforcement of the forward contracts is achieved through the spot market. The system of dispatching by order of merit assures a wide spot market functioning, thus providing the basis of the marginal cost pricing mechanism6.
Actual contracts expressed in terms of options

Some limited risk-forward contracts were taken as examples of transactions. Their conditions were replicated by constructing equivalent transactions by using option contracts. The replication was made on the following terms: A forward contract fixes a price of the commodity. An equivalent transaction by using option contracts implies that the buyer of electricity purchases a call option to have an upper limit to the electricity price; and simultaneously, the same person sells a put option to the electricity supplier. As a result, the buyer of electricity becomes a holder of a call option while the supplier becomes a holder of a put option. This simultaneous position minimizes the costs of hedging \((w^C-w^P)\) for the holder of the call. The sign of this difference becomes a cost for the buyer of electricity if it is positive or a cost for the supplier if it is negative. The equivalence with the ordinary forward contract rests on the fact that the strike prices are the same in the two options, other things being equal.

Since the forward contracts considered had caps and floor prices, thus creating a band of variation for the price of electricity, then the strike prices had to be different. Their levels were taken from the caps and floor of the original contracts.

Three actual contracts involving the purchase of electrical energy were chosen to be transformed into equivalent transactions based on option contracts\(^7\).

Each transaction can be expressed as a set of option contracts with different duration, all starting at the same time but expiring at a different day. For the sake of simplicity, monthly blocks were considered to average the premium cost of daily options. The expiration date of each block was considered at the middle of each month.

The value of every monthly option contract, both call and put, corresponded to the volume of energy traded in the course each month.

The options are European, the riskless annual interest rate was 12%, and the annual volatility rate 33.6%. Both interest and volatility of returns rates were assumed constant during the length of the whole transaction. For the sake of simplification, only normal delivery of energy was considered. The service of guaranteeing further backing was neglected.

Those contracts having 25% participation in gains when the spot price is outside the band of variation, were considered as to be covered by options in the 75% of the value of traded power.

<p>| TABLE 1. Main Characteristics of Actual Forward Contracts Used in the Evaluation |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Terms of Reference | TRANSACTION X1 | TRANSACTION X2 | TRANSACTION X3 |
| Type of Contract | risk-limited forward contract | risk-limited forward contract | risk-limited forward contract |
| Terms of Delivery | 1 May '94 - 30 Apr '95 | 1 May '94 - 30 Apr '95 | 1 May '94 - 30 Apr '95 |</p>
<table>
<thead>
<tr>
<th>Total Quantity of Energy</th>
<th>43,800 MWh*</th>
<th>18,126.2 MWh**</th>
<th>50,307.4 MWh***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Power: 3,600 $/MWh/month</td>
<td>Monomic Price: 34.89 $/MWh (It includes energy price plus 5.19 $/MWh for Power)</td>
<td>Monomic Price: 34.89 $/MWh (It includesenergy price plus 5.19 $/MWh for Power)</td>
</tr>
<tr>
<td></td>
<td>Energy: 31 $/MWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price limits</td>
<td>Cap: 34 $/MWh</td>
<td>Cap:34.16 $/MWh</td>
<td>Cap:34.16 $/MWh</td>
</tr>
<tr>
<td></td>
<td>Floor:29.5 $/MWh</td>
<td>Floor25.50 $/MWh</td>
<td>Floor25.50 $/MWh</td>
</tr>
<tr>
<td>Compensation</td>
<td>If P &gt; 34.16 The supplier gets the 25% of the difference. If P &lt; 25.50 The buyer gets the 25% of the difference</td>
<td>If P &gt; 34.16 The supplier gets the 25% of the difference. If P &lt; 25.50 The buyer gets the 25% of the difference</td>
<td></td>
</tr>
</tbody>
</table>

* Electricity was supplied according to a given average hourly power ruling for each month
** Average hourly power are different for working days, Saturdays, Sundays and holidays. They are no uniform for every month. The volume of power supplied had to be estimated month after month.
*** The volume of energy had to be estimated by averaging different hourly power rates, taking into account working days, week-ends and holidays.

Sources: ENRE-CAMMESA

The simplifying assumptions produced equivalent transactions which depart from the original transactions. However, this did not bias the scope of the intended comparison in terms of costs of hedging. This characteristic can be understood as the use of only part of the original contract just for comparison with operations with explicit hedging costs.

**Adaptation of the option valuation to the electricity case**

The application of the evaluation instruments like B&S model must take account of the specific market for the physical commodity, particularly when no futures market for that commodity exists. The spot price data used to evaluate options has to be adjusted by convenience yield and the volatility has to be purged from the variability due to predictable behaviour of the return series.

If a market of futures for the electric power existed, option contracts could be priced by applying the adequate Black & Scholes formula to the market future prices. In Argentina there is no futures market for electricity, thus option pricing requires the calculation of a shadow futures price for the term of the option contract valued at the beginning of the contracts for each option block.
In the literature about futures the difference between a futures price at time t, for delivery at time T and the spot price at time t, the basis, is dependent on the interest forgone during storage, plus warehousing cost, minus the marginal convenience yield (see A. Serletis and V. Hulleman (1994)). In the electricity case, storage plays no significant role, but the existence of seasonals in the availability of certain resources, like water for example, is associated with recurrent variations in the spot price. This situation prevents the usage of current spot prices in the formula of option pricing. In other words, it is not correct to adopt mechanically for the electricity market, the methods of evaluation of financial assets or other physical commodities with different market behaviour.

Along time, futures and spot prices of electricity generate the occurrence of phenomena like 

\textbf{backwardation} [negative basis] and \textbf{contango} [positive basis]. Nowadays there is no futures market for electricity in Argentina, so these cases cannot be measured. However, if for analytical purposes option prices must be evaluated, then some futures prices or some kind of adjustment on the spot prices, should be estimated. The method applied in this paper was the introduction of the adjustment of spot prices at the beginning of the complete operation by a \textit{convenience yield rate}. The \textit{convenience yield rate} explains the difference between the today's value of electricity spot price and the present value of the electricity futures price. That is, the interest-adjusted basis equals the convenience yield with the changed sign.

When no futures market exists the convenience yield rate should be calculated, both to adjust the spot price to be used in B&S formula with spot prices or to compute directly the futures prices entering the B&S formula for futures prices\textsuperscript{8}.

The pricing of the option contract was calculated by applying the Black\& Scholes formula. There are two ways to apply the formula: (i) If futures prices are available there is a version of B&S equivalent to using the present value of the futures contract at t=0, discounted at the riskless interest rate; (ii) When no futures prices are available the usual B&S is applied to the spot price of the commodity adjusted by the cumulative rate of convenience yield. Finally (ii) was chosen in this study.

The alternative (i) \( w^c = F_t e^{r(T-t)}[N(d_1) - K N(d_2)] \) for a call option price, where 
\[
d_1 = \frac{\ln(F_t/K) + 0.5 s^2(T-t)/s\sqrt(T-t)}{s\sqrt(T-t)} \quad \text{and} \quad d_2 = \frac{\ln(F_t/K) - 0.5 s^2(T-t)/s\sqrt(T-t)}{s\sqrt(T-t)}; (10)
\]

The alternative (ii) \( w^c = P_t e^{-\rho(T-t)}[N(d_1) - Ke^{-\rho(T-t)} N(d_2)] \), where 
\[
d_1 = \frac{\ln(P_t e^{-\rho(T-t)}/K)e^{\rho(T-t)} + 0.5 s^2(T-t)/s\sqrt(T-t)}{s\sqrt(T-t)} \quad \text{and} \quad d_2 = \frac{\ln(P_t e^{-\rho(T-t)}/K)e^{\rho(T-t)} - 0.5 s^2(T-t)/s\sqrt(T-t)}{s\sqrt(T-t)}.
\]

The main symbols are: \( F_t \) = Futures price at t for a transaction with maturity at T; \( K \) = strike price; \( s \) = volatility rate; \( P_t \) = spot price at t; \( r \) = riskless interest rate; and \( \rho(T-t) \) = cumulative convenience yield in period T-t. Here \( \rho \) is a function of T-t.

In the evaluation of electric options for Argentina the estimate of volatility was done according to the methodology followed by the work of Olmsted Teisberg and Teisberg (1991) on natural gas. The volatility rate is considered as the standard deviation of the changes in the rate of return around the deterministic seasonal level of returns. Here volatility does not include deterministic variation.
Estimate of the convenience yield

Estimates of volatility and rates of convenience yield were made upon the basis of electricity spot price data for the period August from '92 to June '94. Daily prices were averaged at monthly level. In order to use B&S formulas rates are continuous.

The observed rates of change in spot prices (rates of return) were fitted by OLS for seasonal influences (quarterly) spring, summer, fall, and winter as dummies and trend. Finally, the trend was neglected due to low significance of the corresponding coefficient. The rate of volatility was measured by the standard deviation of the estimate\(^9\).

The data used in the regression estimate was monthly and three dummies were inserted to repeat their values for each month included in every season. This was done so to save degrees of freedom.

The dependent variable was \(\ln(P_t/P_{t-1})\), where P's are the spot price of electricity in two consecutive periods.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Coefficient</th>
<th>t statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer (D-J-F)</td>
<td>0.17573</td>
<td>3.104695</td>
</tr>
<tr>
<td>Autumn (M-A-M)</td>
<td>0.13243</td>
<td>2.339627</td>
</tr>
<tr>
<td>Winter (J-J-A)</td>
<td>0.04794</td>
<td>0.757498</td>
</tr>
<tr>
<td>Constant (S-O-N)</td>
<td>-0.13022</td>
<td>-3.25355</td>
</tr>
</tbody>
</table>

\(R^2 = 0.389571; \ F (3,18) = 3.829; \ \text{Std error. Est.} = 0.098036;\)

Degrees of freedom = 18; N Obs.= 22;

Therefore, monthly price volatility is measured by the standard error of the estimate. The annual volatility rate is 33.96%, computed as 0.098036 x \(\sqrt{12}\). Thus, volatility was estimated by leaving apart the variation caused by seasonals. The rate of volatility was assumed to be constant when pricing the option contracts. Later on, the adequacy of this assumption is empirically justified.

On the other hand, the rates of convenience yield reflect the influence of the seasonal variations in the price of electricity. No significant trend in the rate of change of spot prices was detected. Therefore, this estimate of rates of convenience yield is only determined by the seasonal factor.

For the sake of simplicity, it was assumed a uniform monthly rate of convenience yield in each season. Then deviations of the seasonal rates of return were calculated for every season with respect to the overall mean. These deviations were reversed in sign, thus expressing monthly convenience yield rates for each season.
Monthly rates of Convenience Yield

<table>
<thead>
<tr>
<th>Season</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>-0.0867</td>
</tr>
<tr>
<td>Autumn</td>
<td>-0.0434</td>
</tr>
<tr>
<td>Winter</td>
<td>0.04109</td>
</tr>
<tr>
<td>Spring</td>
<td>0.08903</td>
</tr>
</tbody>
</table>

The reversal in sign means that the expectation of an increase in the electricity price implies a decline in the convenience yield for electricity. In other words, between $P_t$ and $F(t,T)$. If there is positive seasonality in the expected rate of return, then the convenience yield rate is negative. Therefore to use B&S formula $P_t$ should be increased (by discounting by a negative cy). Conversely, if the expected seasonality is negative, the convenience yield is positive, and the spot price is reduced by discounting by a positive cy. This is the treatment above mentioned as alternative (ii). It consists in valuing options with futures as underlying asset but using the B&S formula with spot prices.

**Evaluation of options**

For expository reasons the year was divided into twelve months, in the middle of which an option contract block was supposed to expire. In the tables 1.A, 2.A, and 3.A (See Annex), are shown the values of call and put option contracts with the corresponding quantity of electricity involved. The tables also include the net premium-cash flow at time zero. From the side of the electricity buyer a positive net premium means a cost of buying hedging and a negative net premium is a revenue for providing hedging to the supplier of energy. The converse holds for the electricity seller.

The electricity trade contracts X1, X2, and X3, show some interesting features, as follows: At the initial moment, 30th April, the spot price of electricity was 31.66 US$/MWh. On that day, the estimate of futures prices, $F(0, T)$ are the following:

**TABLE 2  Estimated futures price at 30th April 1994**

<table>
<thead>
<tr>
<th>Month of Maturity</th>
<th>Futures Price</th>
<th>Month of Maturity</th>
<th>Futures Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>May '94</td>
<td>32.50</td>
<td>Nov '94</td>
<td>24.86</td>
</tr>
<tr>
<td>Jun '94</td>
<td>32.85</td>
<td>Dec '94</td>
<td>25.06</td>
</tr>
<tr>
<td>Jul '94</td>
<td>31.82</td>
<td>Jan '95</td>
<td>27.59</td>
</tr>
<tr>
<td>Aug '94</td>
<td>30.83</td>
<td>Feb '94</td>
<td>30.36</td>
</tr>
<tr>
<td>Sep '94</td>
<td>29.16</td>
<td>Mar '94</td>
<td>32.71</td>
</tr>
<tr>
<td>Oct '94</td>
<td>26.92</td>
<td>Apr '94</td>
<td>34.48</td>
</tr>
</tbody>
</table>

The expiration terms for options used in the B&S formula were: 15, 45, 75, 105, 135, 165, 195, 225, 255, 285, 315 and 345 days.
The comparison between the original forward transaction of energy and the exchange of option contracts, show that a cash balance should have been paid by one party to the other. In the original transaction that payment did not take place. Therefore, the services of hedging were not properly evaluated. Furthermore, it might happen that some party took excess hedging without payment and without ever knowing about it. The caps and floors established for all the length of the transaction in a context of important seasonality implied excess coverage at certain times. In the equivalent transaction, the maintenance of constant strike prices during the year means disregarding of the predictable fluctuation in spot prices and this necessarily created an excess cost of hedging. The operation of simultaneous holding and writing options tended to compensate these costs, but still the excess hedging would be reflected in the net premium.

Contract X1, with strike prices K1= 34 for call and K2= 29.5 for put options generated a net revenue of US$ 52,134.40 for the customer of electricity. This revenue reflects that the produce of his sale of put options outweighed the cost of hedging against rises in prices. The opposite, happened to the electricity supplier. When one looks at the original forward contract, immediately has the feeling that somebody lost a gain and the other party was lucky as not to pay for it. The operation with derivatives shows clearly the cost of hedging. Another point, is to know whether there was a better strategy to manage risk. Of course, there was. However, the aim of this paper was to present the comparison between a forward transaction and an equivalent in terms of options. The way to improve the terms of the operation is a matter of further study and it is beyond the scope of this paper.

If the evaluation for X1 were made with a different strike, say K1=31, the gains of the electricity buyer had declined to US$ 11,312.70. This estimate shows the degree of sensitiveness of the evaluation.

Contract X2, with K1= 34.16 and K2= 25.25, implied a net cost of US$ 2986 for the electricity buyer and a revenue for the supplier.

The Contract X3, with similar strike prices as X2, resulted in net cost of US$ 10,725.20 for the buyer of electricity. The last two cases reflect situations where electric suppliers gave free net-risk-coverage to buyers. While the first case, the buyer gave it free to the supplier.

The tables in the Annex present the details about the values of the option contracts, the net payments between parties, and the amount of energy traded and the variation in premiums. The influence of cyclical behaviour in the spot prices can also be detected in the futures prices presented above.

These exercises lead to the conclusion that a forward contract with caps and floors may be better than older types of forward contracts, but it is still very rigid with respect to operating with derivatives. The latter offer more flexibility in changing strategies, or in being tied up with a forward contract, there are many other complementary transactions in futures and options that may compensate possible losses derived from the forward contract.

Moreover, the evaluation of hidden hedging costs in contracts X1 X2 and X3 can be understood as an evidence of the rigidity of the forward contracts. The absence of a market of futures sets obstacles to the availability of market information to allocate resources through time. The maximum and minimum prices introduced in forward contracts result in implicit hedging costs of difficult evaluation at the beginning of the operation.

As a matter of interest, a call and a put option exchange, obtained from X1, were chosen to express the respective premiums in terms of mathematical expectations and probabilities [as denoted in equations (1) and (2) above]. Both options mature at December 1994. The
adjusted spot price at t=0 was 23.37; the maturity period was 225 days; and the strike prices were K1= 34 for the call and K2=29.5 for the put.

<table>
<thead>
<tr>
<th>Estimates</th>
<th>Call Option</th>
<th>Estimates</th>
<th>Put Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>premium/MWh</td>
<td>0.53093</td>
<td>premium/MWh</td>
<td>5.258815</td>
</tr>
<tr>
<td>Prob[P_t &gt; K]</td>
<td>0.09761</td>
<td>Prob[P_t &lt; K]</td>
<td>0.772091</td>
</tr>
<tr>
<td>exp(-r\Delta t)</td>
<td>0.932524</td>
<td>exp(-r\Delta t )</td>
<td>0.932524</td>
</tr>
<tr>
<td>E[P_t</td>
<td>P_t &gt; K]</td>
<td>39.8352</td>
<td>E[P_t</td>
</tr>
</tbody>
</table>

With these values the equations (1) and (2) can be verified. Analogously this could be made for the rest of option contracts included in the three operations considered in this paper. The example depicts an interesting fact: at first glance the B&S formula seems to evaluate options without appealing to an expected price at expiration of the contract. Nonetheless, there is an implicit expected price in the functioning of the formula. This is the average expected price conditional to the expiration of the contract "in-the-money." This becomes explicit when the log-normal probability density function of the price is openly considered. In the B&S the log-normal function is assumed when the formula is derived.

For the sake of simplification, the European type of option was assumed to evaluate the forward contracts. In NYMEX options are usually of the American type.

**Why is possible having an electricity futures market in Argentina?**

The conditions of Argentina in 1994 were already appropriate for the establishing of a futures market. This could be noticed after examination of the wholesale electricity market concerning the general requirements of the NYMEX. At this point, the evidence considered corresponded to the data available in 1994. In addition, references will be made about later trends of the situation.

**Price Volatility:** NYMEX considers a minimum annual volatility of 20% as a requirement for any physical commodity. The study on Argentina showed 34% in 1994. The monthly volatility measured by the standard deviation of the estimate was 0.098036 and this times the square root of twelve gave the annual volatility of 33.96%.

**Demand and Supply Uncertainty:** NYMEX requires at least 10% variability per annum traded energy. In Argentina, changes in the quantity of electricity traded in the spot market at marginal cost (Feb92-Nov94) showed a monthly volatility of 9.6% and an annual rate of 33.1%. On the other hand, if the computations were made with Feb92-Nov94 data of energy traded in the grid plus the Patagonia system, the monthly quantity volatility was 0.077103, and the yearly volatility amounted to 26.7%.

**Deliverability of the commodity:** From the point of view of a centralized market, electricity in physical terms, (kWh), can be conceived as a commodity being delivered in the load centre of the grid system (Ezeiza node). In this way, the transport costs to particular users' locations can be separated from the centralized wholesale trade market.

**Product homogeneity:** Electricity is homogeneous and can be standardised in blocks. The considerable diversity of situations regarding supplying conditions such as peak and valley
hours, week-ends, etc. requires an operational standardisation in blocks, and the corresponding definition of price for the block.

**Availability of price information and trading opportunities:** This is a condition depending upon the degree of organization, efficiency and transparency of the spot market. Now, the existing wholesale electricity market working in close connection with the spot market under the system of order of merit, provides the basis to fulfill this condition.

**Competitiveness in the Spot Market:**

In the mid-nineties the wholesale trading market in electricity included about 30 generating firms, a similar number of distributors, and over 70 big users. Later, more flexibility was introduced in the regulatory system and smaller users were allowed to purchase electricity directly from generating suppliers. Nowadays, there are 44 suppliers and about 2000 buyers. In fact, the number of participants was enlarged. This increased the degree of competitiveness. Buyers are accepted in the wholesale market with minimum purchases of 30 kW. No doubt, the increase in the number of participants both on the side of demand and supply makes the market more competitive.

**Volatility through time**

So far, the analysis was kept within the boundaries of the Black and Scholes approach to option pricing. In that context both rate of interest and return volatility was considered invariant along the life of the contract. There are many known reasons for maintaining those assumptions while evaluation. Nonetheless, it is necessary to know the actual evolution of volatility, particularly in the period that followed the sample used in the evaluation.

Next step is to know the way volatility behaviour influences the conditions for the establishment of a futures market. An important issue is detecting the response of volatility to new information accruing to the market. Further on, it also will have some implications whether market efficiency holds for electricity.

After 1994, in Argentina took place many changes in the institutional behaviour of the electricity wholesale market. New participants were allowed to come to the market, such as some buyers with a smaller amount of electricity demand, and particularly a new role got in.
That was the trader. This is an agent that goes between the supplier and users of electricity. The increase in the hydroelectric generation and the opening of the international trade of electricity with neighbour countries, These events may surely have effects in the spot price behaviour, and necessarily open new questions about the feasibility of establishing a futures market.

Now, the examination is centred on the monthly changes in volatility during the period October 1992 and April 2000. Unfortunately, it was not possible to get a spot price series corresponding only to the provision of energy alone. A monomic price series was used because CAMMESA presents prices of energy by groups of hours within a day, and the construction of a consistent single-price series required an arduous elaboration. The monomic price brings together the price of energy and the price of power reserve. The price of power reserves usually remains constant during given periods, and represents a fixed amount per MWh. However, within the whole period under examination there were some discontinuous changes in the price of power reserve. Therefore, for the period 1992-2000, the volatility evaluation was calculated based on the monomic electricity price.

Here, volatility was estimated in a similar way as in the previous part of the study. That is, by a regression of the logs of price relatives against a constant and three dummy variables corresponding to summer, autumn and winter, as before. However, this time an-impulse-dummy was introduced to contemplate unusual price behaviour like it happened in June and July in 1996 and 1999. Sometimes unusual weather conditions take place, mainly in
winter, and thermal generators do not have enough liquid fuel to replace a shortage of natural gas. With this information, it is important to see how volatility moved through time.

The analysis starts with the assumption that volatility is a stochastic variable. Then, GARCH (1,1) model was computed in order to describe the dynamic movement of the conditional variance of the residuals obtained from the fitted returns on electricity against seasonal influences. The volatility rates derived from the model are displayed in the Figure 1.

The model computed is,

\[
\text{GARCH}(1,1) \\
\sigma_t^2 = 0.005173 + 0.292833 \sigma_{t-1}^2 + 0.329125 \sigma_{t-1}^2
\]

where \( \sigma_t \) is the variance of residuals at time \( t \) and \( \sigma_{t-1}^2 \) is the squared residuals at time \( t-1 \). The long-run variance associated with this estimate is 0.013685, implying a long-term monthly volatility of 11.70% and an annual rate of 40.52%. This value is not very far from the annual volatility adopted in the evaluation of contracts (33.96%).

The volatility displayed in Figure 1 shows two huge spikes in the years 1996 and 1999. These sharp fluctuations are also related to the unusual behaviour commented above.

Obviously, the GARCH model assumes that volatility is changing through time. It moves oscillating around the long term level. Next step is to test the degrees of autocorrelation existing in the series of squared errors and that corrected by the GARCH estimates of variance. The Ljung-Box test \( Q^*(k) \) where \( k \) is the lag of the autocorrelations shows the following results:

At first sight, the null hypothesis of no autocorrelation for the squared residuals \( \sigma_t^2 \) cannot be rejected, \( Q^*(20) = 25.93 \) for \( \sigma_t^2 \) and \( Q^*(20) = 16.89 \) for \( \sigma_t^2/\sigma_t \) with \( k=20 \) and \( T=91 \). The critical \( \text{CHI}^2(20) = 31.41 \). However, up to lag 3 the null hypothesis is rejected and autocorrelation in the squared residuals must be accepted. For instance, for \( \sigma_t^2 \),

\[
Q^*(1) = 4.42 \quad \text{and CHI}^2(1) = 3.84; \quad Q^*(2) = 8.46 \quad \text{and CHI}^2(2) = 5.99 \quad \text{and Q}^*(3) = 8.53 \quad \text{and CHI}^2(3) = 7.81.
\]

For \( \sigma_t^2/\sigma_t \), the test cannot reject \( H_0 \). So corrected by the modelled variance the autocorrelation disappears.

However, the larger the lag \( k \), lower autocorrelation coefficients obscure the existence of very significant cases at smaller values of \( k \) (See, Cuthbertson, Hall and Taylor (1992)p.111). Therefore, in the short period, with lags of 3 or less, volatility can be forecasted.

Volatility is affected through time by shocks of new information. News is influencing residuals \( \sigma_t^2 \). In financial markets, there are several approaches to measure asymmetrical impact of "good" and "bad news." R. F.. Engle and Victor K. Ng (1993) analysed different models of evaluation of impact of news on volatility. This opens the field for further study in the electricity market. In electricity, "good" and "bad" impulses derived from the combination of weather factors and inventories of fuel or water to keep up with production influence volatility. The substitution of certain fuel for another find resistance in the level of inventories. In this sense, "new information" may refer to different state of affairs. The impact might be
asymmetric and this implies the utilization of other types of model, say EGARCH, to model volatilities.

The electricity market of Argentina, shows persistence in the range of variation of volatility computed from the monomic spot price, with exception of two unusual fluctuations recorded in the middle of 1996 and 1999.

There is evidence of changes in volatility in the short run, and the model computed is good in reflecting these movements. Nonetheless, the assumption to keep a constant volatility rate for a long term operation seems on the average to be justified. That is, the maintenance of the Black and Scholes model used in the evaluation of forward contracts. The favourable conditions, as far as price volatility is concerned, holds beyond the period sampled for the contract evaluation.

**Market efficiency**

The idea that a market is usually considered efficient in the literature if information comes to the market as a series of shocks. Here come the properties of Markov's process mentioned earlier and implicit in B&S model. Under these circumstances, current prices collect all the information available at the time (Bird (1987); Serletis (1991)). Therefore, futures prices and option contracts, become efficient signals to allocate resources through time, provided they reflect all the available information.

The weak condition for market efficiency requires that the price of the underlying commodity, either a physical commodity or a futures contract, in its level or expressed in logarithms, to follow a random walk. In other words, It implies a unit root in the price series. The best estimate of a futures price at T periods ahead is the $F_T$ observable today.

Then, a test was made on the log of the spot price to conclude if the price variable follows a random walk process. Accordingly, the Augmented Dickey-Fuller without intercept test applied on the $\ln(P_t)$ variable for the period 1993(1)-2000(4) gives the following results.

$ADF(k=4) = -0.930$. The value of the statistic rejects the null hypothesis. The variable $\ln (P_t)$ follows a random walk process.

The random walk process excludes the existence of changes in the statistical dependency on the history of prices. If dependency holds, then it would be possible to profit better than the market by taking advantage of that information.

So far, without actual futures prices, the present analysis extracts conclusions from the spot price series. As market efficiency is concerned there are still many aspects that deserve a study in depth. The way in which information affects market behaviour both in the spot and the futures markets must be observed in practice. By now Argentina has no futures market, then it is clear the interconnection between both markets has to be assumed theoretically. Empirical analysis about the particular joint behaviour of spot, futures and options, will have to be postponed up to a futures market establishes and generates sufficient information. The reaction of physical traders to new information may differ in timing with the reaction of arbitrageurs and speculators dominating futures and option markets (See, Bird (1987) and Overdahl and Matthews (1988). These differences in dynamical behaviour of these markets should be tested as well.
Finally, the surrogate derivative market considered in this paper for electricity in Argentina compies with the efficiency property. This outcome goes in favour of the implementation a futures market.

Concluding remarks

The introduction of derivatives on electricity to permit risk-sharing should at best aim at the establishment of a futures market. This will attract a market of options on electric futures contracts. The functioning of these markets require a competitive framework in the electricity trade. An organised futures and options market leads to the minimisation of transaction and hedging costs, with an important gain of liquidity for the assets being traded. The electricity trade has peculiarities such as inability to store electricity in bulk, and seasonality both on demand and supply. These aspects have great influence on spot prices. This will be also reflected in futures and in options prices. Therefore, the application of evaluation models, supposes a careful revision of the computing methods for pricing. In these cases the estimates of the convenience yield and its introduction in the formulas is extremely important.

Actual forward contracts include implicit services of hedging, of which the parties are not fully aware, at least as far as costs are concerned. Those contracts are very rigid agreements and do not allow a management of risk. The three contracts X1, X2, and X3 were replicated in terms of a set of call and put option contracts.

The evaluation of forward contracts by means of surrogated option transactions based on electricity gave quite acceptable results. If one contract under analysis was chosen, say X1, the average ratio of the premium to strike price was 4% for call options and 8.7% for put options.

The cost of hedging associated with the transactions showed a net cash flow representing the net hidden costs implicit in the forwards. In the original transactions these obligations were not met by the debtor. Somebody was unlucky to forego revenue while the other part was benefitted for not paying for net hedging. Electricity trade can benefit from applying strategies with derivatives that reduce significantly the costs of hedging if a market for derivatives on electricity exists. Moreover, the strategies can be varied easily and given place to revision of decisions.

Allocation of resources through time requires a system of signals. The roles of signals, in electricity should be by the spot, futures, and option prices.

Risk measured by long term price volatility varies around the 40% per year. Price volatility in the spot market keeps in acceptable levels, according to international standards (NYMEX). The requirements of the NYMEX -for a commodity to become the underlying asset - were broadly met in the mid-1990's.

Price volatility in the spot market keeps in acceptable levels, according to international standards (NYMEX). In the short term volatility behaves as a stochastic variable. However, this variation has bounds and for long term operations the assumption of constant volatility, a la B&S, seems adequate.

The theory concentrates in the process of Markov for the price of the underlying asset. There is evidence that the electricity price follows a random walk process. This is one more step towards. Even, when electricity cannot be stored, the theoretical treatment in which it fits resembles the one called as theory of storage, though with some different factors affecting the cycle.
Finally, it should be stressed that, when estimating volatility the attention must be focused of random price variations. This implies that price behaviour should be forecasted as much as possible to separate predictable variation from stochastic behaviour. This will help in attaining a better understanding of market movements and a more adequate pricing of derivatives and risk evaluation.

**Notes**

* The author is indebted to Ing. Carlos Mattausch and Ing. Claudio Damiano for their views about the Electric Power System in Argentina, and with whom he benefited from talks about physical trading and its connections with transactions through time with risk-sharing instruments. He is also very grateful to Claudio Damiano for his help in keeping him updated about the main changes that took place in the electricity market of Argentina in the second half of the 1990's.

(1) Some of the evidence presented here, was the result of a research that the author made for the National Comptroller of the Electricity (ENRE) in 1994. The results of the study were presented under the title "Nuevas Tendencias en los Negocios de la Industria" in a Seminar on The Future of Electric Power, organized by the Institute for International Research S.A. in the Alvear Palace Hotel, Buenos Aires, 18-19 April 1995.

(2) Interesting experience of European countries and conditions for establishing futures markets in electricity are analysed in Dieter Helm and Andrew Powell (1991) and Eirik Schroeder Amundsen and Balbir Singh, (1992).

(3) Given K, r, t (the expiration date), and P0 (the commodity price at t=0), the relationship between the values of a call and put is \( w^D = w^C - P_t + K \cdot e^{-r\Delta t} \).

(4) For many commodities the cost of carrying refers to storage, insurance, deterioration costs, etc. In the B&S model \( b = r \). And the same will be maintained for the electricity case. Here the rate plays the role of transforming a price paid today for deferred delivery into a price to be paid when delivery takes place. The convenience yield plays the same role as the dividend payments in the case of stock as underlying asset. The convenience yield was assumed to vary with time and not with price. In this analysis cy is supposed to contemplate the existence of cyclical behaviour of prices.

(5) In the case of cyclical behaviour, things are different. If the prices only moved along the deterministic seasonal path during a given period, a standard deviation against the mean still could be estimated but volatility is zero. This is so because all changes in price can be foreseen exactly and no futures and option market can exist with that standard deviation.

(6) An interesting and simplified description of the conditions of operation of the electricity market in Argentina can be found in Chambouleyron (1997).

(7) The forward contracts identities were not revealed. In this paper, they are referred as Contracts, Transaction, or Operations defined by \( X_1, X_2 \) and \( X_3 \). The exercise centred the emphasis on the trading conditions of current electrical energy, just neglecting other agreements such as renewals to the contracts, guarantees, taxes, etc.

(8) If the convenience yield depends on the time and not on the price, Black & Scholes's formula can be applied to adjusted initial spot prices. The adjustment factor based on a rate of discount is \( \exp[-\sum c_y \Delta t] \) where \( c_y \) is the continuous rate of convenience yield to be applied
to the time t and the sum over t is the length of the contract. In the electricity case the strong seasonality existing on the supply side sets grounds for considering the convenience yield to depend only on time. [Olmsted Teisberg and Teisberg (1991)]

(9) The data used in the regression estimate was monthly and three dummies were inserted to repeat their values for each month included in every single season. This was done so to save degrees of freedom. The dependent variable was ln(P_t/P_{t-1}), where P's are the spot price of electricity in two consecutive periods.

(10) Regression coefficients, and their t statistics between brackets, are:
Constant = -0.0471 [-1.966]; Summer = 0.0695 [2.051]; Autumn = 0.0468 [1.366]; Winter = 0.00018 [0.047]; impulse dummy = 0.1526 [2.342]. R^2 = 0.1024; F(4,87) = 2.4815; (0.0496) and se = 0.117391.
Both in this case and in the 1994 evaluation, the regressions gave better results in treating three seasonal dummies and a constant over monthly data than regressing the rate of change in prices against a constant and 11 seasonal dummies.

ANNEX:

CONTRACT X1

TABLE 1.A Cost of the Operation to the Buyer of Electrical Energy measured in US$ of 30 April 1994* (K1=34 - K2=29.5 - Annual Volatility Rate 33.96%)

<table>
<thead>
<tr>
<th>Month year</th>
<th>Energy MWh</th>
<th>Premium of Call $</th>
<th>Premium of Put $</th>
<th>Net C-P $</th>
</tr>
</thead>
<tbody>
<tr>
<td>May '94</td>
<td>3720</td>
<td>1313.9</td>
<td>284.5</td>
<td>1029.1</td>
</tr>
<tr>
<td>Jun</td>
<td>3600</td>
<td>3828.1</td>
<td>1319.6</td>
<td>2508.5</td>
</tr>
<tr>
<td>Jul</td>
<td>3720</td>
<td>4052.8</td>
<td>3426.4</td>
<td>626.3</td>
</tr>
<tr>
<td>Aug</td>
<td>3720</td>
<td>3961.8</td>
<td>5717.8</td>
<td>-1756.0</td>
</tr>
<tr>
<td>Sep</td>
<td>3600</td>
<td>3003.7</td>
<td>8933.3</td>
<td>-5929.6</td>
</tr>
<tr>
<td>Oct</td>
<td>3720</td>
<td>2096.3</td>
<td>14330.9</td>
<td>-12234.6</td>
</tr>
<tr>
<td>Nov</td>
<td>3600</td>
<td>1612.5</td>
<td>19049.7</td>
<td>-17437.1</td>
</tr>
<tr>
<td>Dec</td>
<td>3720</td>
<td>1975.1</td>
<td>19562.8</td>
<td>-17587.7</td>
</tr>
<tr>
<td>Jan '94</td>
<td>3720</td>
<td>4042.5</td>
<td>14660.1</td>
<td>-10617.6</td>
</tr>
<tr>
<td>Feb</td>
<td>3360</td>
<td>7037.3</td>
<td>9704.5</td>
<td>2667.2</td>
</tr>
<tr>
<td>Mar</td>
<td>3720</td>
<td>12028.8</td>
<td>8432.3</td>
<td>3596.5</td>
</tr>
<tr>
<td>Month and year</td>
<td>Energy MWh</td>
<td>Premium of Call $</td>
<td>Premium of Put $</td>
<td>Net C-P Premium $</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
<td>-------------------</td>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>May '94</td>
<td>1319.1</td>
<td>313.4</td>
<td>0.1</td>
<td>313.4</td>
</tr>
<tr>
<td>Jun</td>
<td>1276.5</td>
<td>964.4</td>
<td>15.6</td>
<td>948.8</td>
</tr>
<tr>
<td>Jul</td>
<td>1319.1</td>
<td>1031.6</td>
<td>122.5</td>
<td>909.0</td>
</tr>
<tr>
<td>Aug</td>
<td>1319.1</td>
<td>1014.2</td>
<td>335.7</td>
<td>678.5</td>
</tr>
<tr>
<td>Sep</td>
<td>1447.5</td>
<td>874.7</td>
<td>835.9</td>
<td>38.8</td>
</tr>
<tr>
<td>Oct</td>
<td>1790.3</td>
<td>736.2</td>
<td>2074.9</td>
<td>-1338.7</td>
</tr>
<tr>
<td>Nov</td>
<td>1732.5</td>
<td>577.5</td>
<td>3270.9</td>
<td>-2693.3</td>
</tr>
<tr>
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<td>1790.3</td>
<td>700.9</td>
<td>3460.2</td>
<td>-2759.2</td>
</tr>
<tr>
<td>Jan '94</td>
<td>1790.3</td>
<td>1423.5</td>
<td>2424.9</td>
<td>-1001.4</td>
</tr>
<tr>
<td>Feb</td>
<td>819.0</td>
<td>1260.0</td>
<td>765.1</td>
<td>494.9</td>
</tr>
<tr>
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<td>1790.3</td>
<td>4266.4</td>
<td>1270.8</td>
<td>2995.6</td>
</tr>
<tr>
<td>Apr</td>
<td>1732.5</td>
<td>5444.1</td>
<td>1044.3</td>
<td>4399.8</td>
</tr>
<tr>
<td>Total</td>
<td>18126.2</td>
<td>18606.9</td>
<td>15620.8</td>
<td>2986.0</td>
</tr>
</tbody>
</table>

* Made with information from E.N.R.E.

**CONTRACT X2**

**TABLE 2.A** Cost of the Operation to the Buyer of Electrical Energy measured in US$ of 30 April 1994* (K1= 34.16 - K2= 25.25 - Annual Volatility Rate = 33.96%)

<table>
<thead>
<tr>
<th>Month and year</th>
<th>Energy MWh</th>
<th>Premium of Call $</th>
<th>Premium of Put $</th>
<th>Net C-P Premium $</th>
</tr>
</thead>
<tbody>
<tr>
<td>May '94</td>
<td>1319.1</td>
<td>313.4</td>
<td>0.1</td>
<td>313.4</td>
</tr>
<tr>
<td>Jun</td>
<td>1276.5</td>
<td>964.4</td>
<td>15.6</td>
<td>948.8</td>
</tr>
<tr>
<td>Jul</td>
<td>1319.1</td>
<td>1031.6</td>
<td>122.5</td>
<td>909.0</td>
</tr>
<tr>
<td>Aug</td>
<td>1319.1</td>
<td>1014.2</td>
<td>335.7</td>
<td>678.5</td>
</tr>
<tr>
<td>Sep</td>
<td>1447.5</td>
<td>874.7</td>
<td>835.9</td>
<td>38.8</td>
</tr>
<tr>
<td>Oct</td>
<td>1790.3</td>
<td>736.2</td>
<td>2074.9</td>
<td>-1338.7</td>
</tr>
<tr>
<td>Nov</td>
<td>1732.5</td>
<td>577.5</td>
<td>3270.9</td>
<td>-2693.3</td>
</tr>
<tr>
<td>Dec</td>
<td>1790.3</td>
<td>700.9</td>
<td>3460.2</td>
<td>-2759.2</td>
</tr>
<tr>
<td>Jan '94</td>
<td>1790.3</td>
<td>1423.5</td>
<td>2424.9</td>
<td>-1001.4</td>
</tr>
<tr>
<td>Feb</td>
<td>819.0</td>
<td>1260.0</td>
<td>765.1</td>
<td>494.9</td>
</tr>
<tr>
<td>Mar</td>
<td>1790.3</td>
<td>4266.4</td>
<td>1270.8</td>
<td>2995.6</td>
</tr>
<tr>
<td>Apr</td>
<td>1732.5</td>
<td>5444.1</td>
<td>1044.3</td>
<td>4399.8</td>
</tr>
<tr>
<td>Total</td>
<td>18126.2</td>
<td>18606.9</td>
<td>15620.8</td>
<td>2986.0</td>
</tr>
</tbody>
</table>

* Made with information from E.N.R.E.

**CONTRACT X3**

**TABLE 3.A** Cost of the Operation to the Buyer of Electrical Energy measured in US$ of 30 April 1994* (K1= 34.16 - K2= 25.25 - Annual Volatility Rate = 33.96%)

<table>
<thead>
<tr>
<th>Month and year</th>
<th>Energy MWh</th>
<th>Premium of Call $</th>
<th>Premium of Put $</th>
<th>Net C-P Premium $</th>
</tr>
</thead>
<tbody>
<tr>
<td>May '94</td>
<td>4272.7</td>
<td>1015.3</td>
<td>0.2</td>
<td>1015.1</td>
</tr>
</tbody>
</table>
Jun | 4134.9 | 3123.9 | 50.4 | 3073.4  
Jul | 4272.7 | 3341.4 | 396.9 | 2944.5  
Aug | 4272.7 | 3285.2 | 1087.3 | 2197.8  
Sep | 4134.9 | 2498.6 | 2387.8 | 110.9  
Oct | 4272.7 | 1757.1 | 4952.0 | -3194.9  
Nov | 4134.9 | 1378.4 | 7806.4 | -6428.0  
Dec | 4272.7 | 1672.9 | 8258.1 | -6585.3  
Jan '94 | 4272.7 | 3397.3 | 5787.4 | -2390.1  
Feb | 3859.2 | 5937.1 | 3605.3 | 2331.8  
Mar | 4272.7 | 10182.3 | 3033.0 | 7149.3  
Apr | 4134.9 | 12993.1 | 2492.5 | 10500.7  
Total | 50307.4 | 50582.5 | 39857.3 | 10725.2  

* Made with information from E.N.R.E.

References:


Hull, John C., (1999), "Options, Futures and Other Derivatives", (Fourth edition), Prentice-Hall


