# How to effectively delta hedge the value of a power station: Results of a backtest

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## Summary

*Operators of power stations try to maximize the income from their assets. This requires a combination of dispatch optimization in the spot markets and prudent hedging in the forward markets. Power plant valuation models aim to predict the total value that can be made in a future time period. Valuation models based on the real option approach are able to clarify not only how much value can be currently locked in (the intrinsic value), but also the value that can be generated additionally (the extrinsic value). Important questions for investment analysis and trading decisions are:*

- *Are the values from a power plant valuation model realistic?*
- *What trading strategy should be employed to generate the extra income with greater certainty?*
- *If the trading strategy had been applied in the past, would the predicted value have been realized?*

*This paper answers these questions by following a delta hedging trading strategy over 2012. It is applied to a gas-fired power station in the German market.*

# Contents

# Introduction: market development

The European power generation sector operates in a very volatile environment. Most players earned a very sound income with their coal and gas fired units over the past decade, but are facing difficult times at the moment. Their gross margin, the spark and dark spreads, have declined and the windfall profits from free carbon allowances are gone. This makes it all the more important to capture the maximum value there is to make, with the lowest risk possible. This paper shows how forward hedging in the market achieves just that by making profits more predictable.

As an example of the market dynamics faced by plant owners, Figure 1 shows the development of the clean dark spread for the calendar-13 peak forward in Germany. For the calculation we used 50% HHV efficiency. The spread initially moved sideways at a moderate spread of about 9 €/MWh. From end of 2011 onwards, however, the spread started a decline to below 0.

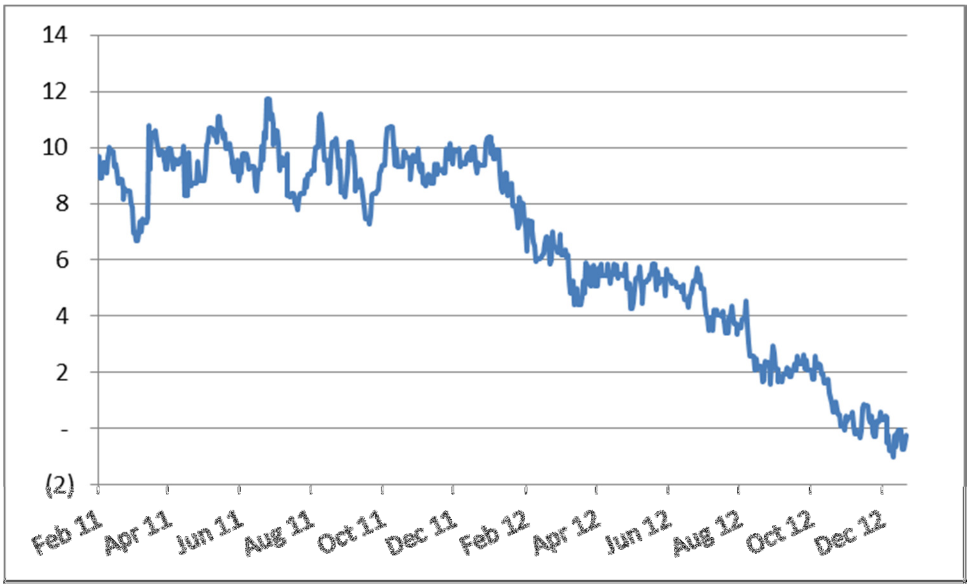


**Figure 1:** Development of the clean spark spread for the calendar 2013 forward in €/MWh.
EEX: German power, NCG German gas and EUA forwards.

# Fair value of a power station

The value of a power plant over some future horizon (e.g. 3 years) can be defined in the following ways:

- ***Tradable intrinsic value***: how much margin can be currently locked in in the forward market?
- ***Hourly intrinsic value***: how much money would the plant make based on the hourly price forward curve?
- ***Full value, or real option value***. This is the value that the owner would make on average, taking into account the volatility of prices in the forward and spot markets. This includes both the expected price variations and all the unexpected movements. The impact of price volatility can be modeled by evaluating a large number of Monte Carlo price simulations, for example with the KySim and KyPlant valuation models.

The hourly intrinsic value is at least as high as the tradable intrinsic value. The reason is that there is more variability in the expected future hourly prices than in the prices at which can be traded right now (e.g. monthly and quarterly blocks). By adjusting the dispatch accordingly, a higher margin can be captured.

Likewise, the full value is at least as high as the hourly intrinsic value, because the realized prices are again more volatile than the predicted (average) hourly prices. This allows the plant owner to benefit even more from the plant's flexibility, simply by adjusting to the current market situation. However, there is always a risk of over- or under-estimation of this flexibility bonus, commonly referred to as extrinsic value.  Furthermore, although the average across Monte Carlo price paths is higher than the intrinsic value, the distribution of outcomes is often wide as well. For that reason, it is important to evaluate how much money could have actually been generated in reality. Is this value close to the estimate made at the beginning of that period or not? The realized value can be calculated with a ***backtest*** in which the plant is virtually dispatched on past spot prices. This value is called the ***realized spot value***.

# Backtest of the realized value in spot and forward markets

It may happen that the plant was valued at a high number (full value), but that during the year the spreads in the market declined. That is what happened in 2012. For that reason, a simple comparison between the estimated full value and the realized spot value is quite unfair. No sensible plant owner will dispatch the full capacity in the spot market without any hedging in the forward market. A proper backtest evaluates both: spot dispatching combined with forward hedging.

In this report we show the benefits of a delta hedging strategy applied to a gas fired power station. Delta hedging means that the trader takes positions in the forward market in order to be most sure about the final income. For example, a plant owner will sell some power forward and buy some gas and $CO_2$ emission rights forward, so he is not or not too much affected by a declining power price or increasing gas price. The combined cashflow in spot markets, forward markets, and operational costs, is:

***realized total value = realized spot cashflow + realized forward hedge result***

The following example can help to clarify the concept. Suppose that we have a 50% efficient plant (HHV) with 100 MW capacity, and at the beginning of the year:

- Forward peak power price = 50 €/MWh
- Forward gas price = 20 €/MWh
- Variable costs = 8 €/MWh
- 3,000 peak hours in this year
- In this example we ignore carbon costs

The tradable intrinsic value is just 50 – 2*20 – 8 = 2 €/MWh. This is 0.6 mln € in total (2 x 3,000 x 100). Based on a large number of price paths, the full plant value is estimated at 1.8 mln € (6 €/MWh). Suppose the delta hedge comes down to selling 50 MW peak power forward, and buying the corresponding volume of gas forward.

In the course of the year, the power prices go down to 44 €/MWh on average, while gas prices stay the same. An optimal dispatch on these prices may yield just 1.0 mln €. However, the forward hedge generates a benefit of (50-44) x 3,000 x 50 = 0.9 mln €. This compensates for the lower spot realization and leads to a realized total income of 1.9 mln €, i.e. close to the estimated full plant value of 1.8 mln €.

# Case study – plant value in 2012

This chapter describes the results of a backtest applied to a gas-fired power station in Germany. The case study clarifies the concepts of valuation and backtesting described in the previous chapters.

The power plant is initially valued at the end of 2011, assuming it will produce in 2012. The maximum capacity is 800 MW with a minimum stable generation level of 450 MW. In between both output levels the efficiency (LHV) increases from 56 to 59%, as displayed in Figure 2. This is a typical pattern for the most recently built, hence most efficient, CCGT power stations.

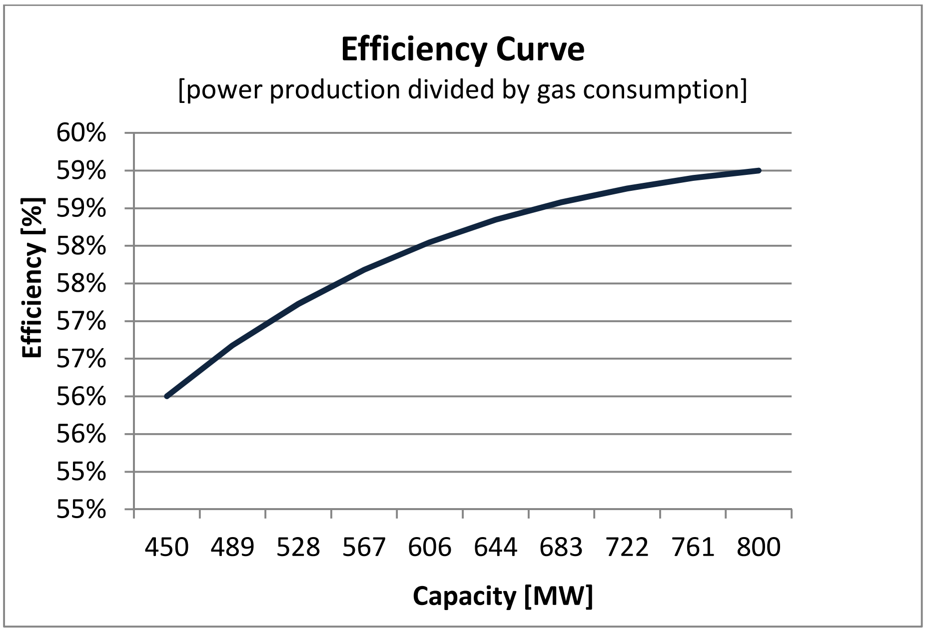


**Figure 2:** Efficiency curve (LHV) for the power station between minimum (450) and maximum load (800 MW).

For the case study we furthermore assumed 2.50 €/MWh variable operations and maintenance costs and the following types of starts:

- Hot start after less than 12 hour shut down. Costs are 20,000 €.
- Warm start after less than 24 hour shut down. Costs are 40,000 €.
- Cold start after 24 hours or more shut down. Costs are 60,000 €.

The start costs can make it beneficial to produce for some time at a loss in order to avoid an expensive start.

At the end of 2011 the power plant was "in-the-money" for peakload production in 2013. The (tradable) intrinsic value was the value that could actually be locked in by a trader by selling forward power and buying forward gas and CO2. A trader could thus lock in 29.08 mln €. It can be decomposed into a gross margin of about 38.5 mln minus start costs of 3.15 mln € and variable O&M costs of 6.26 mln €.

Using an hourly shaped forward curve and 500 realistic price simulations, the full option value is obviously higher. It equals 46.50 mln €. The value implies a considerable extrinsic premium on top of the intrinsic value. The full value is calculated as the average realized income over the 500 price scenarios.

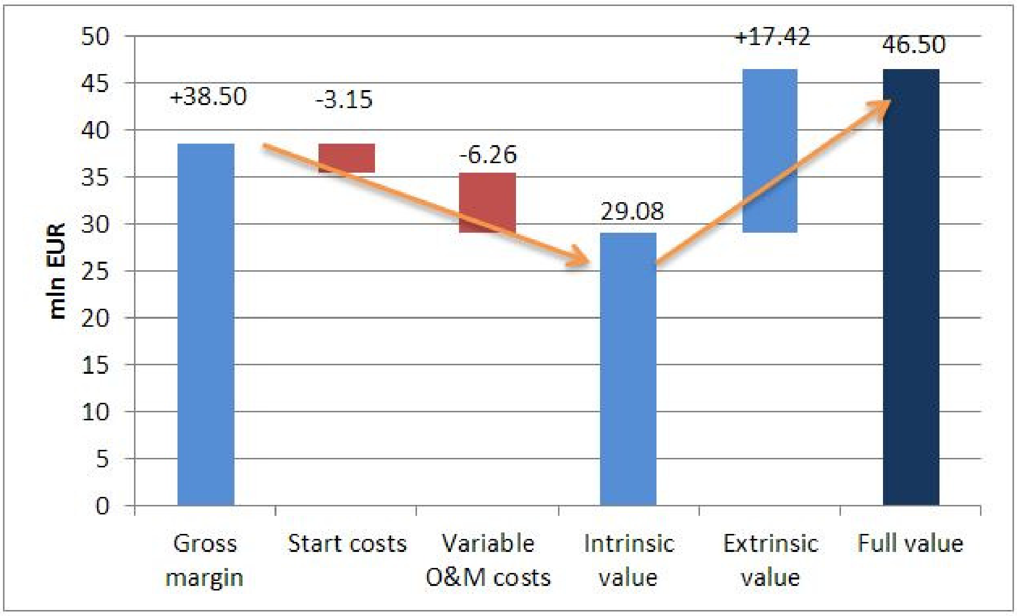


**Figure 3**: Estimated value of the power station in mln €.
The left hand side shows the composition of the tradable intrinsic value;
the right hand side shows how this value plus the extrinsic value make the full plant value.

For the technically interested reader: the price scenarios have been generated with the simulation model KySim. To ensure realistic price dynamics, the model contains a variety of methodologies, including multi-factor simulation, GARCH volatility and cointegration. The optimal dispatch is calculated with the model KyPlant. It finds the optimal hourly dispatch decision per scenario. The optimization method is dynamic programming (DP), and the total time for the optimization is less than 1 second per scenario (5 minutes in total). Dynamic programming gives the exact optimal dispatch, having so-called “perfect foresight” about future price levels. Perfect foresight can lead to some overvaluation. Therefore, in a separate calculation we applied the Least-Squares Monte Carlo (LSMC) approach to avoid this perfect foresight. The expected plant value is then 44.49 mln € (and calculations even faster with less than 2 minutes in total). Depending on the ability of the dispatcher to accurately forecast price levels for the next few days, the true “fair” value of the power station is somewhere in between 44.49 (LSMC) and 46.50 mln € (DP).

# The realized value of the power plant

It is always attractive when a model shows a high value, but can it really be generated? That question is addressed in a backtest. In step 1 the model analyzes how much money could have been generated in the spot market.  Figure 1 already showed the downward price trend during 2012, so it is no surprise that the income was far below expectations. The pure spot result was a meager 6.43 mln €. The plant was much fewer hours in production during 2012 than anticipated at the beginning of the year. And the margin during those hours was considerably lower too.

Luckily, a prudent trader would have hedged the positions from the start. The initial delta hedge (end of December 2011) was for 4,291 GWh short power, 6,987 GWh long gas and 1,330 kton long $CO_2$. During a large part of 2012, the spark spread was in almost continuous decline, leading to an optimal delta hedge position that had to be reduced. In fact, the declining delta hedge mainly shows that the expected production volume is revised downwards in response to the declining spread. In the backtest the delta hedge is adjusted at the end of each month (on the 27th of the month), based on the then prevailing forward market prices. The traded volumes in peak power are a good example and displayed in Table 1. The table shows that the initially hedged peak volume was 1,995 GWh. Especially in the first three months of 2012 a considerable part of this volume was bought back in order to remain optimally hedged. A large portion of the originally sold offpeak volumes were also bought back within the first three months.

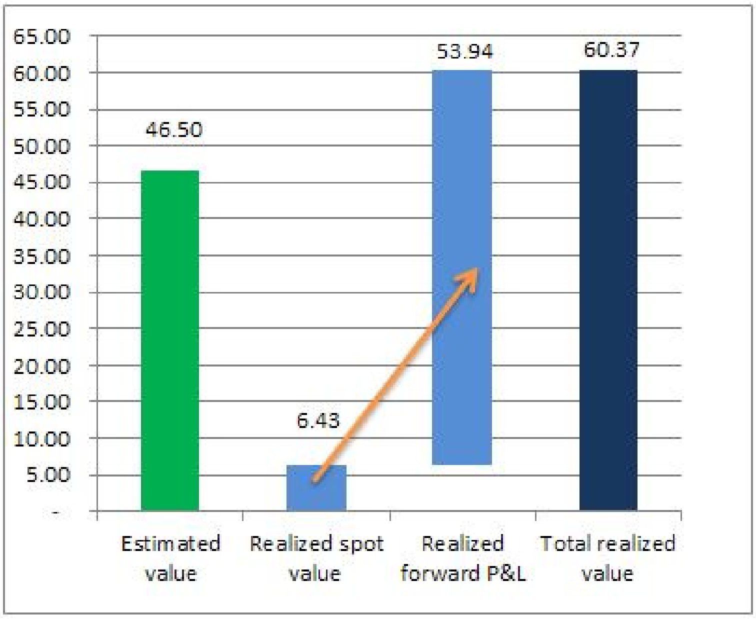


**Figure 4**: Estimated value of the power station, compared to the actually realized income, in mln €.

The total profit on the forward hedge activity equals 53.94 mln €. This profit originates from the original sale of the spark spread at a relatively high price, and a gradual purchasing back at lower spread levels. This brings the combined performance of the trading strategy to 6.43 (spot) plus 53.94 (forward) = 60.37 mln €. This is above the expected value of 46.50 mln €.

The total realized income is 20-25%% above the expected value of 46.50 mln €. If we would repeat this exercise every year, the expected value and realized income will be closer on average. The main reason for the higher realized value in this particular year, is the sharp decline in the spread. The spread decline is larger than what could normally be expected from the volatilities of the individual commodities. In addition, rehedging in the analysis is always postponed to the end of the month, so not very frequent. Since rehedging generally means that the spread is bought back at a lower level, which is lower at the end of the month than at the beginning, this has led to an unusually high forward hedging profit. In short: in a market that moves a lot up and down, frequent rehedging generates most income, but in a market that trends upward or downward, less frequent hedging generates more income. Additional backtests will be performed in the coming period to investigate the hedge performance under a range of different market conditions.

**EEX Peak power traded in volumes (MWh)**

| Month | 27-Dec-11 | 27-Jan-12 | 27-Feb-12 | 27-Mar-12 | 27-Apr-12 | 27-May-12 | 27-Jun-12 | 27-Jul-12 | 27-Aug-12 | 27-Sep-12 | 27-Oct-12 | 27-Nov-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-Jan-12 | -179,684 | - | - | - | - | - | - | - | - | - | - | - |
| 01-Feb-12 | -173,274 | 13,020 | - | - | - | - | - | - | - | - | - | - |
| 01-Mar-12 | -185,879 | 51,999 | 13,677 | - | - | - | - | - | - | - | - | - |
| 01-Apr-12 | -154,166 | 45,056 | 20,988 | 9,634 | - | - | - | - | - | - | - | - |
| 01-May-12 | -160,851 | 41,196 | 16,077 | 16,530 | 5,157 | - | - | - | - | - | - | - |
| 01-Jun-12 | -145,856 | 32,947 | 10,857 | 18,662 | 2,219 | -18,194 | - | - | - | - | - | - |
| 01-Jul-12 | -162,316 | 30,308 | 23,113 | 7,719 | 9,947 | -16,754 | 3,759 | - | - | - | - | - |
| 01-Aug-12 | -171,082 | 38,544 | 32,797 | -6,772 | 13,004 | -3,900 | -2,476 | -14,973 | - | - | - | - |
| 01-Sep-12 | -139,356 | 38,836 | -14,506 | 13,266 | -3,808 | -5,977 | 20,821 | -9,419 | -40,175 | - | - | - |
| 01-Oct-12 | -184,521 | 26,676 | -446 | 7,626 | -9,564 | -5,427 | 16,721 | -480 | 10,176 | -14,603 | - | - |
| 01-Nov-12 | -162,827 | 30,971 | 11,058 | 17,448 | -39,449 | -2,088 | -10,876 | -17,573 | 10,000 | -9,926 | 1,539 | - |
| 01-Dec-12 | -175,495 | 11,906 | -2,194 | 2,371 | 12,861 | 8,238 | -11,089 | -384 | 3,523 | -5,217 | 11,055 | -9,063 |
| | **-1,995,307** | **361,461** | **111,420** | **86,483** | **-9,632** | **-44,101** | **16,859** | **-42,829** | **-16,477** | **-29,747** | **12,594** | **-9,063** |

**EEX OffPeak power traded in volumes (MWh)**

| Month | 27-Dec-11 | 27-Jan-12 | 27-Feb-12 | 27-Mar-12 | 27-Apr-12 | 27-May-12 | 27-Jun-12 | 27-Jul-12 | 27-Aug-12 | 27-Sep-12 | 27-Oct-12 | 27-Nov-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-Jan-12 | -202,371 | - | - | - | - | - | - | - | - | - | - | - |
| 01-Feb-12 | -190,447 | -8,402 | - | - | - | - | - | - | - | - | - | - |
| 01-Mar-12 | -231,911 | 52,988 | 60,751 | - | - | - | - | - | - | - | - | - |
| 01-Apr-12 | -166,697 | 30,633 | 46,497 | 34,819 | - | - | - | - | - | - | - | - |
| 01-May-12 | -172,666 | 30,622 | 42,236 | 43,573 | 1,725 | - | - | - | - | - | - | - |
| 01-Jun-12 | -164,686 | 18,135 | 39,528 | 32,875 | 11,446 | -2,087 | - | - | - | - | - | - |
| 01-Jul-12 | -210,946 | 45,169 | 43,981 | 26,687 | 5,243 | 5,171 | 2,672 | - | - | - | - | - |
| 01-Aug-12 | -192,548 | 27,450 | 62,142 | 15,252 | 6,695 | -2,328 | 5,607 | 7,561 | - | - | - | - |
| 01-Sep-12 | -180,289 | 33,819 | 83,797 | -27,332 | -22,531 | 7,366 | 28,294 | -850 | -59,036 | - | - | - |
| 01-Oct-12 | -182,795 | 30,882 | 34,740 | 24,214 | -43,812 | 4,756 | 4,328 | 10,939 | 9,426 | -773 | - | - |
| 01-Nov-12 | -160,687 | 37,370 | 38,656 | 22,462 | -55,554 | -8,241 | -9,261 | -19,045 | 19,514 | -1,136 | -12,251 | - |
| 01-Dec-12 | -239,863 | 26,826 | 28,613 | 17,888 | 88,405 | 17,941 | -98,793 | 2,134 | 10,736 | 12,588 | 15,730 | -40,706 |
| | **-2,295,905** | **325,492** | **480,940** | **190,438** | **-8,384** | **22,577** | **-67,153** | **739** | **-19,359** | **10,679** | **3,479** | **-40,706** |

**NCG Gas traded in volumes (MWh)**

| Month | 27-Dec-11 | 27-Jan-12 | 27-Feb-12 | 27-Mar-12 | 27-Apr-12 | 27-May-12 | 27-Jun-12 | 27-Jul-12 | 27-Aug-12 | 27-Sep-12 | 27-Oct-12 | 27-Nov-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-Jan-12 | 612,665 | - | - | - | - | - | - | - | - | - | - | - |
| 01-Feb-12 | 600,488 | -14,219 | - | - | - | - | - | - | - | - | - | - |
| 01-Mar-12 | 700,301 | -207,403 | -112,267 | - | - | - | - | - | - | - | - | - |
| 01-Apr-12 | 515,272 | -144,252 | -94,895 | -76,396 | - | - | - | - | - | - | - | - |
| 01-May-12 | 531,910 | -133,083 | -79,094 | -102,631 | -14,451 | - | - | - | - | - | - | - |
| 01-Jun-12 | 498,283 | -98,802 | -63,063 | -89,234 | -25,893 | 32,704 | - | - | - | - | - | - |
| 01-Jul-12 | 600,019 | -152,967 | -80,482 | -58,698 | -26,943 | 19,079 | -15,373 | - | - | - | - | - |
| 01-Aug-12 | 600,361 | -126,472 | -144,407 | -13,877 | -35,280 | 11,288 | -7,816 | 8,565 | - | - | - | - |
| 01-Sep-12 | 523,724 | -138,735 | -97,318 | 24,123 | 47,905 | -3,409 | -88,456 | 17,145 | 170,530 | - | - | - |
| 01-Oct-12 | 598,091 | -112,975 | -41,706 | -53,654 | 93,620 | 3,358 | -38,535 | -21,875 | -34,027 | 25,096 | - | - |
| 01-Nov-12 | 519,546 | -134,786 | -60,813 | -66,086 | 163,076 | 18,174 | 38,235 | 65,706 | -55,668 | 20,965 | 16,116 | - |
| 01-Dec-12 | 686,538 | -84,524 | -29,113 | -39,868 | -181,061 | -46,351 | 197,130 | -3,333 | -23,218 | -17,864 | -45,609 | 84,165 |
| | **6,987,199** | **-1,348,218** | **-803,157** | **-476,321** | **20,973** | **34,844** | **85,186** | **66,209** | **57,617** | **28,198** | **-29,494** | **84,165** |

**CO2 traded in volumes (ton)**

| Month | 27-Dec-11 | 27-Jan-12 | 27-Feb-12 | 27-Mar-12 | 27-Apr-12 | 27-May-12 | 27-Jun-12 | 27-Jul-12 | 27-Aug-12 | 27-Sep-12 | 27-Oct-12 | 27-Nov-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-Jan-12 | 116,670 | - | - | - | - | - | - | - | - | - | - | - |
| 01-Feb-12 | 114,107 | -3,447 | - | - | - | - | - | - | - | - | - | - |
| 01-Mar-12 | 132,931 | -39,678 | -20,199 | - | - | - | - | - | - | - | - | - |
| 01-Apr-12 | 98,276 | -27,540 | -17,773 | -14,352 | - | - | - | - | - | - | - | - |
| 01-May-12 | 101,076 | -25,116 | -14,505 | -19,431 | -2,772 | - | - | - | - | - | - | - |
| 01-Jun-12 | 95,257 | -19,086 | -11,562 | -16,701 | -4,924 | 6,598 | - | - | - | - | - | - |
| 01-Jul-12 | 113,975 | -28,673 | -15,214 | -10,759 | -5,177 | 3,815 | -2,843 | - | - | - | - | - |
| 01-Aug-12 | 114,103 | -24,490 | -26,595 | -2,545 | -6,558 | 2,354 | -1,526 | 2,116 | - | - | - | - |
| 01-Sep-12 | 99,514 | -26,597 | -17,076 | 4,052 | 8,476 | -76 | -16,478 | 3,230 | 32,201 | - | - | - |
| 01-Oct-12 | 114,504 | -21,553 | -7,200 | -9,875 | 17,076 | 431 | -7,180 | -3,801 | -6,471 | 4,763 | - | - |
| 01-Nov-12 | 99,642 | -25,507 | -11,140 | -12,589 | 30,801 | 3,473 | 6,924 | 12,693 | -10,151 | 3,871 | 2,603 | - |
| 01-Dec-12 | 129,646 | -15,314 | -4,781 | -7,353 | -33,670 | -8,772 | 36,635 | -898 | -3,837 | -2,975 | -9,066 | 15,331 |
| | **1,329,700** | **-256,999** | **-146,045** | **-89,553** | **3,252** | **7,824** | **15,531** | **13,340** | **11,742** | **5,659** | **-6,463** | **15,331** |

**Table 1**: Implemented forward hedges in the backtest for delivery month 1-12 in the year 2012. Note that for simplicity we assume each month can be traded individually, there is no minimum trade size, nor any transaction or interest costs.