# Energy Economics, Winter Semester 2026-7
# Lecture 5: Energy Trading

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# Introduction to Energy Trading

# What is energy trading?

**Trading** is buying and selling, i.e. exchanging commodities.

A **commodity** is a homogeneous product – uniform and standardised.

Examples of commodities: agricultural (wheat, coffee), metals (gold, steel) etc.

Examples of energy commodities: electricity, natural gas, crude oil, LNG, coal.

Related markets: freight, CO2 emission allowances.

Distinguish between **underlying** commodity and **derivatives** (e.g. futures, forwards, options, swaps) that **derive** their value from the underlying assets.

Energy trading has parallels to financial markets (shares, bonds and other financial instruments) – even with its particularities due to the physical nature of electricity (gas/oil/coal etc.) as underlying.

# Energy versus financial markets

Future prices cannot be predicted based on historical prices.

The best prediction of tomorrow's price $p_{t+1}$ is today's price $p_t$.

The unique reason for a change in price is arrival of "news" not correlated with information available at time $t$.

Transparency (availability of information to all market participants) is a crucial prerequisite for efficient market functioning.

# Trading forms: Exchange versus OTC

**Mediated trading**: pool or exchange

- organised auction resulting in a uniform price
- highly standardised products; no room for negotiation
- transparency
- regulated
- clearing and colateral costs

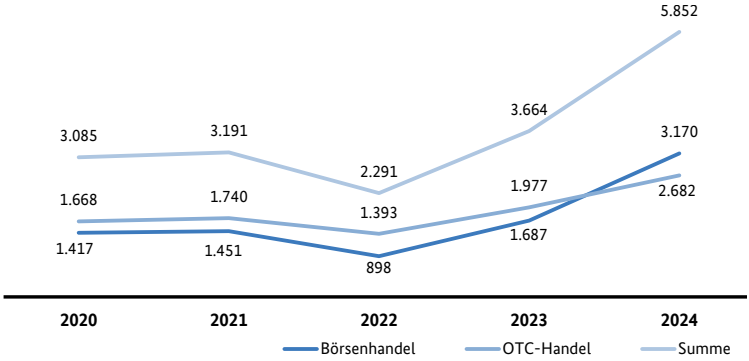
**Bilateral trading**: over-the-counter (OTC)

- intermediation cost (opportunity cost or broker fee)
- individual prices agreed between pairs of buyers and sellers
- ($\sim$ pay-as-bid principle)
- standard framework agreements: EFET/GTMA; ISDA; DRV etc.
- unregulated

Typically: Combination of exchange and OTC trading.

# Exchange trading and registered OTC futures

German power futures: trades executed on EEX versus OTC deals later registered for clearing (TWh):




**OTC** deals are agreed outside the exchange. Some are later registered with EEX/ECC for clearing; others are settled bilaterally or cleared elsewhere. The chart counts only EEX-registered deals.

Source: BNetzA/BKartA, Monitoring Report 2025, Fig. 80

# What is a trading product?

A **trading product** is combination of transaction features:

| Feature | example |
|---|---|
| **Underlying asset** | electricity |
| **Delivery point** | TSO control area |
| **Delivery period** | start date / end date |
| **Delivery amount** | contract capacity [MW] / contract quantity [MWh] |

A **bid** (offer to buy) or **ask** (offer to sell) is characterised by: product, price, trading day and time.

# Product types

## Physical vs. Financial

- Physical product implies physical delivery of the underlying (i.e. electricity).
- Financial product implies exchange of cash without physical delivery (no set-up with TSO required) $\rightarrow$ Swap.

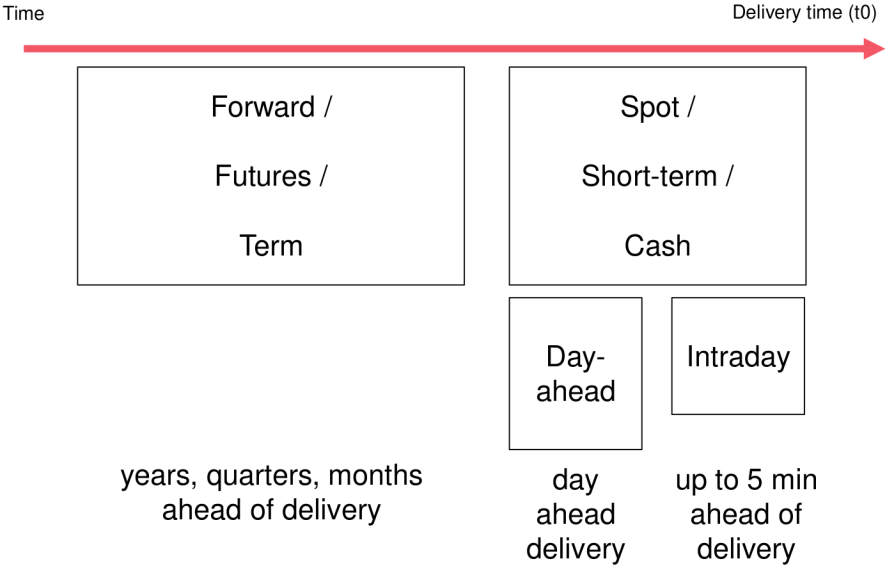
## Fixed-price vs. floating price (index-based)

- Fixed price is stated as an amount of money per unit of underlying.
- Floating price is determined by reference to a price index publication at a time point after deal conclusion.

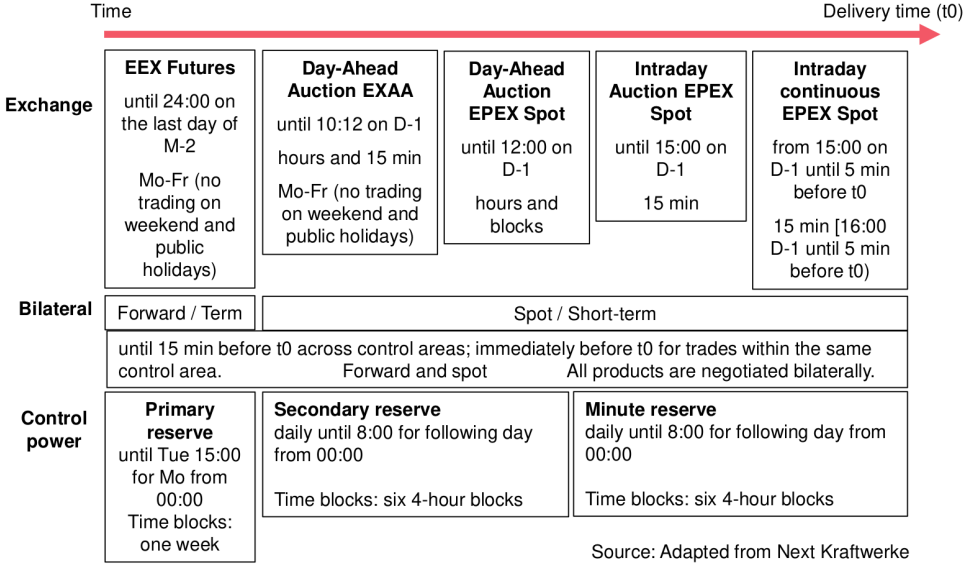
## Fixed-amount vs. options

# Submarkets and trading forms

# Energy sub-markets

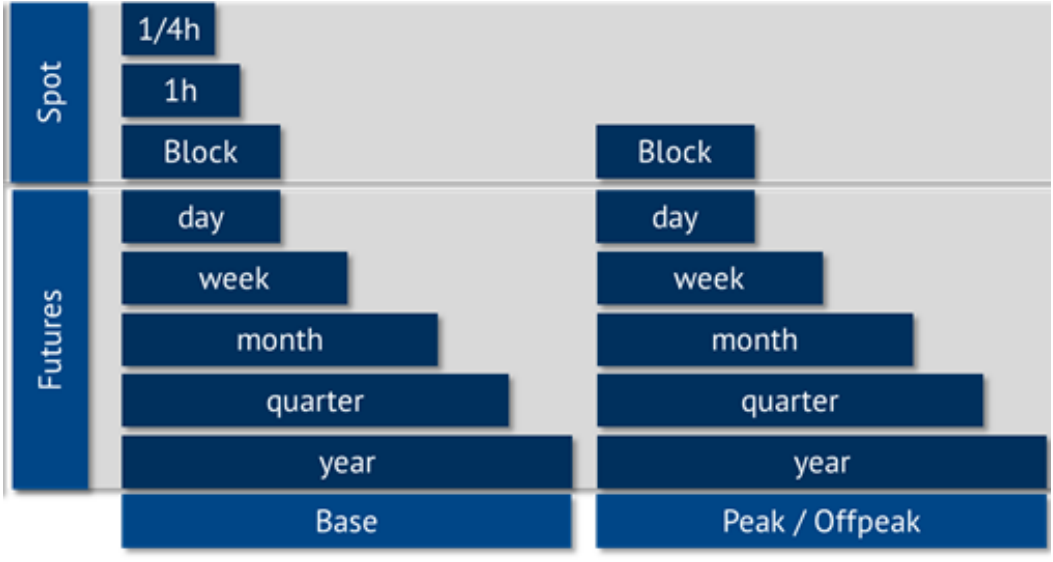


# Energy sub-markets: detail for electricity




Source: Adapted from Next Kraftwerke

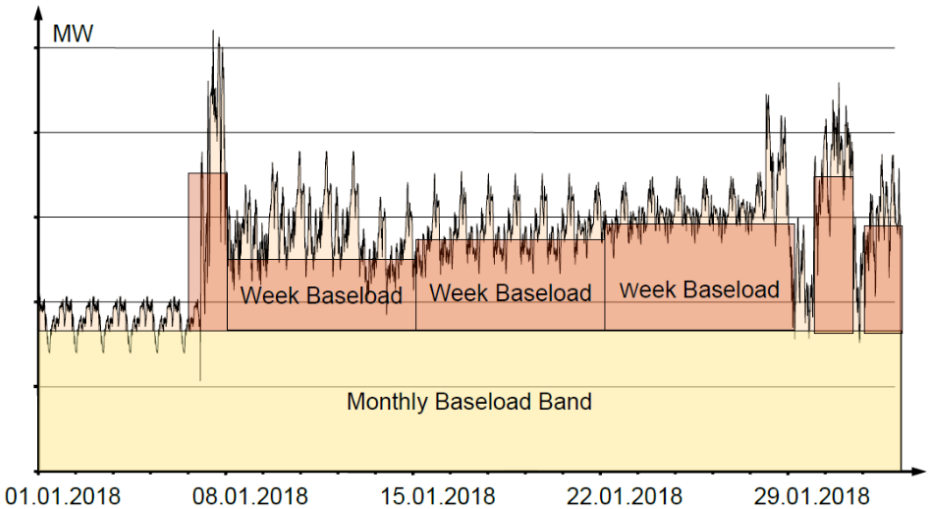
# Electricity product types based on delivery period



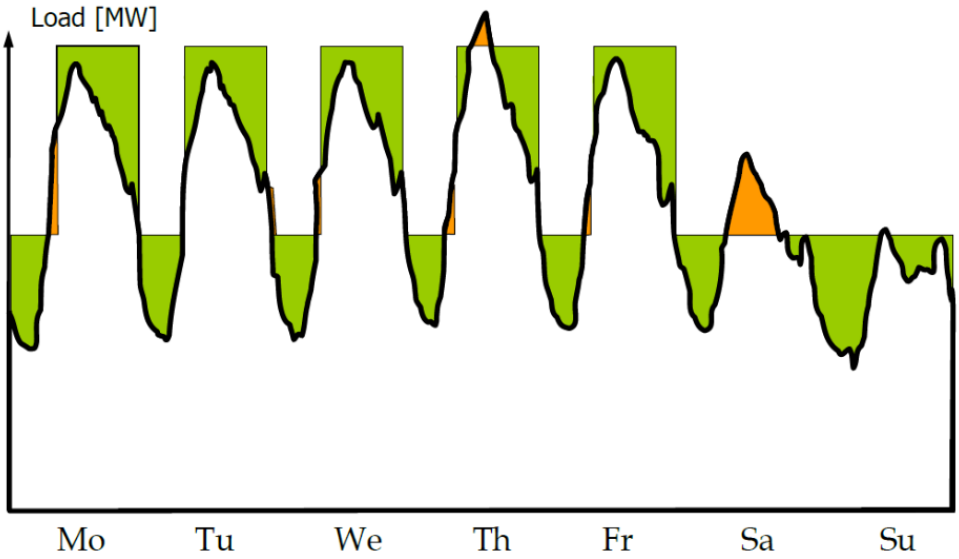

Source: Energy Brainpool

# Sample power purchase portfolio

Standardised futures do not match with typical load schedules.

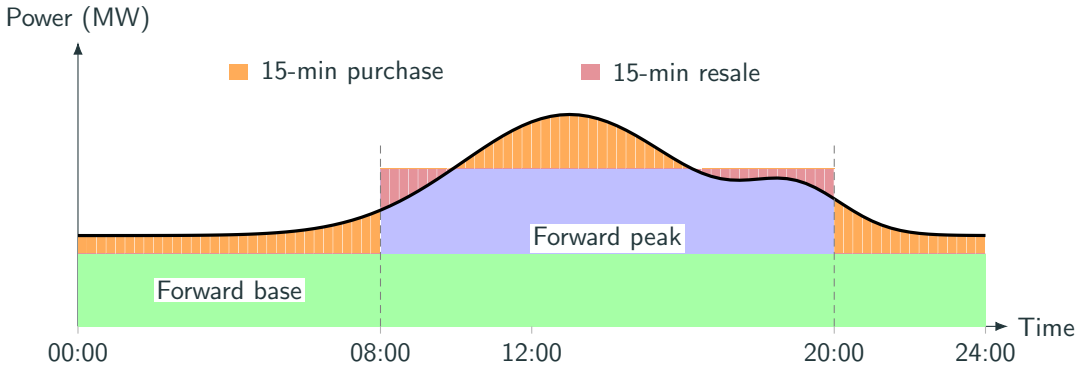


# Portfolio management of a power retailer



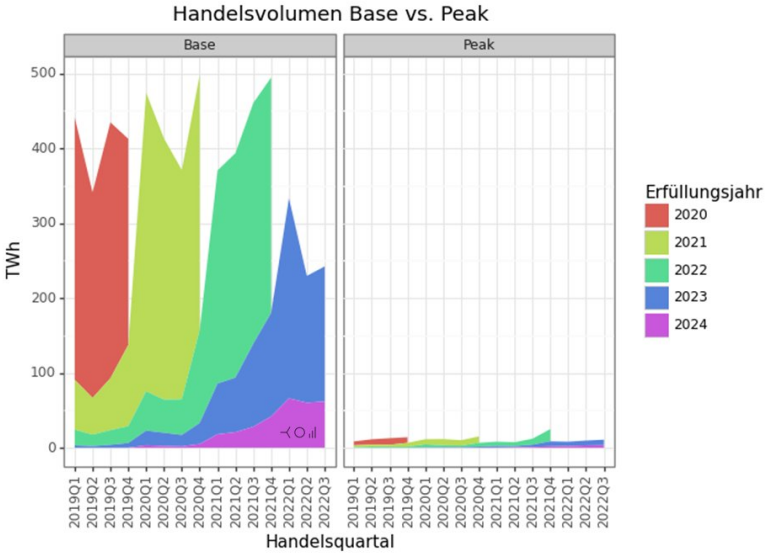
# Day-ahead contracts for quarter-hours

Base covers the full day; peak covers 08:00–20:00. Day-ahead trades fill gaps and resell excess purchases.




Source: ENTSO-E, SDAC (2025)

# Historical example: base and peak futures trading






Source: Lion Hirth, 2022; historical example

# EPEX Spot Day-ahead auction

A **spot market** is for short-term physical delivery 'on the spot', as opposed to futures.

The EPEX Spot day-ahead auction has the following features:

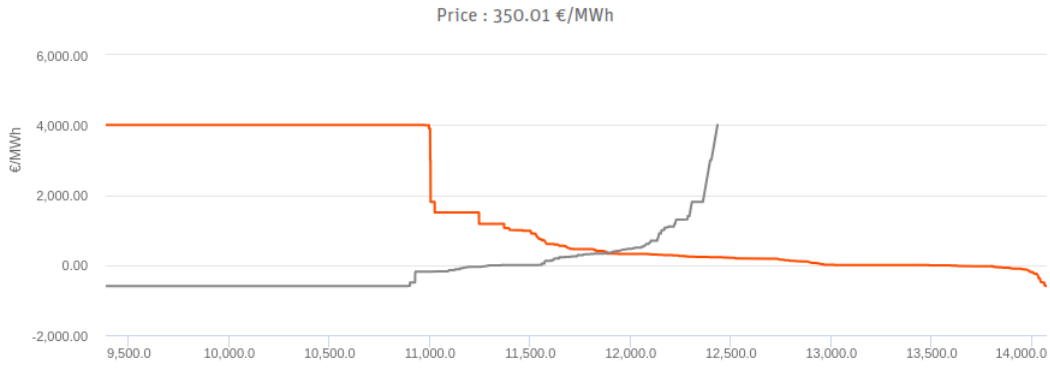
- Double-sided auction: bid and ask order book (order book trading)
- Uniform price auction: one market clearing price for each 15-minute period
- Quarter-hourly products (hourly until October 2025); block orders can link periods
- Occurs daily at 12h for delivery on the following day (0-24h) (i.e. **day-ahead**)
- Results published after market coupling and clearing



Source: ENTSO-E, Single Day-ahead Coupling

# Aggregated day-ahead bids: real example

**EPEX SPOT**: aggregated bids for one 15-minute delivery period in DE–LU (9 November 2026, 10:15–10:30). The supply curve ranks *sell bids* by price. It is not the physical merit order of generators: traders may resell electricity bought earlier.




Source: **EPEX SPOT, 2026**

# Day-ahead product: delivery periods

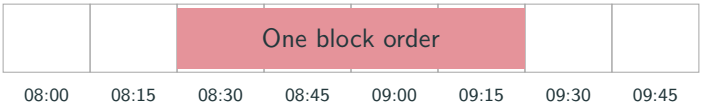
- The coupled day-ahead auction clears **15-minute market time units** for delivery the following day.
- A normal day has 96 such periods; clock changes give 92 or 100.
- A separate market clearing price is published for each period and bidding zone.
- Germany and Luxembourg form one bidding zone; the former Germany–Austria zone ended in 2018.



Source: ENTSO-E, Single Day-ahead Coupling

# Day-ahead product: block orders

A block order links several delivery periods: acceptance is decided for the linked profile, subject to its order conditions.



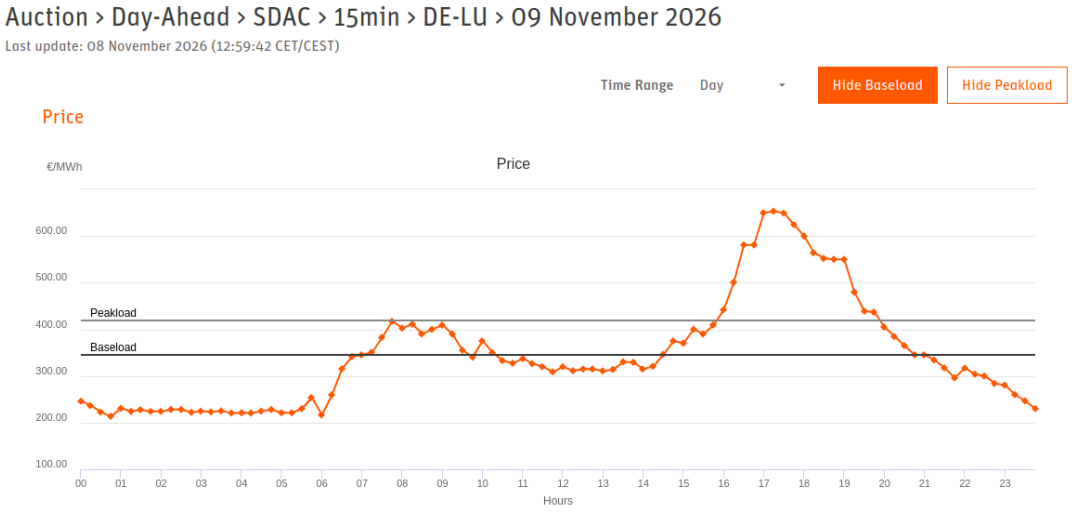

Its acceptance depends on the prices across the covered periods; each period still has its own clearing price.



Source: ENTSO-E, Single Day-ahead Coupling

# Day-ahead results from 2026 for DE-LU

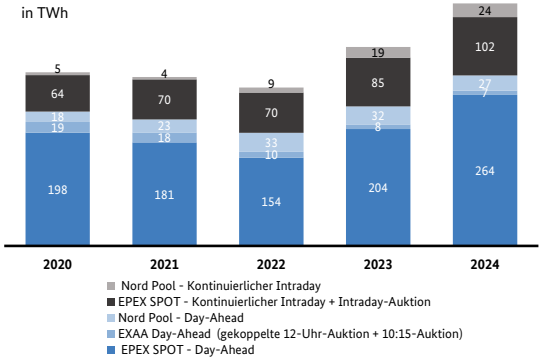
Baseload is all day, peakload is for 8am to 8pm.




Source: EPEX SPOT, 2026

# Spot trading volumes in Germany

Volumes traded on German day-ahead and intraday exchanges (TWh):




These are trading volumes, not exclusive shares of electricity consumption: positions can be bought, sold and adjusted more than once.



Source: BNetzA/BKartA, Monitoring Report 2025, Fig. 72

# Intraday market

The **intraday market** reflects a growing need for flexibility close to delivery due to uncertain forecasts for demand and variable renewables.

The intraday market serves for adjusting trading positions based on corrected forecasts closer to real-time.

Products:

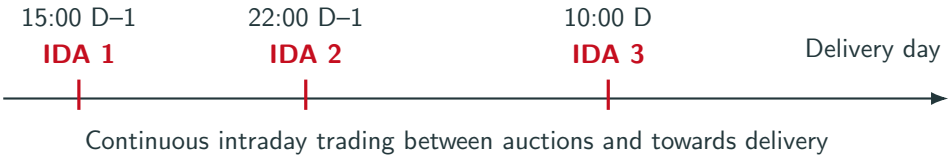
- 15-minute auctions at 15:00 and 22:00 (D-1) and 10:00 (D)
- continuous intraday trading close to delivery; gate closure depends on the market

Continuous: as soon as two entered bid and ask orders match, the trade is executed (cf. shares and bitcoin trading).



Source: ENTSO-E, Intraday Auctions on SIDC

# Three intraday auctions and continuous trading



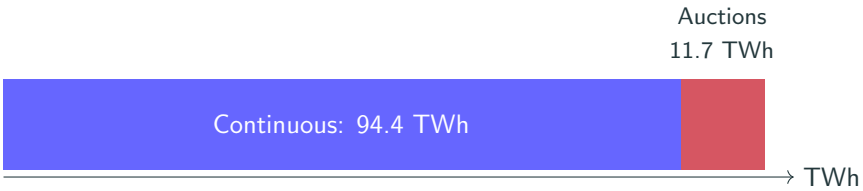

The three auctions price cross-border intraday capacity. Continuous trading matches orders as they arrive.



Source: ENTSO-E, Intraday Auctions on SIDC

# German intraday trading at EPEX SPOT in 2025

EPEX SPOT traded **106.0 TWh** in the German intraday market in 2025:




This counts trades on EPEX SPOT, not all German intraday exchanges or physical consumption. (Other exchanges offering German intraday include Nord Pool and ETPA.)



Source: EPEX SPOT, Annual Trading Results 2025, p. 8

# Balance group concept

# Balancing group: Linking the virtual and physical worlds

A **balancing group** (BG) is a virtual energy volume account associated with one or more grid users within a control area.

- each grid connection point is allocated to one balancing group
- example: electricity supplier for a group of customers, or power plant
- **balance responsible party** (BRP) is responsible for balancing its BG's saldo (feed-in and consumption) for each 15 min – incl. through trading on spot markets
- remaining deviations are settled at the imbalance price

Analogy to a bank account:

| TSO | Bank |
|---|---|
| Balance responsible party | Account holder |
| EIC | Account number |
| Balancing group | Bank account |
| Energy delivers | Payments |

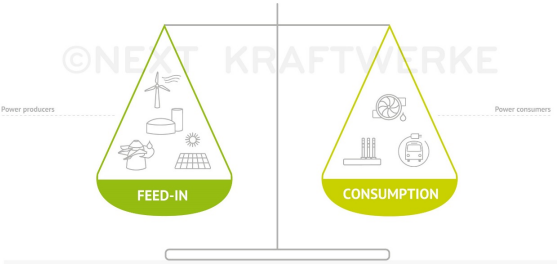
# Balancing group: Linking the virtual and physical worlds

Trading on transmission grid level, i.e. performing delivery by scheduling to TSO, assumes no physical restrictions within a market area.

Depending on the nature and composition of a balancing group, the BGR transmits to the TSO forecasted load or generation and/or buy and sell amounts.

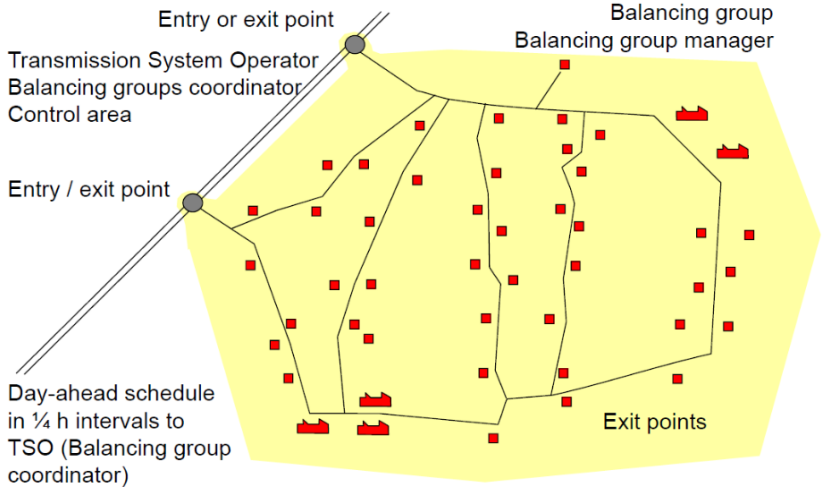
Imbalance fee is uniform for the control area (in Germany: for all four control areas), symmetric and based on actual activation of control power.

Schedule is power per time unit exchanged between BCs, fed into or consumed from the grid.



# Balancing groups across grid levels (1/2)

BRPs schedule and balance their portfolios; the TSO coordinates the control area and settles deviations.

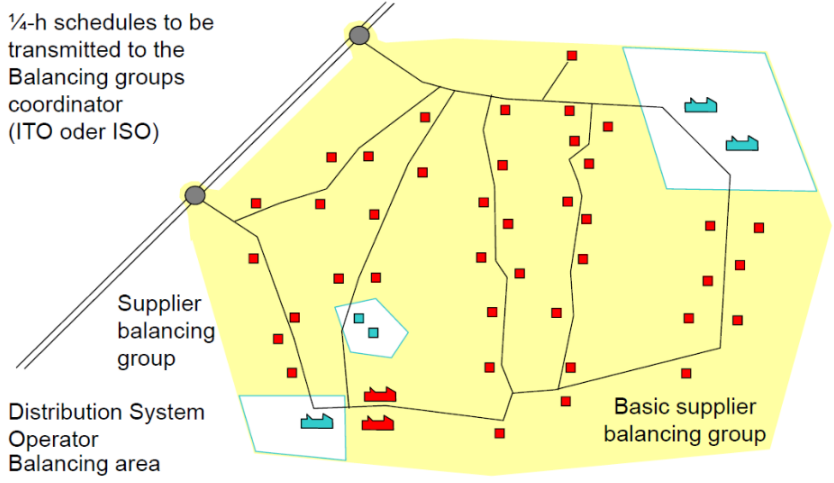





Source: German standard balancing-group contract

# Balancing groups across grid levels (2/2)

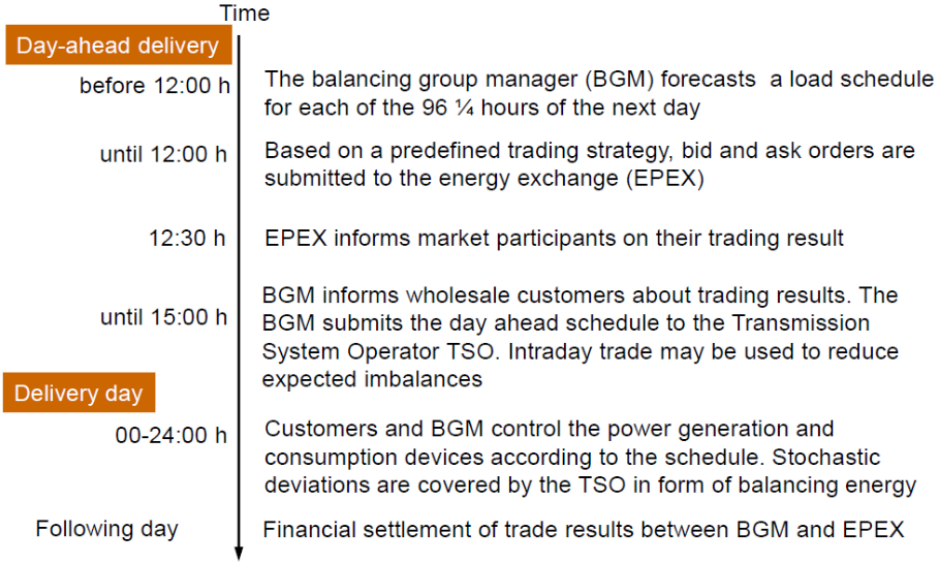
The DSO assigns connections and supplies metering data. The same balancing groups extend through the distribution grid.






Source: Amprion, Balancing areas

# Tasks of the balancing group management



# Reasons for imbalances

- Unplanned outage of generation units
- Unplanned outage or activation of large loads
- Forecast gap in variable RES generation
- Inaccurate forecast of demand

# Futures, options and hedging

# Trading motives and trader types

Trader categories:

- **asset-backed** – trade to optimise assets / hedge price risk
- **merchant / proprietary** – trade to speculate / gamble

Generators have a natural net **long position**: their value increases with rising prices.

Final consumers have a natural net **short position**: they benefit from falling prices.

Marketers who buy and resell power can be long or short.

Generators are exposed to volatile fuel prices / fixed selling prices.

Retailers are exposed to volatile purchase prices / fixed selling prices.

# Trading strategies: Managing price risk

**Risk** is a source of **uncertainty** about the future, that could involve a **potential loss**.

E.g. our business model depends on future prices for what we sell and our material inputs, on interest rates, on demand, on political developments.

There is a fundamental tradeoff between risk and return.

E.g. for a higher risk, we expect a higher return to offset the possibility of loss.

Risk management is identifying and analysing risks and deciding if to accept or mitigate uncertainty.

The goal is to achieve an optimal risk-return profile of a portfolio.

# Purpose of hedging

Hedging is reducing risk (i.e. uncertainty) by taking a position that offsets the risk of the existing position (equal and opposite exposure to the same underlying asset). Hedging limits a potential loss and reduces a potential profit.

Final consumers (industrial and commercial), typically, lack trading capability and sufficient market insight and resort to hedging for better cost planning.

Traders hedge positions that they are not able or willing to close (e.g. long-term supply contract at a fixed price).

Generators like wind and solar projects may hedge the price risk via long-term fixed-price power purchase agreements (PPA) to facilitate financing.

# Energy sub-markets: futures and forwards

A **forward contract** is a non-standardized contract between two parties to buy or to sell an asset at a specified future time at a price agreed upon today. They are bilateral and not exchange-traded.

A **futures contract** is a standardized contract between two parties to buy or sell a specified asset of standardized quantity and quality for a price agreed upon today with delivery and payment occurring at a specified future date. They are traded on an exchange.

In 98% of cases physical delivery of energy futures does not take place, and the futures contract is closed financially or by buying or selling another futures contract on or near the delivery date.

The forward and futures markets are key markets for trading, speculation, and risk management, allowing market participants opportunities to manage or **hedge** price risks.

In electricity, around 80-90% of power needs of retailers and other consumers are secured through futures and forwards. Less than 20% is covered by the spot market.

# Long and short positions

An entity is **long** on a commodity if it benefits from a price increase.

Example: a generator is long on electricity, since they hope electricity prices will rise.

An entity is **short** on a commodity if it benefits from a price decrease.

Example: an electricity consumer is short on electricity, since they hope prices with drop.

A marketer who buys and resells power can be either long or short. If they have bought fixed-price power before finding a market for that power they are long; if they have sold fixed-price power before securing supply they are short.

# Pricing futures

The price of a futures contract is a function of:

- the underlying asset's spot price
- interest rates
- storage costs
- expectations of future supply and demand conditions

Most important is the current price of the underlying cash commodity.

Even though actual delivery is quite rare, the possibility of delivery provides the critical link between spot and futures markets, enabling arbitragers to profit when prices get too far out of line.



Source: Stoft et al, 1998

# Pricing futures: example

A firm expects to need 1000 barrels of oil in 6 months' time. The firm can either buy the commodity today and store it for 6 months ("buy and store" approach) or purchase a futures contract for delivery in 6 months.

Suppose the futures price for delivery in 6 months is \$ 18/barrel.

What does "buy and store" cost? Spot price today is \$ 16/barrel, storage for 6 months is \$ 1/barrel and the interest rate is 10%. Total cost:

| | |
|---|---|
| \$ 16.00 | spot price |
| \$ 0.80 | opportunity cost of investment (\$ 16 · 10% · 0.5 years) |
| \$ 1.00 | storage cost |
| \$ 17.80 | total |

⇒ Firm should choose "buy and store" approach. Firm could do this for more barrels, then sell a futures contract for riskless profit. If too many firms do this, price of future will come down.



Source: Stoft et al, 1998

# How electricity generators and consumers use futures to hedge

An entity with a long position in the electricity market (e.g. generator) can hedge by selling a future.

An entity with a short position (e.g. consumer) can hedge by buying a future.

E.g. if a generator has a marginal cost of 15 €/MWh, they may choose to sell a future for next month with a price of 20 €/MWh to lock-in a profit now. By avoiding a loss, they forgo potential profit if the spot price is higher than 20 €/MWh.

The generator now has a **short futures position**, i.e. they profit from the future when prices decline below 20 €/MWh.

If a consumer has a marginal benefit of 100 €/MWh, they may choose to buy a future with a price of 20 €/MWh to lock in the benefit. They forgo benefit if the spot price is lower than 20 €/MWh.

The consumer now has a **long futures position**, i.e. they profit from the future when prices go above 20 €/MWh.

# How electricity generators and consumers use futures to hedge

Hedgers mitigate risk by taking opposite positions in the physical and futures markets.

| | End User | Generator |
|---|---|---|
| Cash Position | **Short** the physical commodity (electricity) at a future date. | **Long** the physical commodity (electricity) at a future date. |
| Risk from Cash (Physical) Position | | |
| • Spot Price Increase<br>• Spot Price Decrease | Profits decrease ↘<br>Profits increase ↗ | Profits increase ↗<br>Profits decrease ↘ |
| Hedge<br>(Futures Position) | **Long** Electricity Futures.<br>(bought futures) | **Short** Electricity Futures.<br>( sold futures) |
| Risk from Futures Position | | |
| • Spot Price Increase<br>• Spot Price Decrease | Profits increase ↗<br>Profits decrease ↘ | Profits decrease ↘<br>Profits increase ↗ |

With a **perfect hedge** the magnitude of the corresponding gains and losses in the physical and futures positions will be exactly the same.



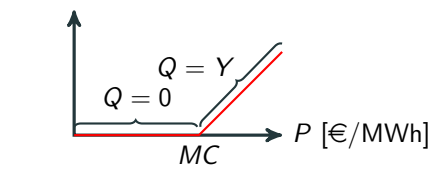
Source: Stoft et al, 1998

# Generator hedges price risk

Consider a generator with linear cost function $C(Q) = MC \cdot Q$, capacity $Q \leq Y$.
It maximises profit:

$$\Pi_G(Q, P) = P \cdot Q - MC \cdot Q$$

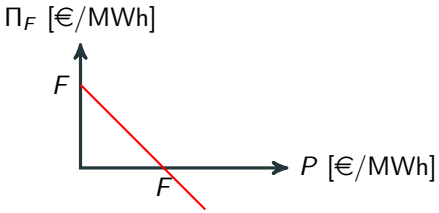
If $P < MC$ it doesn't run $Q = 0$ and if $P > MC$ it runs at maximum capacity $Q = Y$.




For the sale of its generation, it has a **long** position (i.e. benefits from high $P$).

If it had sold a future for quantity $X$ at price $F$, it must settle the future based on the current spot market price $P$. Its total income from the future is now:

$$\Pi_F(P) = F \cdot X - P \cdot X$$




For the future it has a **short** position (i.e. benefits from low $P$).

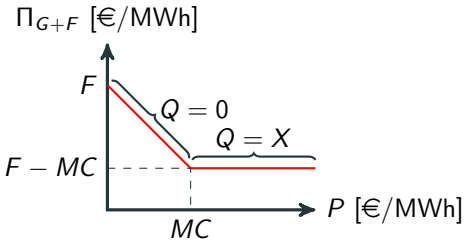
# Futures allow to hedge without distorting real-time incentives

Combining the generation income with the future, the generator maximises net income:

$$\Pi_{G+F}(Q,P) = P \cdot Q - MC \cdot Q + F \cdot X - P \cdot X$$

NB: The future only affects the original profit function $\Pi_G(Q,P)$ by a constant that doesn't depend on output $Q$, so its behaviour is still the same! Its real-time incentives remain: if $P < MC$ then don't run $Q = 0$ and if $P > MC$ then run at $Q = Y$. **Futures do not distort real-time incentives.**

If the future quantity is equal to the generator's capacity $X = Y$ then the generator is perfectly hedged and can even benefit when prices go below $MC$:

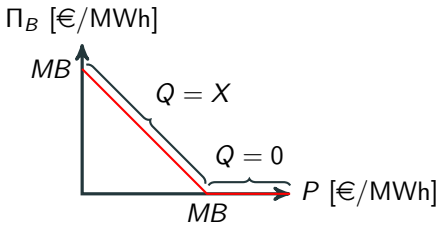


# Consumer hedges price risk

Considerations are similar for consumers.
Assume a linear benefit function $B(Q) = MB \cdot Q$, consumption capacity $Q \leq Y$.
It maximises net benefit:

$$\Pi_B(Q, P) = MB \cdot Q - P \cdot Q$$

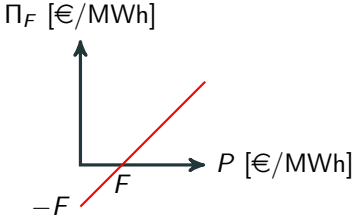
If $P > MB$ it doesn't consume $Q = 0$ and if $P < MB$ it consumes at max capacity $Q = Y$.




For energy consumption, it is **short**.

If it had bought a future for quantity $X$ at price $F$, it would receive on expiry the current spot market price $P$. Its total income from the future is now:

$$\Pi_F(P) = -F \cdot X + P \cdot X$$




For the future it has a **long** position (i.e. benefits from high $P$).

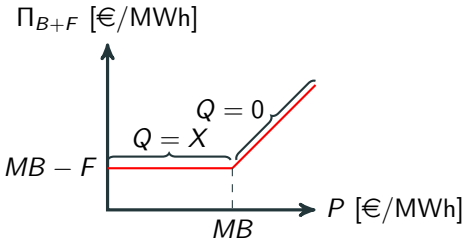
# Futures allow to hedge without distorting real-time incentives

Combining the consumption net income with the future, the consumer maximises net benefit:

$$\Pi_{B+F}(Q,P) = MB \cdot Q - P \cdot Q + -F \cdot X + P \cdot X$$

NB: The future only affects the original profit function $\Pi_B(Q,P)$ by a constant that doesn't depend on $Q$, so its behaviour is still the same! Its real-time incentives remain: if $P > MB$ then don't consume $Q = 0$ and if $P < MB$ then consume at $Q = Y$. **Futures do not distort real-time incentives.**

If the future quantity is equal to the consumer's capacity $X = Y$ then the consumer is perfectly hedged and can even benefit when prices go above $MB$:



# End of futures contract

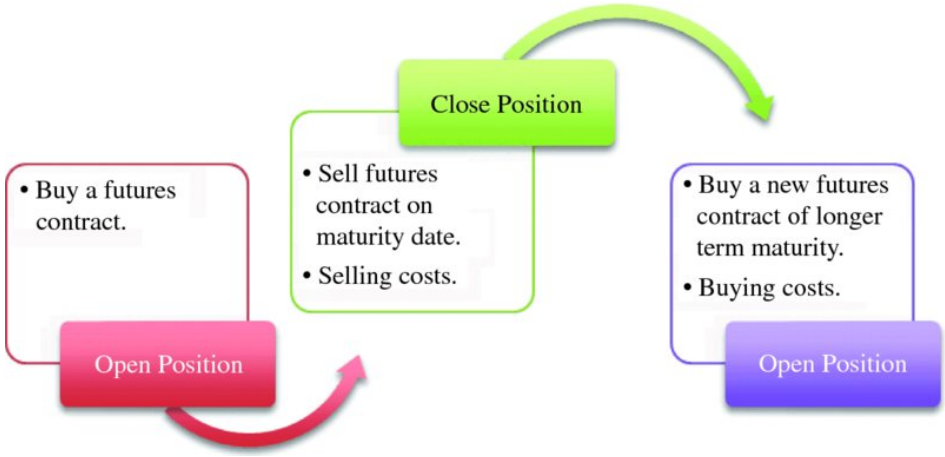
When a futures contract ends you have three options:

- **Settle** the contract by providing the underlying service (physical settlement, e.g. electricity) or cash (financial settlement).
- **Offset** position by taking out opposite and equal transaction. E.g. if you sold 2 futures for September, need to buy 2 futures for September. The difference in price between initial and offset position is the profit/loss on trade.
- **Rollover**, i.e. offset existing position, buy future for next period. When rolling forward, a trader will simultaneously offset their current position and establish a new position in the next contract month.

Electricity futures can also **cascade** nearer delivery into shorter-term products.

# Rolling

Rolling, i.e. offseting an existing position and buying a future for the next period, enables a trader to maintain the same risk position beyond the initial expiration of the contract.




Source: Source: Mack, Energy trading and risk management, 2014

# Cascading

**Cascading**: At the beginning of the delivery period, the initial product splits into a set of equivalent shorter-term products. Longer maturities cascade into corresponding shorter maturities. For example, a future for year 2022 will cascade in December 2021 into futures for months Jan, Feb, Mar in 2022 and for quarters 2, 3, 4 in 2022.





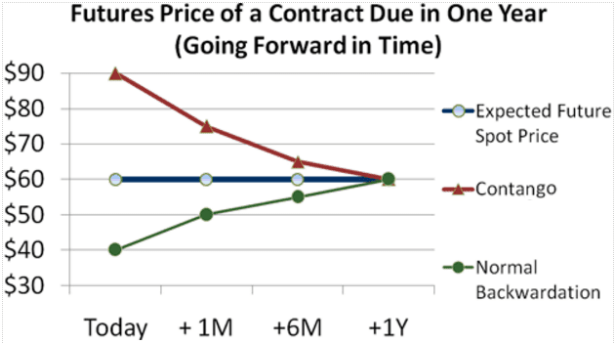

Source: Trading Technologies

# Futures market: price development patterns

**Contango**: futures price exceeds the spot price.

**Backwardation**: spot price exceeds the futures price.

Market participants are driving the futures price up/down in line with their expectations.




Since producers are less diversified than consumers, they have higher risk and would tolerate lower futures prices, so we expect backwardation to be the norm.

Source: Source: Mack, Energy trading and risk management, 2014

# Options

An **option** gives the holder the right, but not the obligation, to buy or sell a specified quantity of an underlying on (or before) a specified future date, at a predetermined price.

Excercising the option is buying or selling the underlying.

- **Call option** is a right to buy.
- **Put option** is a right to sell.

Expiry (expiration/maturity date) is the date on (or until) which the option can be excercised.

- European options can be excercised only at expiry.
- American options can be excercised at any time up to expiry.

**Strike (exercise) price** is the pre-agreed buy or sell price.

Option **premium** is a fixed amount paid by the holder (option buyer) to the writer (option seller) upon concluding an option.

# Options Pricing

Suppose a stock costs € 34.80 today. Consider the premiums of particular strike prices for call (right to buy) and put (right to sell) options that expire in 1 month:

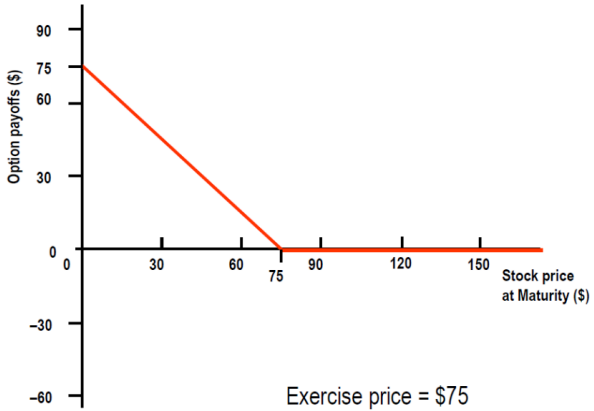
| Strike Price | Call Option Premium | Put Option Premium |
|---|---|---|
| 30 | 5.00 | 0.01 |
| 35 | 0.53 | 0.60 |
| 40 | 0.01 | 6.00 |

The higher the strike price, the lower the call option premium and the higher the put option premium. For an option expiring in 9 months, premiums are higher since there is more risk:

| Strike Price | Call Option Premium | Put Option Premium |
|---|---|---|
| 30 | 6.85 | 1.17 |
| 35 | 3.70 | 2.83 |
| 40 | 1.75 | 5.55 |

# Put Option Payoff

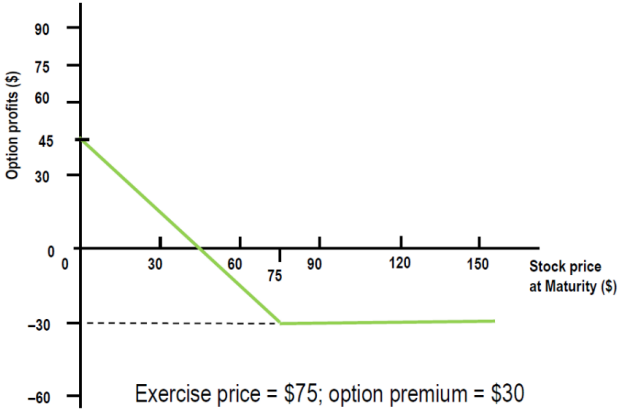
Suppose we purchase a put option (i.e. right to sell) with an exercise price of \$75 and a premium of \$30. If the spot market price at maturity is less than \$75, we can buy at the lower price, then sell at \$75. If the price is more than \$75 then we do not exercise the option.



# Put Option Profit

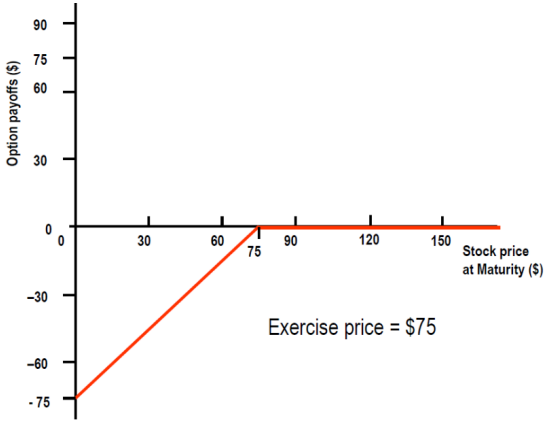
But remember we still have to pay the option premium which offset the payoff. We will make a loss if the spot price is below $45.

Note that the premium will be higher the higher the exercise price is.



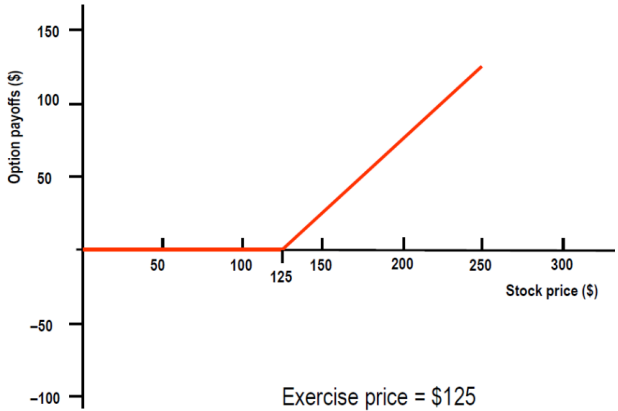
# Put Option Writer Payoff

For the writer who sold the option, the payoff is opposite.



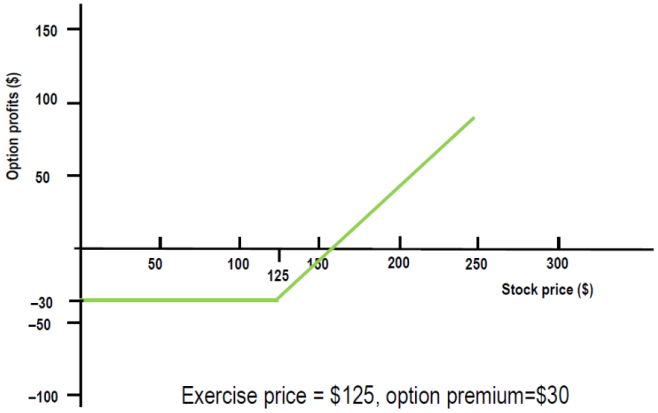
# Call Option Payoff

Suppose we purchase a call option (i.e. right to buy) with an exercise price of $125 and a premium of $30. If the spot market price at maturity is more than $125, we can buy at $125 and sell for the higher price. If the price is less than $125 then we do not exercise the option.



# Call Option Payoff

But the payoff needs to be offset against the premium. We will make a loss if the spot market price is below $155.



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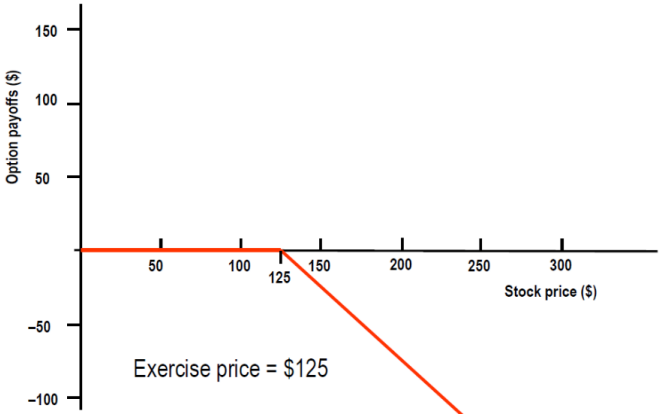


# Further Option Terminology

**In-the-money**: positive payoff in case of option excercise.

**At-the-money**: zero payoff in case of option excercise.

**Out-of-the-money**: negative payoff in case of option excercise.

A call option is in-the-money if strike price $<$ spot price.

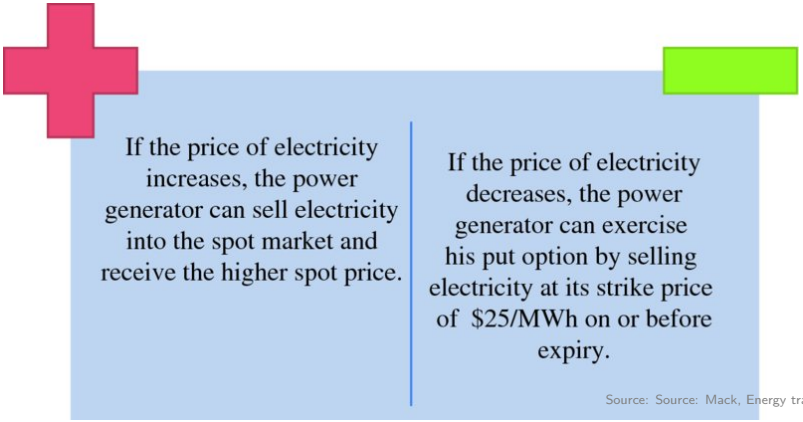
A put option is in-the-money if strike price $>$ spot price.

**NB**: Options allow you to keep choices open.

**NB**: Options have an asymmetric payoff (unlike perfect hedging with futures).

# Generator hedging with put options

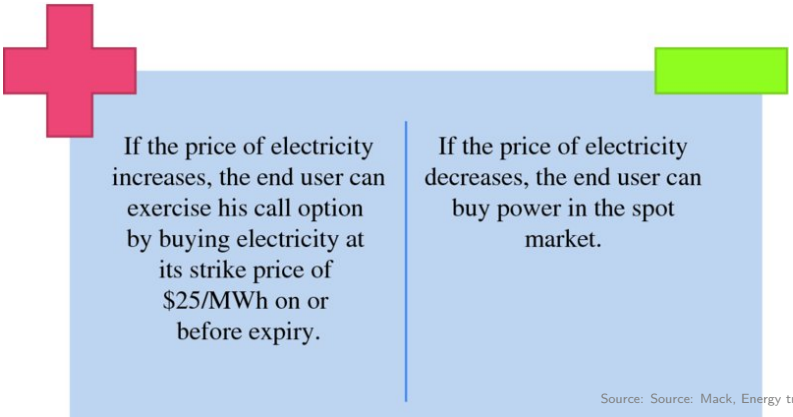
A power generator uses put options to guarantee a minimum selling price for its generated electricity. Suppose the electricity futures contract price is \$25/MWh. The power generator wishes to receive at least \$25/MWh for the physical sale of power. To accomplish this, the power generator purchases a put option for a premium of \$1/MWh.




Source: Source: Mack, Energy trading and risk management, 2014

# Consumer hedging with call options

A power consumer can hedge against price increases by purchasing a call option. Suppose the electricity futures contract price is \$25/MWh. The end user wishes to pay no more than \$25/MWh. To accomplish this, the end user purchases a call option for a premium of \$0.75/MWh.




Source: Source: Mack, Energy trading and risk management, 2014

# Swaps

A forward contract locks in the terms of a single future transaction right now.

A **swap** is similar, but applies for a **series** of future transactions. E.g. An electricity swap is equivalent to a strip of forward contracts with multiple settlement dates and identical forward price for each settlement.

It replaces a risky variable floating transaction for a risk-free fixed transaction. Price exposures are **swapped** between the parties.

E.g. mobile phone fixed monthly contract for unlimited calls.

Swaps are bilateral and traded over-the-counter (OTC).

# Contracts for Difference and Virtual Power Purchase Agreements

**Contracts for Difference** (CfDs) and **Virtual Power Purchase Agreements** (VPPAs), common ways of financing renewable energy, are financial swaps.

In a CfD or VPPA agreement, the generator receives a fixed amount per MWh for their electricity (the **strike price**) from the purchaser.

If the market price is below the strike price, the generators receives the difference from the purchaser; if the market price is above the strike price, the generators pays the difference to the purchaser. Price risk is transferred from the generator to the purchaser.

Consider a CfD (common in UK for renewables, also used for planned nuclear plant Hinkley Point C) with a strike price of £ 50/MWh.

If the market price is £ 20/MWh, the generator receives the difference, £ 30/MWh, from the CfD purchaser.

If the market price is £ 100/MWh, the generator pays the difference, £ 50/MWh, to the CfD purchaser.

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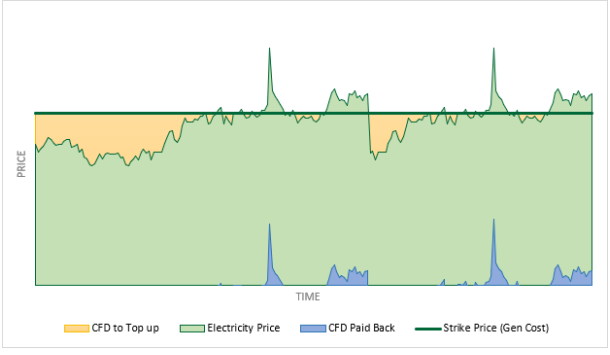


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Source: LGEnergy