Energy derivatives and hedging strategies

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1. Introduction

The next few decades are expected to see another big rise in energy consumption. Depletion of existing energy sources and the need to comply with environmental regulations will simultaneously mean a shift towards alternative energy sources. This will bring huge shifts to the energy landscape and require massive investments. Without doubt, efficient derivatives markets will be a great help in making the right investments. They help to provide the right forward-looking price signals, assess future volatility levels and provide instruments now and in the future to manage energy exposure on both the production and consumption sides.

What makes trading and hedging in energy markets special? That is the central theme of this chapter. There is a wide variety of energy commodities and products, which reduces liquidity in individual products. Differences also exist in product specifications of the traded products, price behaviour and relevant hedging schemes. This chapter devotes considerable attention to power, the purest and most ready-to-use form of energy. The difficulty of storing and transporting power makes it an ideal candidate to demonstrate various properties of energy derivatives in general. Given the large variety of energy products, it is not always evident which derivatives product and which hedging scheme is most effective in reducing exposures. Therefore, proxy hedging is worth a reasonably detailed discussion, taking both an electricity end user and an electricity generator as examples. Finally, the chapter contains a detailed case study of using weather derivatives to hedge exposures resulting from the seasonal and weather-driven demand for energy. It shows that a company's profit and loss can be directly affected by volume variations, and how weather derivatives assist to mitigate that risk.

2. Strategic considerations for energy hedging

While many companies have quite strict policies for (almost) fully hedging foreign exchange (FX) exposures, the hedging of energy exposures is often left to the discretionary insight of individual managers. In most cases less than 50% of the exposure for the upcoming two to three years is actually hedged. In our corporate commodity advisory practice we find that the desired level of hedging is badly defined: even the largest and most professionally managed companies may leave such decisions to local plant or business unit managers. This is surprising given the sometimes large share of energy costs in the total cost structure, in combination with the significant volatility in energy prices. The past few years have demonstrated that energy prices can double within a year, leading to volatility levels that are four to five times larger than those of the primary FX rates.

We believe that there are at least three important explanations for the somewhat limited (but increasing) attention paid by corporate firms to the central and active management of energy exposures. First, because of their physical nature, energy exposures are less easily recognised as a financial risk. It is often necessary to involve local managers in signing commodity and country-specific purchase contracts. Aggregation of natural exposures and contracts to financial risk figures is generally perceived as a difficult next step to apply consistently throughout the company.

A second explanation is the large diversity in energy exposures that companies may face, in terms of both products and geographical locations. This complicates consistent reporting and effective financial risk management. Furthermore, each product and market has its own product specifications and trading conventions, making it necessary to involve a range of specialists to perform the financial analysis and execute transactions. The handful of dealers dominating the market, notably Goldman Sachs and Morgan Stanley, assist companies in carrying out transactions; but at the same time they have a natural comparative advantage to arbitrage pricing differences and among their customers.

The third hurdle for consistent energy risk management among corporate firms is the difficulty of defining an appropriate benchmark. On the one hand, it may be argued that income stability is the ultimate goal for any company – avoiding the cost of financial distress, making it more attractive to work for and do business with and lowering the cost of capital, among other things. The logical consequence would be to hedge all exposures as many years into the future as possible. On the other hand, company shareholders actually prefer certain exposures so that they can choose their own level of hedging. For example, investors deliberately take an oil price exposure by investing in oil majors. For this and other reasons, companies may choose a hedging strategy that aligns well with their competitors. Still, given the huge variations in energy prices, whatever the outcome it is important for companies to define a clear benchmark. This benchmark can be communicated internally for better financial control and reduced transaction costs, and communicated to investors for transparency.

3. Energy derivatives contract structures

The bulk of derivatives trading is in products that are based on a financial concept or product, such as FX rates, interest rates and company stocks. In contrast, trading in energy derivatives, and commodity derivatives in general, means that the underlying is a physical product. This physical product or underlying must be defined very exactly and price formation must be the result of a fairly active trading activity to make a derivatives product viable. The example below provides details for European steam coal. Due to the large diversity in energy products in terms of quality and location, the standardisation and publication of generally accepted indices are not evident. In practice, only a limited number of physical indices become successful and form the basis for hedging strategies. This also means that actual exposures might differ from the hedge product, and companies face the challenge of maximising hedge effectiveness (as discussed later in this chapter).

Example: Coal API-2 – physical indices as the underlying for financial derivatives

Steam coal is the largest fuel for power generation worldwide, but is not a homogeneous product. The usual unit of measurement is based purely on weight, but weight alone is not suitable for comparing prices due to substantial differences. Standardisation to a specific quality level offers a solution. The most typical specifications of steam coal imported into Europe are, for example, based on a calorific value of 6,000 calories per kilogram, an ash content of 8% to 15% and a size of 0 millimetres (mm) to 50 mm. Most European coal trading is for coal with exactly those specifications and delivered in one of the northwest European harbours (Amsterdam, Rotterdam or Antwerp). The most commonly used index, API-2, is published each week in the jointly owned *Argus/McCloskey's Coal Price Index Report*. It is an estimated average price for physical coal transactions following those specifications. Derivatives products, mainly swaps, are traded with this 'physical' API 2 index as an underlying. Importantly, the coal swap market can thrive only if the underlying physical market has been standardised and is liquid enough to avoid price manipulation.

The flexibility in energy assets and the embedded flexibility (optionality) in various long-term contract structures would suggest that energy market players trade options actively. Options could help to manage the risks from those more basic physical positions. However, although in oil and weather markets option structures may have gained some popularity, in the other energy markets trading activity is generally quite low. The (limited) activity is primarily over-the-counter based. Probably the main explanation is again the fragmentation of products and markets. This makes it difficult to channel enough trading activity to a specific product type.

Derivatives products that trade a linear pay-off are swaps, futures and forwards. Naming can be quite confusing, with forwards and futures being traded on the same exchange. Many exchanges for trading energy derivatives exist worldwide, ranging from the well-known New York Mercantile Exchange and Intercontinental Exchange to rather small exchanges for regional power markets. Nevertheless, various studies indicate that the abundance of trading activity is over the counter. Financially settled swaps are the most popular instruments in oil and coal markets; physically settled forwards are generally most popular in power and gas. The forward structures demonstrate most clearly the 'flow' nature of power and gas: a forward delivery means the delivery over the full maturity period (month, quarter, season, year) of a constant volume during every hour of the day.

4. From price exposure to spread exposure

Although price developments of different energy products may not be the same over shorter time periods, the overall trend over a three to five-year period (or less) is often very similar. The improved transportability helps to tighten the links between geographic locations. Larger oil tankers and bulk carriers, and especially the boom in liquefied natural gas facilities, have supported this trend. At the same time, energy commodities have natural interdependencies. For example, the power production sector is the primary end user of coal and natural gas; natural gas prices are often priced against refined oil prices (especially in Europe and Asia); and crude is naturally linked to refined oil. Also, the developments of emissions trading markets, such as the EU Emissions Trading Scheme, create further linkages: the power sector is the largest emitter of carbon dioxide and nitrogen oxide, followed by the oil and gas industry.

Crack spreads, spark spreads, dark spreads, winter-summer spreads, Atlantic-continental spreads, contracts for differences: the price risk management of energy exposures often comes down to the management of spreads, as follows:

- A gas storage operator primarily manages the flexibility of the storage asset to capture time spreads. It can use the flexibility as a hedge against expected and unexpected load fluctuations from the rest of its portfolio (eg, customers, gas-fired power plants) or use it as a source of trading revenue itself.
- A shipping company or the owner of pipeline capacity manages the flexibility to exploit locational spreads. For example, the Interconnector gas pipeline between Bacton, United Kingdom and Zeebrugge, Belgium attracts a variety of trading companies. The capacity is used to exploit price differences between the UK National Balancing Point (NBP) and continental European gas prices. In addition, it is used to enjoy the flexibility of using gas of one market (typically, the more liquid NBP) as a physical hedge against positions in the other market.
- Intra-commodity spreads are the primary concern for processing companies (eg, refineries and fuel-fired power plants). For example, the spark spread of a gas-fired power plant is the gross margin of that plant for a set of power prices, gas prices and (if applicable) emission prices. A rise in the power price does not mean an increased profit margin, as it may be accompanied by an equal or even larger rise in gas prices. In practice, a power plant owner is exposed to a range of spark spreads: various maturities and various production types can be distinguished, including base load (all hours of the day), peak load (business hours only) and off peak (non-business hours).

Later in the chapter the management of spark spreads is described in detail. However, before jumping to that rather advanced topic, there are a couple of general principles that apply to the management of energy commodities in general.

5. Optimal hedge ratio and hedge effectiveness

Important questions for a portfolio or risk manager to address include the following:

- What is my exposure?
- How can I optimally hedge it?
- What is the effectiveness of the hedge?

Various aspects come into play to address these basic questions: volatility, correlations, hedging costs, risk premiums and volume uncertainty, to name a few. We go on to explain how each of these elements plays a role, starting simply and then moving to a more advanced example. One of the most advanced examples, the hedging of a power station, is worked out in detail at the end.

When a company can make an accurate forecast of its exposure, and when that exposure is a tradable contract, the optimal hedge equals the exposure. Take, for example, a mobile phone manufacturer in Finland. Suppose that on January 1 it has a firm expectation that its electricity demand in the following year will be 1,200 megawatt-hours (MWh) per day, spread equally over the day. The exposure exactly matches with 50MW of the base-load front-year calendar contract on the Nordpool Exchange. Some statistics are as follows:

- Assuming that the year-ahead contract currently trades at €50/MWh and has an annual volatility of 20%, a movement of 20% up or down is very likely.
- Under the assumption of normally distributed returns, the 5% worst case movement would be to a level of €70/MWh around the end of the current year.
- With about 5% probability, the (commodity) cost for the electricity demand can therefore rise from the present €21.9 million (365 x 50 x 1,200) to €30.66 million or more.
- The difference is the one-year 95% value-at-risk, which equals €30.66 million minus €21.9 million – €8.76 million. Leaving this position open may turn profits into a loss.

As a solution, the company may buy a 50MW base-load year-ahead contract on Nordpool for delivery in Finland. When the contract is for physical delivery, the electricity can be used for the plant directly. However, in most cases the contract (whether financial or physical) will serve merely as a financial hedge, giving the company time to negotiate an end-user contract with an electricity supply company. Among other things, the end-user contract will contain the necessary flexibility for some variation in offtake, in contrast to the fully constant load from a tradable contract. However, because the end-user contract will be directly priced as the Nordpool market price plus a mark-up, the Nordpool hedge of 50MW provides the full financial protection; it is the optimal hedge. At the time the company signs an end-user contract, the contract will be unwound.

In practice, the exposure might not be equal to a liquid tradable contract. The solution is to find a tradable product whose price movements closely mimic the actual exposure. This is a 'proxy' (or 'basis') hedge. There are multiple reasons for a proxy hedge:

- The commodity specifications may be different;
- The location may be different;
- The delivery period of the contract may be different; or
- The contract size may not match what is needed.

With a proxy hedge, various items start to influence the optimal hedge size and the hedge ratio. In this example, the base-load demand is replaced by a peak-load demand. On Nordpool, the peak-load contract is considerably less liquid than the base load, which is a good reason to consider using the base-load contract to hedge the peak exposure. There are four different types of hedge:

- Volume hedge - with a demand of 50MWh per hour in peak hours (8:00am to 8:00pm on business days) and 3,168 peak hours a year, the total demand equals 158.4 gigawatt-hours. It is not uncommon to hedge this with the (approximately) same volume in the proxy product. In this case, that would mean buying 18.1MW of base-load power (158.4/8.76; 8,760 hours in a year). The implicit or explicit assumption behind a volume hedge is that an increase in the underlying exposure is compensated by an equal price movement in the hedge product. For example, when the peak price moves from €60 to €80 per MWh, the base-load must move from €50 to €70 per MWh in order to have a perfect hedge.
- Value hedge: - there is a lot of statistical evidence that the correlation between many market prices is stronger in terms of percentage price changes than in terms of absolute price changes. For example, when the peak price moves from €60 to €80 per MWh, the comparable movement in the base-load product would be from €50 to €66.67 per MWh. If so, it is more effective to take a position in the hedge product that matches the value of the exposure instead

of the volume. The company's profit and loss would be unaffected if the value of the hedge equalled €9.5 million (158,400 x 60), or a tradable base-load volume of 21.7MW.

- Optimal correlation-based hedge - both volume and value hedge ignore the possibility that the price of the hedge product may not move in tandem with the exposure. If the correlation between price returns is less than 100%, then (under certain assumptions) statistical models demonstrate that the value at risk of the combined position is minimised when the value hedge is rescaled with the correlation. For example, an 85% return correlation between base load and peak-load year-ahead contracts implies an optimal hedge of 0.85 x 21.7 = 18.4MW base load. This number can be further scaled down if the volatility of the hedge product is actually higher than that of the exposure, and vice versa. Even though such a hedge is the best that can be achieved, it does not bring the value at risk to zero. It brings the value at risk down by 53% (the square root of $1\text{-}85\%^2$) of the initial value at risk.
- Optimal correlation and co-integration based hedge - most risk management systems have the functionality to calculate value at risk or similar risk measures. Most of the calculation methods rely on volatilities and correlations of daily price returns. In commodity markets, many pairs of price series actually move more closely together than the correlation of daily price returns suggests. In other words, the daily return correlation underestimates the true linkage between prices. For example, while (Dutch) title transfer facility and (UK) NBP gas prices might not show returns that are the same on each day, the overall trend is rarely different over one week or one month. This implies that the spread between the markets is mean-reverting. Such a co-movement of spreads has been modelled successfully by so-called 'co-integration' or 'error-correction' models. Although a simple optimal hedge rule is not available as for correlation, a stronger co-integration generally implies that the optimal hedge ratio moves from 85% closer to 100%. The co-integration also makes the hedge more effective. At the same time, one must be careful that the effectiveness of a hedge typically looks better on paper than it performs in real life: a hedge is often unable to provide protection against occasional market disruptions (eg, due to pipeline failures).

What to do in practice? In order to define an optimal hedge programme, it is first important to have a good view on the actual aggregate exposures. This requires the right systems and risk management tools to be in place (eg, aggregating the forecasts and exposures from various production locations). Second, the goals of the hedging programme must be crystal clear and part of a policy covering issues such as the following:

- What is the horizon being hedged?
- What percentage of price uncertainty is left 'open'?
- Who is responsible for implementation and monitoring?
- What products can be traded and with what counterparts?
- What should be done in extreme market situations?

Furthermore, the discussion of the four hedging approaches highlights that a company should define whether its goal is to minimise short-term mark-to-market variations in its exposure (eg, minimise one or 10-day value at risk), or whether longer-term cash flow at risk or profit at risk are the central aim. In the former case, the correlations and volatilities provide all statistical information to define 'optimal hedges'; in the latter case, the co-integration parameters must be incorporated. In any case, the expectations for the effectiveness of a hedge should not be set too high because markets are likely to behave differently than expected.

6. Hedging exposures with 'flexibility': the case of a power plant

Many of the peculiarities of energy hedging come together in the management of a gas-fired power station. First, the exposure is not a single commodity, but a spread (the clean spark spread). Second, the management involves the use of products with multiple maturities and granularities, ranging from spot to multiple calendar forwards. Finally, a gas-fired power station has a flexible level of generation and its exposure therefore varies with the spark spread in the market.

Let us first review the 'natural' unhedged position. Without any forward hedge and any other position (eg, a customer portfolio), the plant will sell its production in the spot market. When its spark spread (gross margin) is positive in a certain period, it will produce; otherwise it will not - or at least not at full capacity. This could mean that the plant:

- generally runs at maximum capacity (eg, 400MW) Monday to Friday from 6:00am to 11:00pm;
- is switched off over the weekend when spreads are clearly negative; and
- runs at minimum stable generation (eg, 200MW) in the night hours of Monday to Friday when spreads are negative, but a start-stop is too costly.

Any hedging scheme will leave this optimal dispatch pattern unaffected: it merely stabilises the total income. Even if this production pattern is known with certainty, there is no perfect hedge because it does not coincide with standard traded blocks. In this case, depending on the market's peak-load definition, the exposure is a combination of 100% peak load and a little off-peak (early morning and late evening full capacity, and night hours minimum capacity).

Still assuming full dispatch certainty, a market hedge would first mean selling forward 400MW peak-load power and buying corresponding volume of gas and (potentially) emission credits. Based on a risk analysis involving volatilities, correlations and co-integration, the off-peak hedge might be 100MW. The peak-load hedge will certainly mean that a positive margin is locked in, but the off-peak 'lock-in' can be negative, since in this example only a few off-peak hours are expected to be positive. This negative lock-in is often difficult to understand; the logic stems from the fact that the plant will actually produce only in a small percentage (roughly 25%) of the hours. When it comes to spot trading, about 75% of the forward sold off-peak power will be repurchased, while for the remaining 25% additional power will be sold in the market. From a profit-stabilising perspective, this is preferred above selling the full off-peak production volume in the spot market. The loss from the forward lock-in will be compensated for by a profit-in-spot market. This can be compared to the hedging of an out-of-the-money financial option.

In reality, the optimal future dispatch is not certain. When forward spark spreads rise, the expected production will rise, as will the hedge volumes. A delta sensitivity of the power plant towards a specific tradable contract (eg, power, gas, emissions) equals the sensitivity of the plant value due to changes in those market prices. An approximation to this delta sensitivity can be calculated using variations of the Margrabe spread option formula. However, ideally, this plant value is calculated on the basis of a large number of potential future price scenarios, because that is the only way to incorporate technical constraints (eg, start-stop) and the special dynamics of forward and spot power prices, as well as co-integration. With sophisticated power plant simulation and valuation models, a market player can therefore hedge more accurately and stabilise a larger proportion of its plant value.

The weather markets

It is taken for granted that weather impacts on the agricultural, commodity and energy markets. The news headlines of Summer 2010 were replete with disastrous crop failures in Russia, heatwaves in North America and calamitous rains in parts of Asia. What, if anything, can be done to mitigate the economic losses caused by the weather?

Fortunately, the answer is quite a lot. The Chicago Mercantile Exchange (CME) offers weather products related to temperatures, hurricanes, snowfall and frost. Furthermore, weather hedge funds, reinsurance companies and weather market makers offer weather cross-commodity products for agricultural and energy participants requiring idiosyncratic weather risk coverage. In this section the motivation for a weather hedge and the weather hedge's effectiveness are presented for a fictional natural gas retailer (Amigos) doing business in the northeastern United States.

Case study: weather derivatives

Retail natural gas providers are directly impacted by weather. Consider Amigos, a fictional natural gas distribution company doing business in the northeastern United States. The reason that Amigos desires a weather hedge is because in a colder than average (normal) winter heating season, Amigos will sell greater volumes of natural gas to its end users. Conversely, in a warmer than average heating season, Amigos will sell smaller volumes of natural gas to its customers.

The weather risk endemic to Amigos' natural gas operations is illustrated in Table I. The second column shows the total heating degree days accumulated during the winter heating season, November 1 to March 31 for the 14 heating seasons spanning 1997 to 2010. As can be seen in the table, lower average temperatures result in higher heating degree day totals. What is striking is that New York heating degree day totals for the 1997 to 2010 winter heating seasons range from a minimum of 3,063 (in 2002) to a maximum of 4,254 (in 2003).

In the third column it is readily apparent that in cold winter heating seasons, Amigos' unhedged margins are concomitantly higher than during mild winter heating season because Amigos sells a greater volumes of gas to its end users.[1] To obtain a sense of the weather risk, note that Amigos' expected (average) margin is $18.582 million. In the mild winter of 2002 Amigos realised unhedged margins of $16.525 million, an approximate shortfall of $2 million from the company's expectation. In contrast, in the very cold 2003 winter, Amigos realised unhedged margins of $20.785 million, an approximate windfall of $2.1 million. Put differently, Amigos' margins swung by more than $4.1 million between the 2002 and 2003 heating seasons.

Table I
This shows the heating degree days at LaGuardia Airport and the unhedged margins at Amigos. The expected margin is $18.5 million and ranges from $15.9 million to $21.2 million.

Year	Heating degree days	Unhedged margins
1997	3753.5	$19,022,500
1998	3473.0	$17,455,000
1999	3556.5	$17,467,500
2000	3535.0	$17,980,000
2001	4132.0	$21,070,000
2002	3063.0	$16,525,000
2003	4254.0	$20,785,000
2004	3994.5	$20,037,500
2005	4007.0	$19,645,000
2006	3475.5	$16,682,500
2007	3443.0	$15,960,000
2008	3701.5	$17,977,500
2009	3977.5	$21,212,500
2010	3658.0	$18,330,000

The senior management at Amigos decides to hedge this weather risk. The hedge envisaged is to be structured such that Amigos will receive payment when a winter heating season is warmer than normal (relatively fewer heating degree days) and Amigos will make payment when a winter heating season is colder than normal (relatively more heating degree days). This hedging strategy enables Amigos to recoup any margin shortfall associated with a warmer than normal heating by forfeiting potential windfall profits associated with a colder than normal heating season. Another way to consider the hedge is that Amigos is able to decrease the volatility of its winter heating season margins.

The weather hedge
In order to hedge its weather risk effectively, Amigos must:

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1 We assume for ease of exposition that price margins are fixed and hedged.

- be confident that there is a statistically significant relationship between its unhedged margins and the weather at a particular location (LaGuardia Airport heating degree days); and
- determine the type and size of the hedge to be implemented.

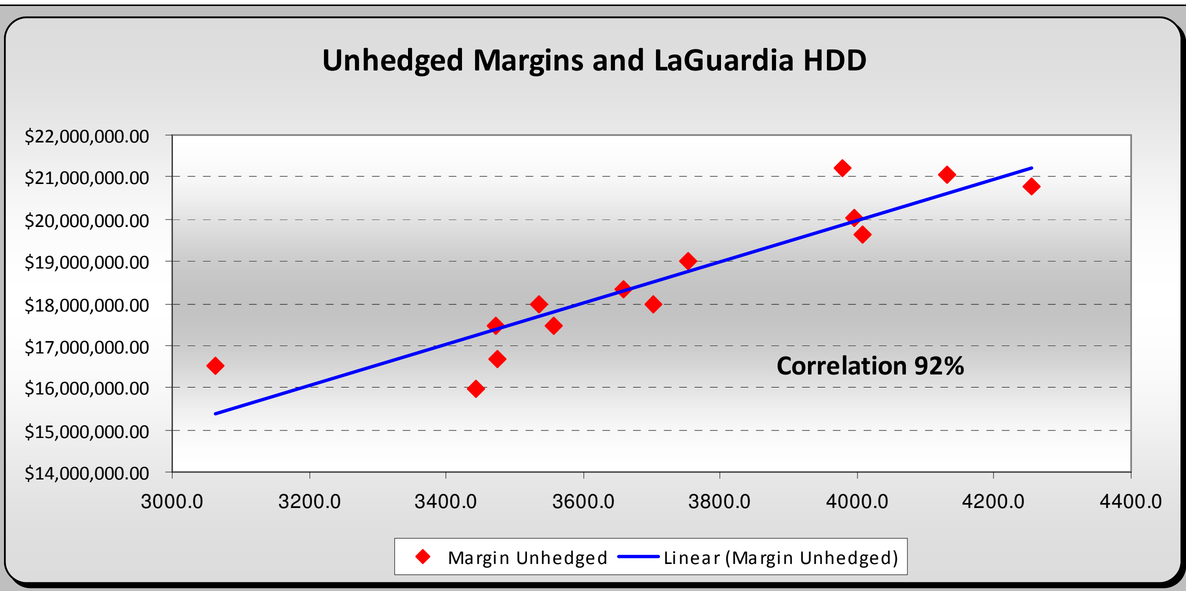
With respect to the first point, CME offers a seasonal strip heating degree days index futures swap contract for 24 US cities.[2] The contract is so named because the strip specifies a (consecutive) series of futures contracts that span a specific time period. The winter heating season strip typically spans November 1 to March 31. Further, a heating degree day is a temperature metric. Specifically, a heating degree day = max(65 – T, 0), where max is the maximum operator and T is the daily average temperature in degrees Fahrenheit.[3] For example, if the average temperature on a day is 35 degrees, the corresponding heating degree day is calculated as max(65-35, 0) = 35. As a counter example, if the average temperature on a day is 75 degrees, the corresponding heating degree day is calculated as max(65-75, 0) = 0. Third, the CME contract specifies a location. For our example, a New York winter heating season index is equal to the sum of the daily heating degree days from November 1 to March 31 at LaGuardia airport. The contract size is $20 times the respective CME Seasonal Strip Heating Degree Days Index.

In addition to the contract specifications, it is necessary to distinguish between the buyers and sellers of the futures contract. Buyers are deemed to be long the contract and sellers are said to be short the contract. To clarify further, consider one LaGuardia contract that trades on October 25 2009. The futures swap is traded at 3,760 heating degree days for the winter heating season, November 1 2009 to March 31 2010. Suppose further that the heating degree day index settles at 3,685 heating degree days. The pay-off to the long is (3685 – 3760) x $20 = -$1,500 and the pay-off to the short is +$1,500. Another useful way to think of the pay-offs is that the index settled warmer than 3,760 heating degree days and this profited the short.

Fortunately for Amigos, as shown in Figure I, there is in fact a 92% correlation between heating degree days and Amigos' unhedged margins and this convinces Amigos that a weather hedge will be effective. The type of hedge will be a heating degree day swap so that, as discussed above, Amigos receives payment in a mild heating season and Amigos pays out in a cold heating season. Amigos is said to be short the swap. To determine the size of the swap, Amigos estimates that each New York heating degree day is equivalent to approximately $5,000 in margin.

Figure I
Figure I depicts the correlation between winter heating degree days (at LaGuardia Airport in New York) and Amigos’ unhedged margins.

2 For a full list of CME weather products see www.cmegroup.com/trading/weather/.
3 T, the average daily temperature, is the average of the daily high and daily low temperatures.



Utilising the standardised CME weather contract requires Amigos to sell $5,000/$20 = 250 contracts to hedge its weather exposure.

Hedge results

The impact of any one heating season's weather hedge is contained in Table II. Amigos' unhedged margins, the swap pay-out and its hedged margins are compiled for the entire 14-year sample. For example, in the colder than normal 1997 heating season, Amigos' unhedged margin was $19.022 million and the weather swap required Amigos to pay out $0.188 million, such that the hedged margins totalled $18.835 million. In contrast, the warmer than normal 1998 heating season resulted in unhedged margins of $17.455 million, and the weather swap paid $1.215 million to Amigos, such that the hedged margins totalled $18.670 million.

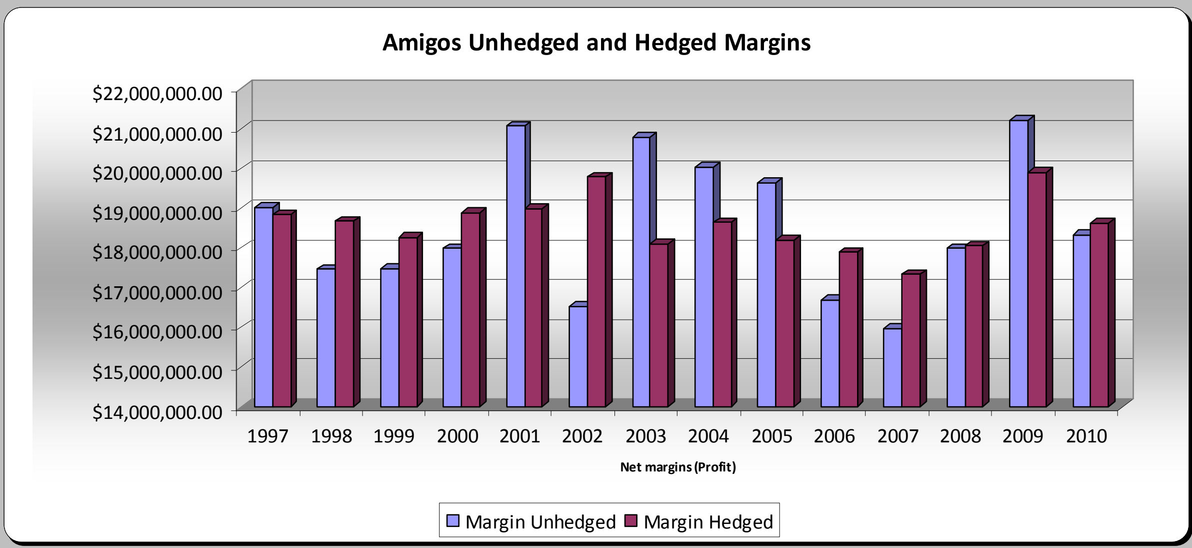
Table II

The swap was agreed at 3,716 heating degree days. The standard deviation of the unhedged margins is $1.6 million and the standard deviation of the hedged margins is $0.675 million.

Year	Heating degree days	Unhedged margins	Swap pay-out	Hedged margins
1997	3753.5	$19,022,500.00	$(187,500)	$18,835,000
1998	3473.0	$17,455,000.00	$1,215,000	$18,670,000
1999	3556.5	$17,467,500.00	$797,500	$18,265,000
2000	3535.0	$17,980,000.00	$905,000	$18,885,000
2001	4132.0	$21,070,000.00	$(2,080,000)	$18,990,000
2002	3063.0	$16,525,000.00	$3,265,000	$19,790,000
2003	4254.0	$20,785,000.00	$(2,690,000)	$18,095,000
2004	3994.5	$20,037,500.00	$(1,392,500)	$18,645,000
2005	4007.0	$19,645,000.00	$(1,455,000)	$18,190,000
2006	3475.5	$16,682,500.00	$1,202,500	$17,885,000
2007	3443.0	$15,960,000.00	$1,365,000	$17,325,000
2008	3701.5	$17,977,500.00	$72,500	$18,050,000
2009	3977.5	$21,212,500.00	$(1,307,500)	$19,905,000
2010	3658.0	$18,330,000.00	$290,000	$18,620,000

In addition to looking at any particular season's hedge, it is edifying to look at the backcast of all the hedges. In Figure II the unhedged margins are plotted side by side with the hedged margins. A quick inspection of Figure II suggests that the hedged margins are less variable than the unhedged margins. In fact, this is the case, with the unhedged margins having a standard deviation of $1.678 million and the hedged margins having a standard deviation of $0.675 million. Moreover, recalling that the expected margins are $18.582 million, the hedged margins are also $18.582 million. This is an artifact of ignoring transaction costs associated with the weather hedge. In practice, the hedged margins will be reduced by an amount proportional to brokerage commissions and the bid-ask spread in the weather market.[4]

Figure II
Figure II illustrates the reduction in margin volatility for Amigos.



Conclusion
Weather derivatives can be extremely effective hedges of volumetric risk. The weather hedge presented above is highly stylised and in our experience, our clients often seek hedging strategies that manage extreme (tail) weather risks. Weather options are particularly useful for managing extreme (non-linear) weather risks. Combining options and futures positions makes it possible to tailor a more effective weather hedge. Moreover, utilising weather options may benefit the hedger because of increased market depth, liquidity, price discovery and lower total costs.

Weather derivatives are increasingly incorporated in cross-commodity transactions. To wit, our clients are engaged in designing, managing and transacting weather contingent power and/or gas options. For example, gas retailers reticent to buy (sell) incremental gas volumes on very cold (warm) winter days, can purchase (sell) temperature contingent gas options. The main advantage of layering weather onto gas options is that a hedger can benefit from the correlation between temperatures and gas prices.

Finally, weather derivatives and hedges range from the ‘plain vanilla’ to the complex and exotic. As discussed earlier in this chapter, the fundamental co-integrated nature of the gas, power, coal and commodity markets generally extends naturally to weather markets.

4 Brokerage rates are negotiable. Assuming a one-quarter of a tick brokerage rate, Amigos would pay $5,000 / 4 = $1,250 in brokerage. New York (LaGuardia) is considered a deep and liquid seasonal heating degree day weather market.