

Energy Economics, Winter Semester 2024-5

Lecture 5: Energy Trading

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1. Introduction to Energy Trading
2. Submarkets and trading forms
3. Balance group concept
4. Futures, options and hedging

Introduction to 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.

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.

Mediated trading: pool or exchange

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

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.

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) → Swap.

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

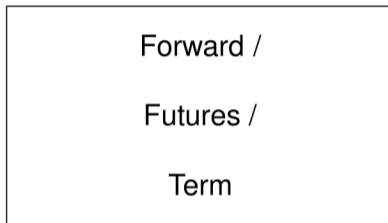
- Fixed price is stated as an amount of money per unit of underlying.
- Floating price is determined by reference to a price index publication at a time point after deal conclusion.

Fixed-amount vs. options

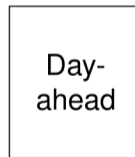
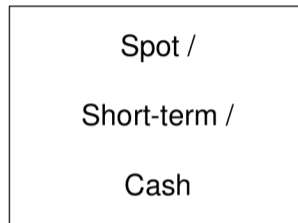
Submarkets and trading forms

Time

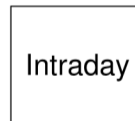
Delivery time (t_0)



years, quarters, months
ahead of delivery

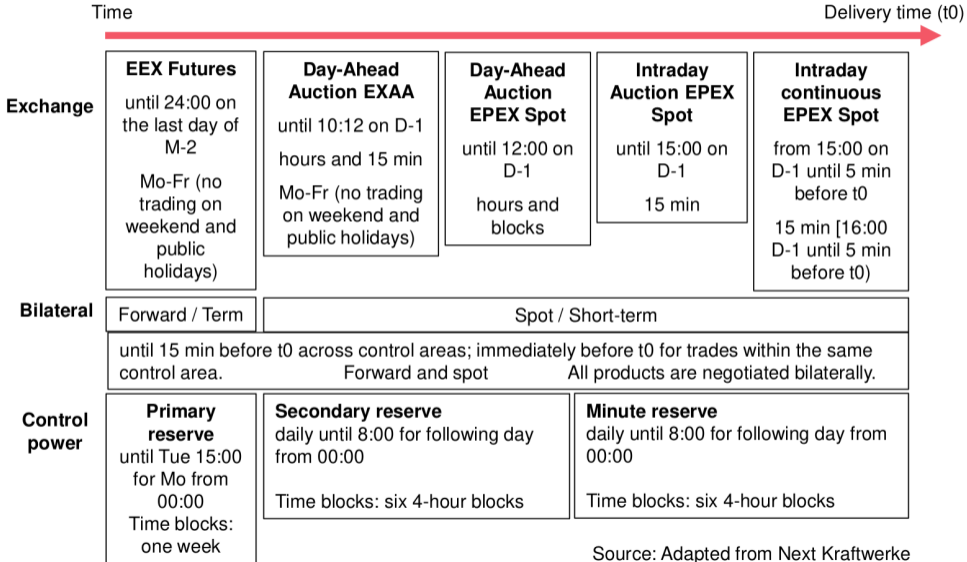


day
ahead
delivery



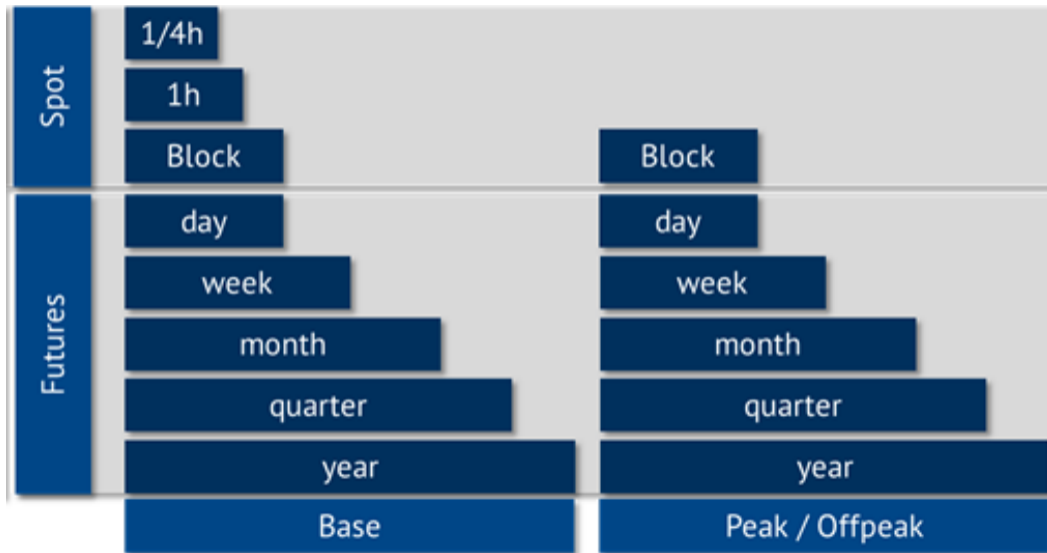
up to 5 min
ahead of
delivery

Energy sub-markets: detail for electricity

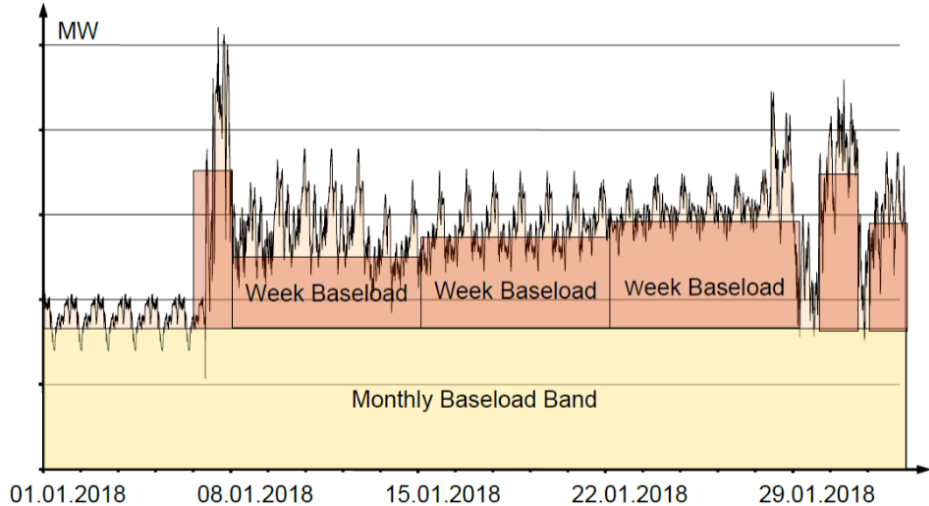


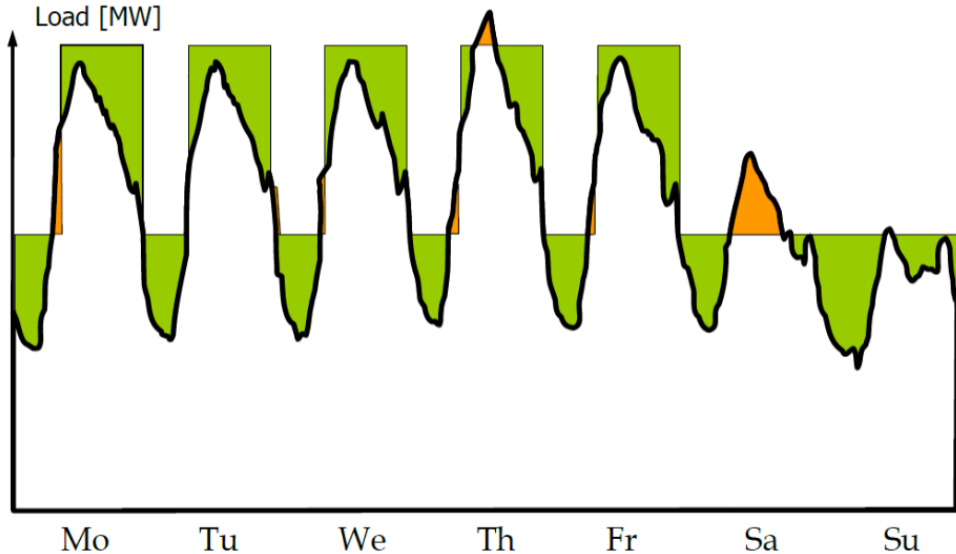
Source: Adapted from Next Kraftwerke

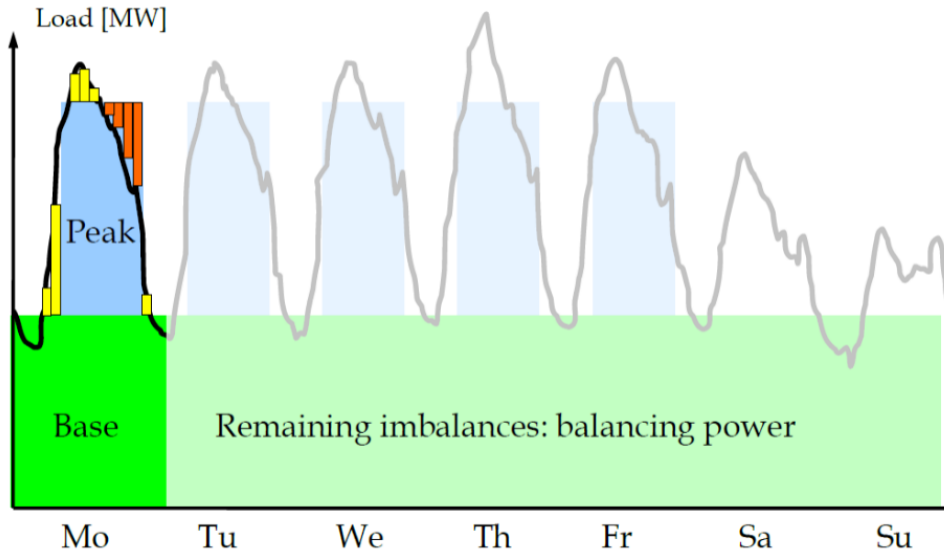
Electricity product types based on delivery period



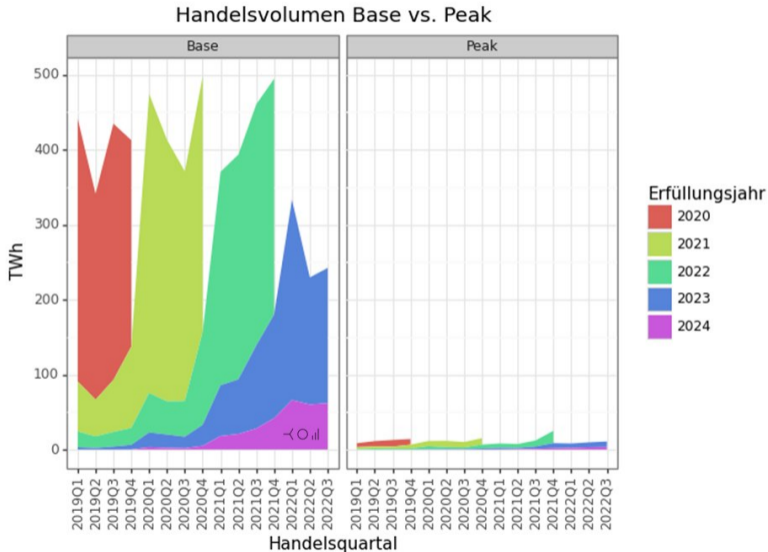
Standardised futures do not match with typical load schedules.







Trading volumes for base are higher than peak; NB: effect of crisis



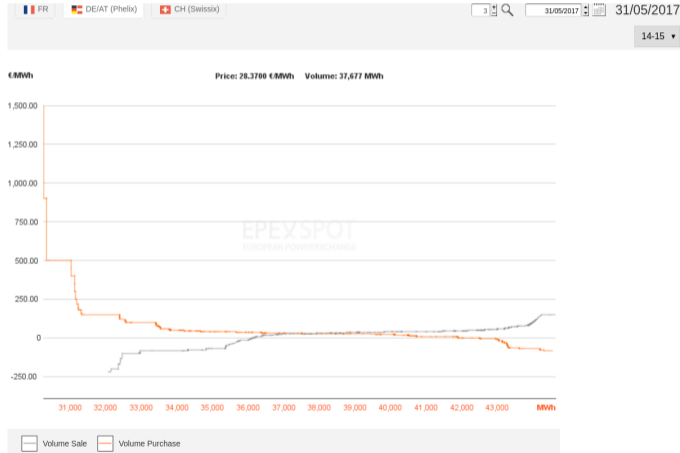
A **spot market** is so-called because delivery is “on the spot” i.e. now, as opposed to futures.

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

- Double-sided auction: bid and ask order book (order book trading)
- Uniform price auction: market clearing price for each product (hour or block)
- Hourly contracts and blocks (base, peak etc.)
- Occurs daily at 12h for delivery on the following day (0-24h) (i.e. **day-ahead**)
- Price publication time: asap from 12:42h
- Volume tick (min order amount/amount increment): 0.1 MWh
- Min price: -500 €/MWh; Max price: 4000 €/MWh

Supply-Demand Curve Real Example

At epexspot.com you can find the real supply-demand curves for every hour, here's an old example for Germany-Austria from 2017:



Day-ahead auction with delivery on the German/Luxembourg TSO zones

Size

The minimum volume increment is 0.1 MW for individual hours and 0.1 MW for blocks.

Tick

The minimum price increment is EUR 0.1 per MWh.

Underlying

Electricity traded for delivery the following day in 24 hour intervals.

Special case: A full 25 hour Excel template is needed when the clocks are set to winter time. Hour 3 and 3X can contain different values. When the time is switched to summer time the system automatically deletes the exceeding quantities for hour 3 (i.e. 2.00 am to 3.00 am).

Place of Delivery

Deliveries are made within either of the following TSOs zones:

- Amprion GmbH
- Tennet TSO GmbH
- 50Hertz Transmission GmbH
- TransnetBW GmbH

All these places of delivery form one market zone.

Auction hours:

The daily auction takes place at 12.00 pm, 7 days a week, year-round, including statutory holidays.

Type of orders:

-Individual hours

Orders contain up to 256 price/quantity combinations for each hour of the following day. Prices must be between -500 €/MWh and 3000 €/MWh. The 256 prices are not necessarily the same for each hour. A volume – whether positive, negative or nil – must be entered at the price limits. A price-inelastic order is sent by putting the same quantity at the price limits.

-Blocks

Block orders are used to link several hours on an all-or-none basis, which means that either the bid is matched on all of the hour or it is entirely rejected. Block orders have a lower priority compared with single hourly orders. The quantity may be different for every hour of the block. A block order is executed for its full quantity only. A block order is executed or not by comparing its price with the volume-weighted average of the hourly market clearing prices related to the hours contained in the block.

Standard block orders

- Block Baseload covering hours 1 to 24
- Block Peakload covering hours 9 to 20
- Block Night covering hours 1 to 6
- Block Morning covering hours 7 to 10
- Block High Noon covering hours 11 to 14
- Block Afternoon covering hours 15 to 18
- Block Evening covering hours 19 to 24
- Block Rush Hour covering hours 17 to 20
- Block Off-Peak 1 covering hours 1 to 8
- Block Off-Peak 2 covering hours 21 to 24

Source: <https://www.epexspot.com/en/market-design>

EPEX spot day results

DATA TABLE DATA CHART AGGREGATED CURVE

FR CH (Swissix) DE-LU AT Former DE/AT (Historical data until 30/09/2018)

14/11/2019 14/11/2019

Day Week Month Quarter Year

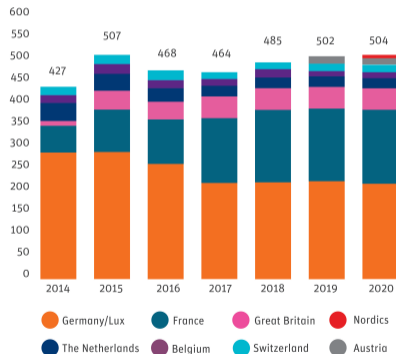
no average



Price Price Baseload Price Peakload Volume

Not all power is traded on the day-ahead

Only around a third of consumed electricity in Germany is traded on the day-ahead spot market. Here are the day-ahead volumes:



The rest is traded over the counter (OTC) or on the intraday market.

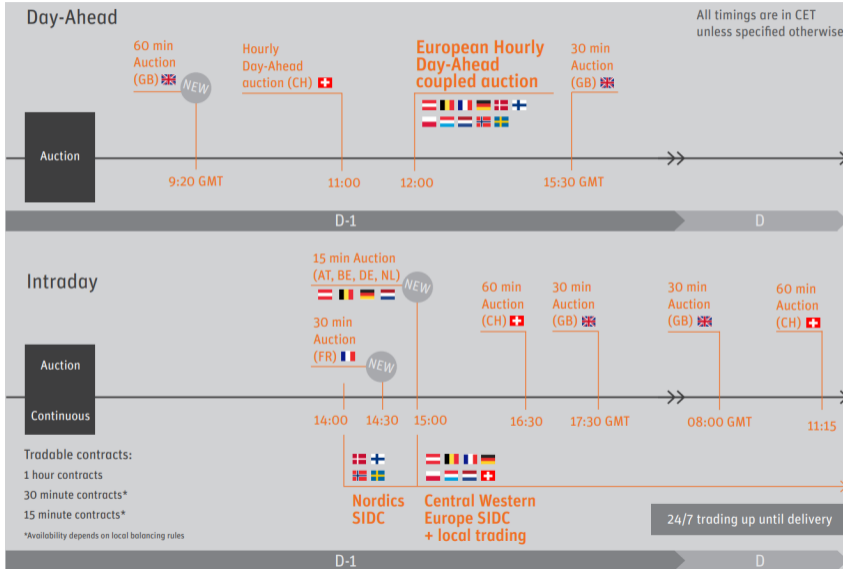
The **intraday market** reflects a growing need for flexibility close to delivery due to uncertain forecasts for demand and variable renewables.

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

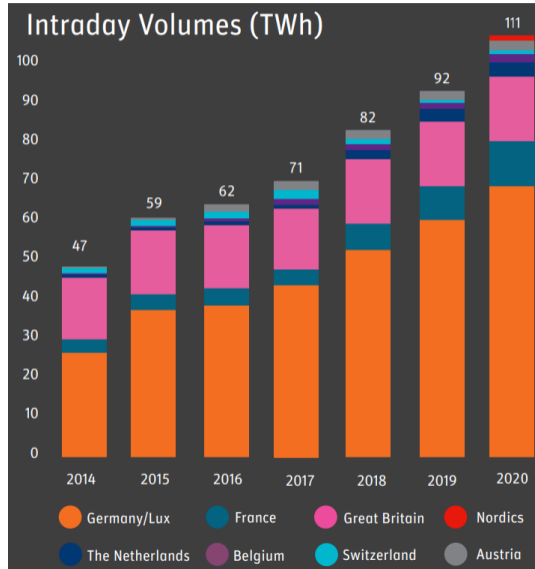
Products:

- uniform price auction for 15-min products; daily at 3 pm (D-1)
- continuous intraday market up to delivery for hourly/15-min products

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



Intraday market volumes have been increasing



Balance group concept

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
- deviations are penalised by imbalance fees

Analogy to a bank
account:

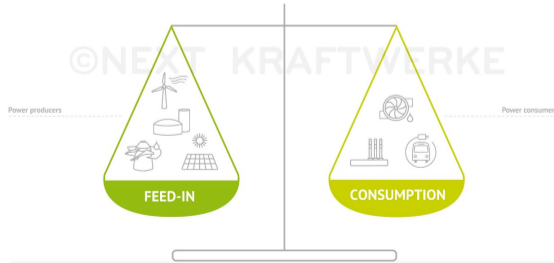
TSO	Bank
Balance responsible party	Account holder
EIC	Account number
Balancing group	Bank account
Energy delivers	Payments

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

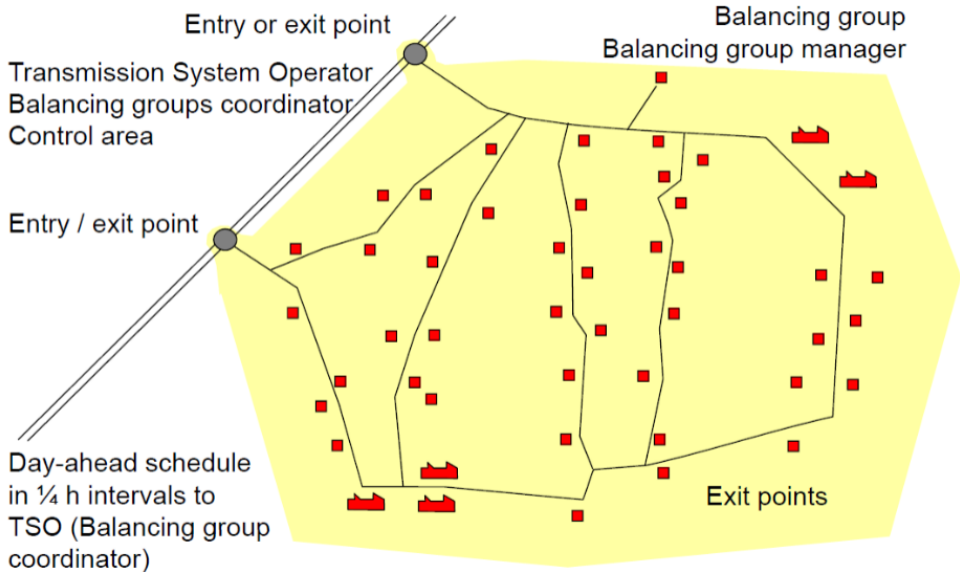
Depending on the nature and composition of a balancing group, the BGR transmits to the TSO forecasted load or generation and/or buy and sell amounts.

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.



Market roles and processes at TSO level



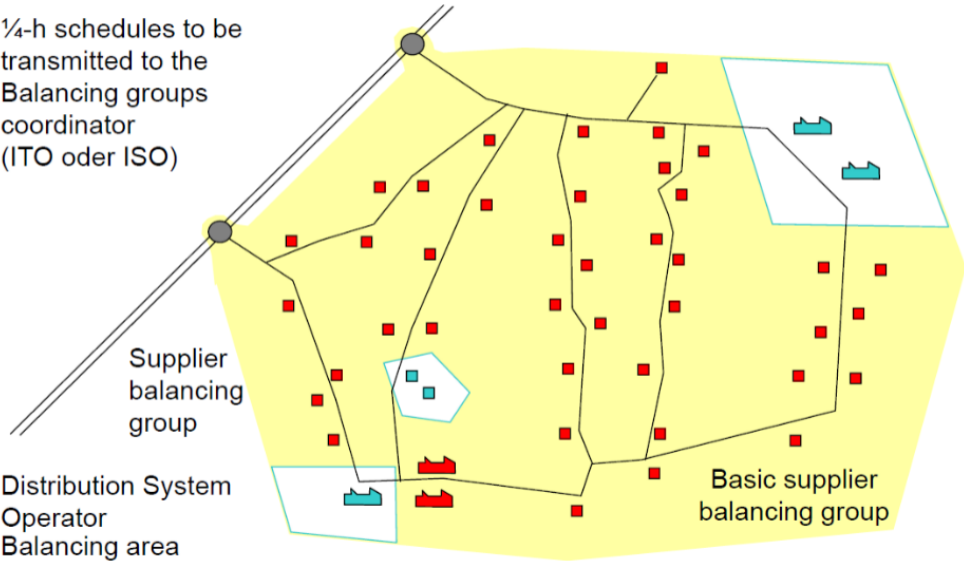
Market roles and processes at DSO level

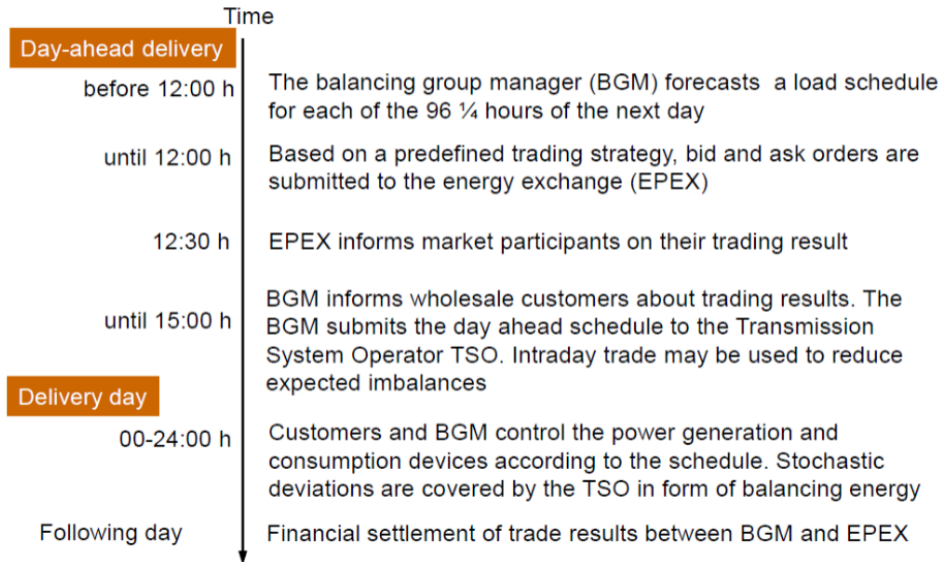
1/4-h schedules to be transmitted to the Balancing groups coordinator (ITO oder ISO)

Supplier balancing group

Distribution System Operator Balancing area

Basic supplier balancing group





- 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

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.

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.

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.

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.

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 will 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.

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.

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 ($\$ 16 \cdot 10\% \cdot 0.5 \text{ years}$)
\$ 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.

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		
<ul style="list-style-type: none"> ● Spot Price Increase ● Spot Price Decrease 	Profits decrease ↘ Profits increase ↗	Profits increase ↗ Profits decrease ↘
Hedge (Futures Position)	Long Electricity Futures. (bought futures)	Short Electricity Futures. (sold futures)
Risk from Futures Position		
<ul style="list-style-type: none"> ● Spot Price Increase ● Spot Price Decrease 	Profits increase ↗ Profits decrease ↘	Profits decrease ↘ Profits increase ↗

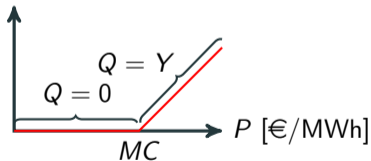
With a **perfect hedge** the magnitude of the corresponding gains and losses in the physical and futures positions will be exactly the same.

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 $Q = Y$.

Π [€/MWh]

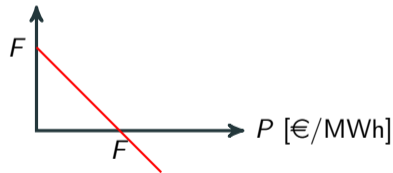


For the sale of its generation, it has a **long** position (i.e. benefits from high P).

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:

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

Π_F [€/MWh]



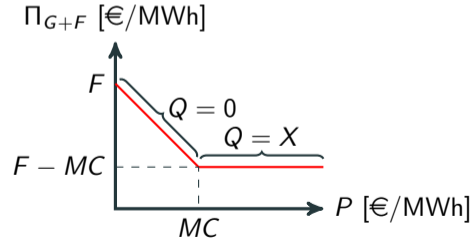
For the future it has a **short** position (i.e. benefits from low P).

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 :



Considerations are similar for consumers.

Assume a linear benefit function

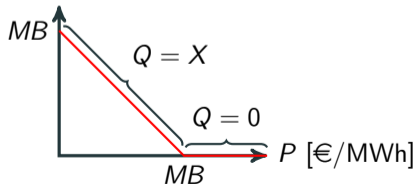
$B(Q) = MB \cdot Q$, consumption capacity $Q \leq Y$.

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 $Q = Y$.

Π_B [€/MWh]

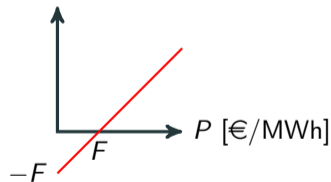


For energy consumption, it is **short**.

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:

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

Π_F [€/MWh]



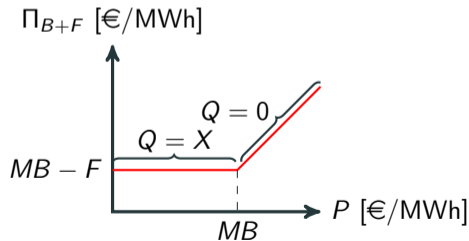
For the future it has a **long** position (i.e. benefits from high P).

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 :

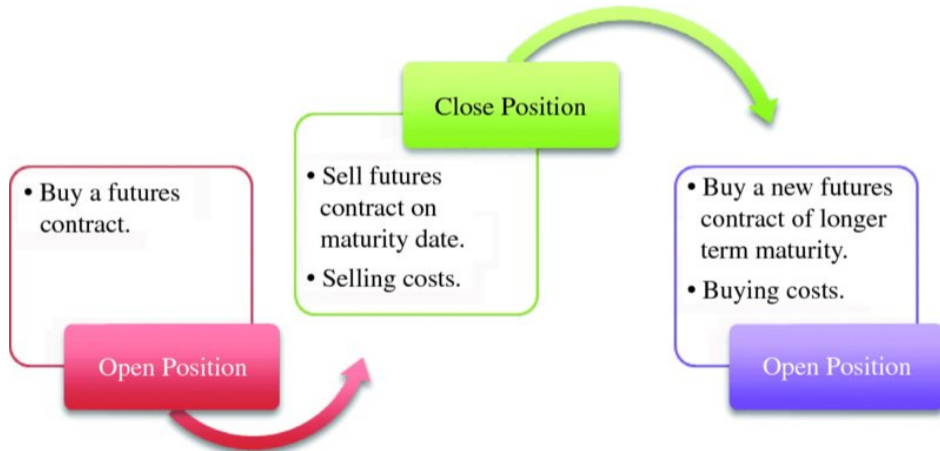


When a futures contract ends you have three options:

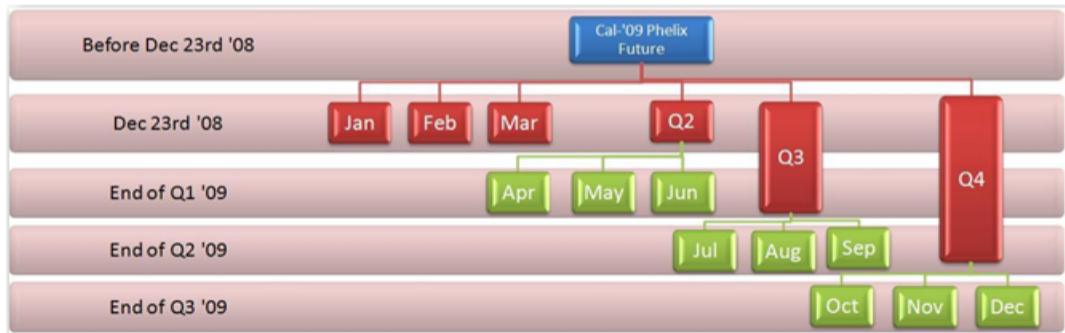
- **Settle** the contract by providing the underlying service (physical settlement, e.g. electricity) or cash (financial settlement).
- **Offset** position by taking out opposite and equal transaction. E.g. if you sold 2 futures for September, need to buy 2 futures for September. The difference in price 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, i.e. offsetting 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.



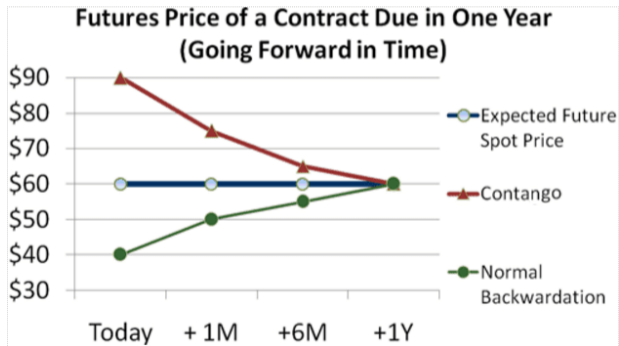
Cascading: At the beginning of the delivery period, the initial product splits into a set of equivalent shorter-term products. Longer maturities cascade into corresponding shorter maturities. For example, a future for year 2022 will cascade in December 2021 into futures for months Jan, Feb, Mar in 2022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



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.

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.

Exercising 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 exercised.

- European options can be exercised only at expiry.
- American options can be exercised 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.

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:

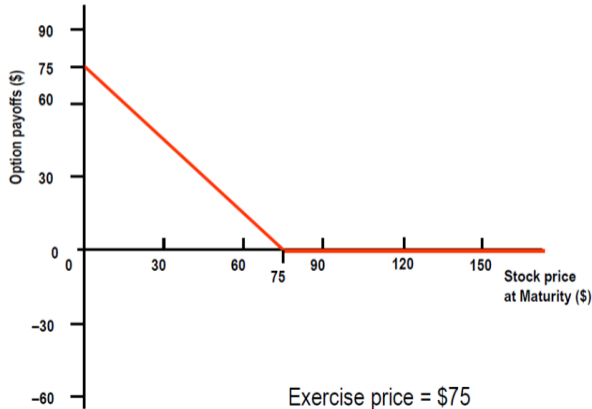
Strike Price	Call Option Premium	Put Option Premium
30	5.00	0.01
35	0.53	0.60
40	0.01	6.00

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

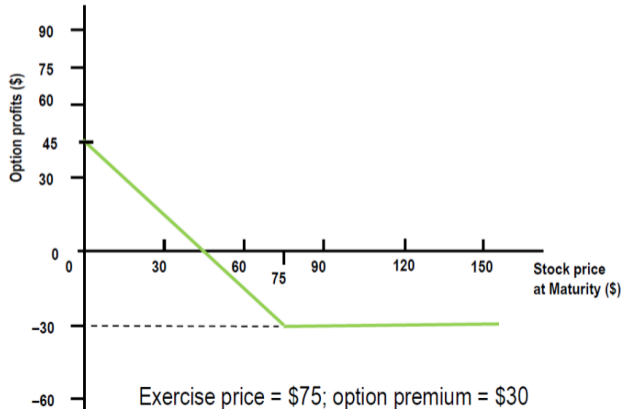
Put Option Payoff

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.



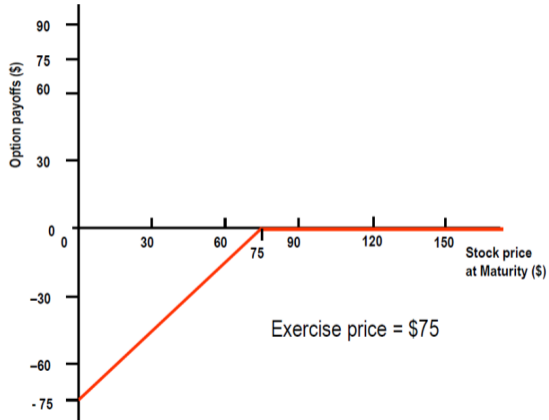
But remember we still have to pay the option premium which offset the payoff. We will make a loss if the spot price is below \$45.

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



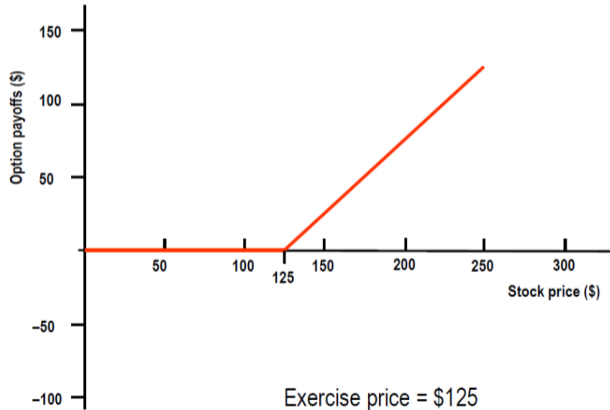
Put Option Writer Payoff

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

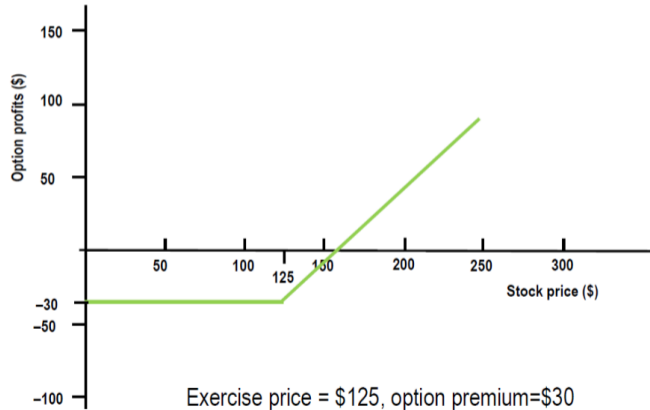


Call Option Payoff

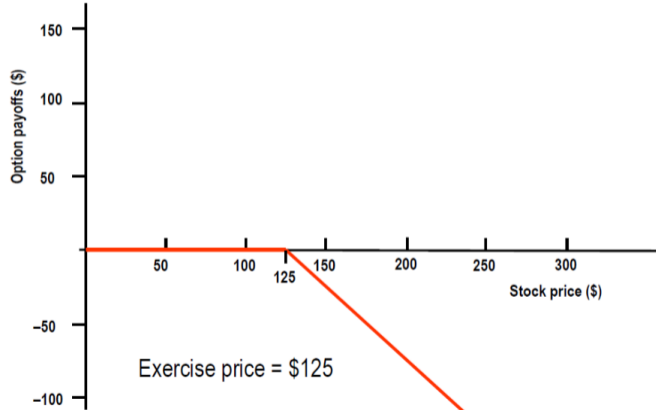
Suppose we purchase a call option (i.e. right to buy) with an exercise price of \$125 and a premium of \$30. If the spot market price at maturity is more than \$125, we can buy at \$125 and sell for the higher price. If the price is less than \$125 then we do not exercise the option.



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



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



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

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

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

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).

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.



If the price of electricity increases, the power generator can sell electricity into the spot market and receive the higher spot price.

If the price of electricity decreases, the power generator can exercise his put option by selling electricity at its strike price of \$25/MWh on or before expiry.

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.



If the price of electricity increases, the end user can exercise his call option by buying electricity at its strike price of \$25/MWh on or before expiry.

If the price of electricity decreases, the end user can buy power in the spot market.

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 (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.

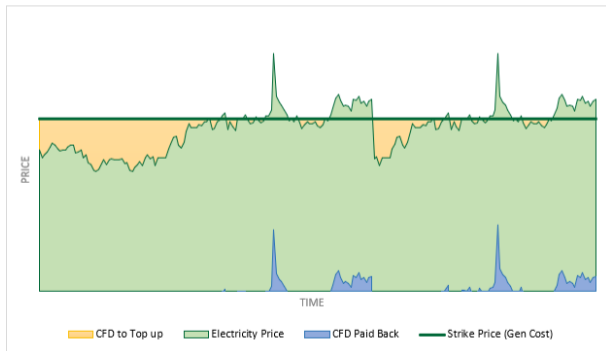
Consider a CfD (common in UK for renewables, also used for planned nuclear plant Hinkley Point C) with a strike price of £ 50/MWh.

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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