

# Introduction to Commodities Derivatives

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# Introduction

- ▶ Energy Derivatives are unique.  
examples, load serving deals, swing options, power plants, storage
- ▶ Price Evolution Processes are unique: high volatility, price spikes, stochastic volatility, regime switching, correlation & need of joint distributions
- ▶ The Derivatives payoffs are unique  
Cash flows associated with energy assets could be solutions of complicated dynamic programming problem subject to a number of operational and environmental constraints
- ▶ Energy derivatives require Special Risk Management Tools

We would like to present ( on a very introductory level) some examples of typical energy derivatives and some of the techniques which could be used to provide evaluation and risk.

# Markets

Energy markets are a collection of commodities that are quite different in nature

1. Fuels: oil, gas, coal and their derivatives
2. Electricity
3. Weather, emissions
4. Agriculturals
5. Metals, as base metals and precious metals

As with any physical commodity the markets involve three sets of activities: production, distribution and consumption. The organizational details of the physical market have a substantial impact on the workings of the corresponding forward and derivative markets.

# Futures

Futures are highly standardized exchange traded contracts for purchase or sale of an underlying commodity at a specified price over a certain future period of time. Commodity futures require the following characteristics to be defined:

- ▶ Volume
- ▶ Price
- ▶ Delivery Location
- ▶ Delivery period
- ▶ Last trading date or settlement date

The attractive feature of futures contracts is the virtual elimination of counter party credit risk.

Example: Nymex gas futures, primarily traded on Nymex  
Specifications:

- ▶ Volume 10,000 MMBtu
- ▶ Price quotation: \$/MMBtu
- ▶ Delivery location: Henry Hub in Louisiana
- ▶ Delivery period: From the first day of the delivery month to the last day of the delivery month
- ▶ Delivery rate: As uniform as possible
- ▶ Last trading day: Six business days prior to the first calendar day of the delivery month

# Typical options in commodities

## Vanilla (European) Options

- ▶ call =right but not obligation to buy energy at a predetermined strike price
- ▶ put=right but not obligation to sell energy at predetermined strike price
- ▶ exercised once, at the specified date

- ▶ specifications typically include
  - location
  - delivery conditions (on peak, off peak)
  - volume
- Example: Monthly OPTION %) MW ERCOT on peak June 2016 \$60 call
- can be settled financially , using financial index

$$\Pi_{call} = \max(S - K, 0)$$

or physically ( options on power): buying power at the strike price and then selling power at spot market.

- ▶ can be priced using various valuation methodologies ( for example, the famous Black formula) . The important element in the valuation is the *volatility* of the underlying commodity.
- ▶ can be used for managing risk, as price spikes, outages, etc.



## Spread options

- ▶ Spread options are extremely important in energy markets. Practically every energy asset has a spread option embedded in it. Examples include power plant, storage, transmission, transportation, refinery.
- ▶ By definition, a spread option is an option on a spread. Thus an option holder has the right but not the obligation to enter into a forward or spot spread contract.
- ▶ Example 1 : power plant can be represented as a spark spread option, so an option on the spread between power and fuel prices. If  $P$  is the spot price of power,  $G$  is the price of fuel,  $HR$  is the heat rate (number of fuel unit needed to produce a unit of power) and  $V$  is the cost of running the plant, then decision to run or not to run the plant is straightforward. If

$$\Pi = P - HR * G - V > 0$$

then we will run the plant and sell the generated power for positive gain. If it is negative, then it is not economical.

## Examples of spread options

- ▶ Power plant can be run on more than one fuel. For example, if we have a choice of two fuels  $G_1$  and  $G_2$  then the payoff can be expressed as

$$\Pi = \max(P - HR_1 * G_1 - V_1, P - HR_2 * G_2 - V_2, 0)$$

so here we have maximum of two spreads. We also can have a situation when the cost is comprised of a basket of fuels and emissions

$$\Pi = \max(P - (HR * G + E) - V, 0)$$

- ▶ Example 2 : Transmission contract is a right to move power or gas from a liquid point A to a liquid point B. If  $T^{AB}$  is the tariff on moving a unit of power or gas from A to B, then the cashflows generated by the transmission contract can be expressed as

$$\Pi = \max(P^B - P^A - T^{AB}, 0)$$

# Correlation

- ▶ Evaluation of spread options is more complicated than vanilla, as it involves prices and volatilities of two legs ( or more), and also a *correlation* between them. Correlation is a crucial quantity in the valuation of many energy derivatives, and its modeling presents one of the biggest challenges.

## Asian options

- ▶ The Asian options are options on average price:

$$\Pi = \max(A_T^\tau - K, 0)$$

$$A_T^\tau = \frac{\sum_{i=\tau}^T S_i}{T - \tau}$$

The averaging period can start at the inception of the contract or at a later date. Often contracts do not have a fixed strike but rather are struck at the first of the month index price. They could be volume weighted as well.

- ▶ Asian options can serve as a price protection mechanism.
- ▶ Asian options might appear in combination with other structures. For example, there might an option on a spread of the average prices at two locations.

Not for redistribution

## Extendible options

- ▶ Extendible options are contracts in which one party has an option to extend the term of the underlying option on the same or modified terms (compound option).
- ▶ In commodities, extendible options are often options on spread options or on more complicated spread dependent structures such as energy assets.

## Examples of extendible options

- ▶ Typical example: call on toll : This compound option allows its holder to enter, if she chooses so, into a tolling agreement at some future date  $T_0$  in exchange for a specific payment  $K$ . Fundamentally, a tolling agreement can be viewed as a financial replication of a long term lease of a physical asset, such as a power plant. Call option on a toll is a relatively inexpensive way to have an access to a power plant in the future.

$$V_{toll} = S(t, F_1^{power}, \dots, F_1^{fuel}, \dots, \sigma_1^{power}, \dots, \sigma_1^{fuel}, \dots, V)$$

$$\Pi = \max(S(T_0, F_1^{power}, \dots, V) - K, 0)$$

The payoff of the call on toll option depends on the forward price and volatility data observed at the future time  $T_0$

## Valuation techniques used in commodities

- ▶ Options can be priced as solutions of Partial Differential Equations with certain boundary condition. For example, an European option on forward contract can be found as a solution of

$$\frac{\partial \Pi}{\partial \tau} = \frac{1}{2} \sigma^2 F^2 \frac{\partial^2 \Pi}{\partial F^2}$$

where  $\tau = T - t$  with boundary condition

$$\Pi(0, F) = \max(F - K, 0)$$

- ▶ MC methods are quite popular in commodities. Sometimes they are used in combination with optimization techniques.
- ▶ Optimization techniques is often used for valuation of energy assets.
- ▶ Knowledge of statistics, numerical methods is very important in commodities modeling.
- ▶ Data analysis, time series



- ▶ Linear algebra, linear programming program
- ▶ Stochastic processes, stochastic differential equations
- ▶ Good knowledge of programming languages is a must.

# Risk calculation

- ▶ Along with the evaluation of an asset or derivative, one needs to provide the sensitivities of the value with respect to the inputs.
- ▶ The sensitivities are important for hedging, P&L explanation, backtesting, calculation of overall risk (VaR)
- ▶ Energy derivatives could require special advanced techniques for calculation of risk.

# Types of risks

Besides the most obvious market risk there are other types which must taken into account:

- ▶ Execution risk - inability to execute trades at quoted prices and of necessary size
- ▶ Liquidity Risk - inability to hedge at the right time, at the right price, and at the right size, similar to execution risk
- ▶ Credit risk - inability to borrow cash to meet margin requirements

## Risk calculation for energy derivatives

- ▶ Evaluation of practically all energy derivatives involves optimization, therefore finding the boundary of optimal exercise. First, we investigate the role of those boundaries for sensitivities calculation. It turns out that for sufficiently “nice” payoffs, we can ignore the impact from boundary moves due to moves of inputs in interest.
- ▶ Due to the sophisticated nature of some energy derivatives, many pricing models could be very complex, and often involve MC methods, PDE, etc. Moreover, the current emphasis of the industry on quantitatively sound risk management practices increases computational challenges and operational cost. Therefore, the traditional methods for the calculation of the price sensitivities, as “bump and reval”, can be too expensive and inefficient, especially for energy derivatives in view of big number of inputs. They can also result in unstable, “noisy” Greeks.

## Examples of advanced techniques for risk calculation

- ▶ One of the techniques is the Operator Calculus, which gives useful relationships between different Greeks, see [Carr]. This can be useful in the calculation of the second derivatives Greeks, which is fundamentally more difficult than the first order Greeks.
- ▶ Another one, is the Adjoint Greeks calculation [Grienwak, Walter], can be very efficient for path dependent payoffs valued with MC methods. Commodity derivatives typically have a large number of inputs. Therefore the standard methods of calculation of sensitivities by “bumping” can be very expensive computationally. For the adjoint calculation of risk, the computational cost does not increase with the number of inputs.

## Example : power generation

A typical power plant would have the following characteristics (simplified version)

1.  $HR$  marginal heat rate as a function of generation level
2.  $C_{min}$  minimum generation level and  $C_{max}$  maximum generation level (could be a function of temperature)
3.  $SC$  fixed start up, a function of the time from the latest shutdown
4.  $FSC$  fuel start up: the amount of fuel required for a start up. A function of the time from the latest shutdown
5.  $PSC$  power start up, : power consumption at start up (from the grid). A function of the time from the latest shutdown
6.  $VOM$  variable , cost to run the power plant
7.  $D_{min}$  minimum run time
8.  $D_{shutdown}$  minimum time after a shutdown at which one can attempt a start up again
9.  $D_{start-up}$  start up duration, the time from the decision to start up to unit availability ...

The decision variables include

1.  $q$  generation level
2.  $u^{on}$  start up decision 1 -start up, 0 no start up
3.  $u^{off}$  shutdown decision, 1 shutdown, 0 no shutdown

The state variables are given by

1.  $P_{ti}$  power price on day  $t$  at hour  $i$
2.  $G_t$  natural gas fuel price on day  $t$
3.  $\Theta_{ti}$  temperature on day  $t$  hour  $i$
4.  $d^{start-up}$  time from the latest start up
5.  $d^{shut}$  time from the latest shutdown
6.  $U_{ti}^{on}$  operational status online or offline
7.  $U_{ti}^{off}$  operational offline status

The decisions are performed in the day ahead market : the operator can structure a bid so that he is assured of non negative payoff, if he dispatched or gets zero if his bid is out of merit and the unit will not be committed.

In the deterministic case, if we know all the prices, etc the optimization problem can be formulated as follows

$$\Pi = \max_{q,u} \sum [q_{(t,i)} (P_{(t,i)} - HR(q_{(t,i)}, \Theta_{t,i}) G_t - VOM) \dots - u_{(t,i)}^{on} (SC(d_{t,i}^{sht}) + FSC(d_{t,i}^{sht}) G_t + PSC * d_{t,i}^{sht}) P_{(t,i)})]$$



such that we satisfy all the operational constraints



1. The generation level is within feasible levels
2. The changes in the generation level are in allowed levels
3. The unit remains off if not enough time has elapsed since the most recent shutdown
4. The unit stays on if the minimum run time has not yet elapsed

The list by no means exhaustive, and in reality the optimization might be much more complicated ( multi fuel capability, optimization across power markets, optimization across settlements, etc.) Plants often have particular features.

In reality, in making the operational decisions, we have to account for uncertainty. The problem can be reformulated in terms of stochastic dynamic program. In that framework we reflect the impact of uncertainty on the decisions by optimizing the choices with respect to the conditional expectations of the impact of our decisions on the future cash flows.

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