Energy Economics, Winter Semester 2021-2
Lecture 5: Energy Trading

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Table of Contents

Introduction to Energy Trading

What is energy trading?

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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.

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

Time

Delivery time (t0)

Forward / Futures / Term

Spot / Short-term / Cash

Day-ahead

Intraday

years, quarters, months ahead of delivery

day ahead delivery

up to 5 min ahead of delivery

Energy sub-markets: detail for electricity

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Time → Delivery time (t0)

Exchange

- **EEX Futures**
  until 24:00 on the last day of M-2
  Mo-Fr (no trading on weekend and public holidays)
- **Day-Ahead Auction EXAA**
  until 10:12 on D-1
  hours and 15 min
  Mo-Fr (no trading on weekend and public holidays)
- **Day-Ahead Auction EPEX Spot**
  until 12:00 on D-1
  hours and blocks
- **Intraday Auction EPEX Spot**
  until 15:00 on D-1
  15 min
- **Intraday continuous EPEX Spot**
  from 15:00 on D-1 until 5 min before t0
  15 min [16:00 D-1 until 5 min before t0)

Bilateral

- Forward / Term
- Spot / Short-term

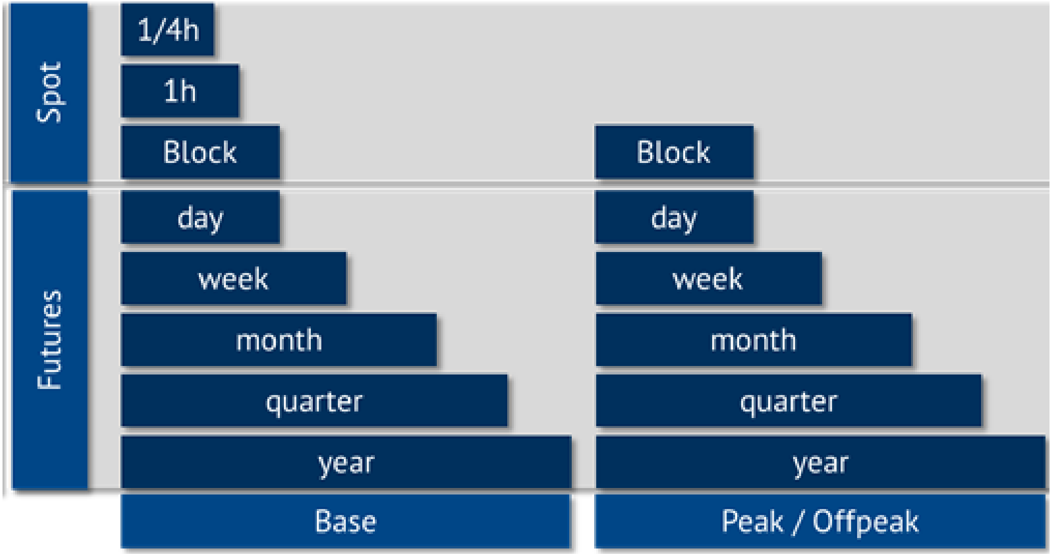
until 15 min before t0 across control areas; immediately before t0 for trades within the same control area. Forward and spot All products are negotiated bilaterally.

Control power

- **Primary reserve**
  until Tue 15:00 for Mo from 00:00
  Time blocks: one week
- **Secondary reserve**
  daily until 8:00 for following day from 00:00
  Time blocks: six 4-hour blocks
- **Minute reserve**
  daily until 8:00 for following day from 00:00
  Time blocks: six 4-hour blocks

Source: Adapted from Next Kraftwerke

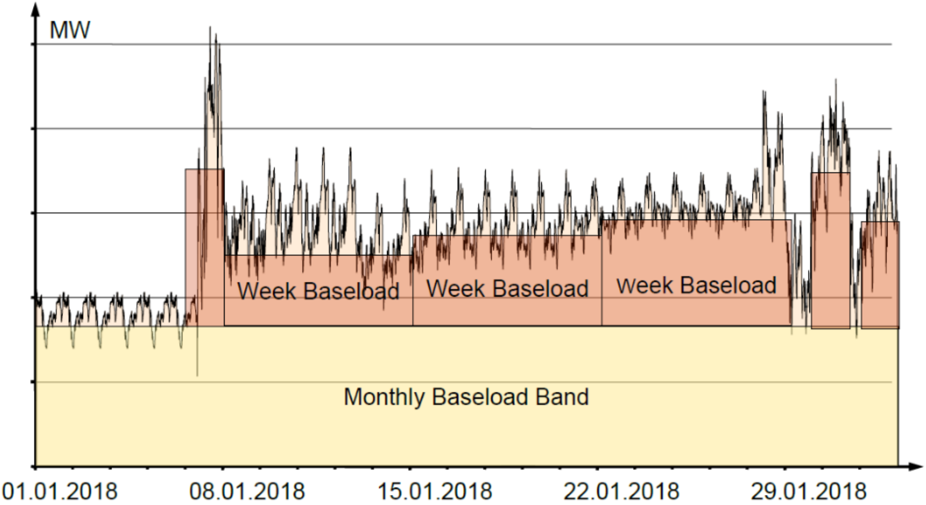
Electricity product types based on delivery period



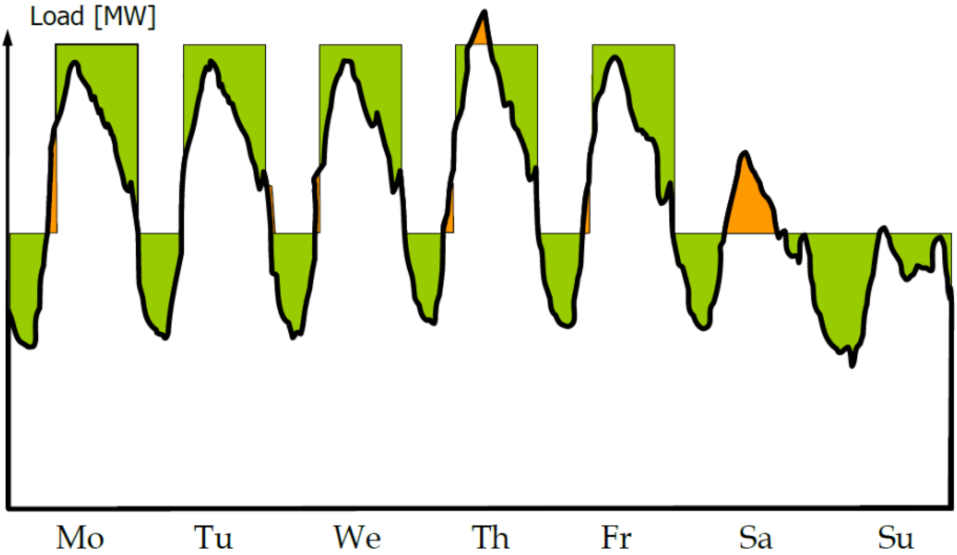
Source: Energy Brainpool

Sample power purchase portfolio

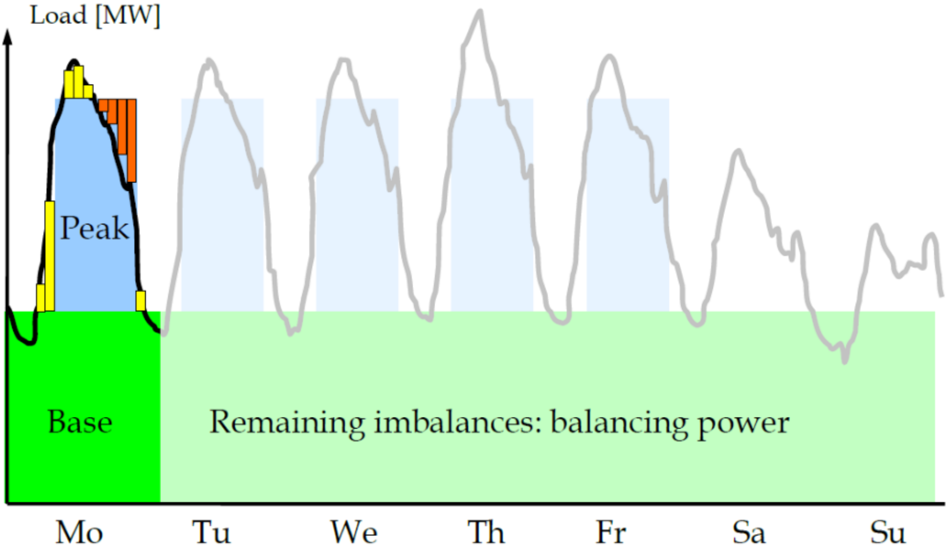
Standardised futures do not match with typical load schedules.



Portfolio management of a power retailer



Day-ahead contracts for single hours



EPEX Spot Day-ahead auction

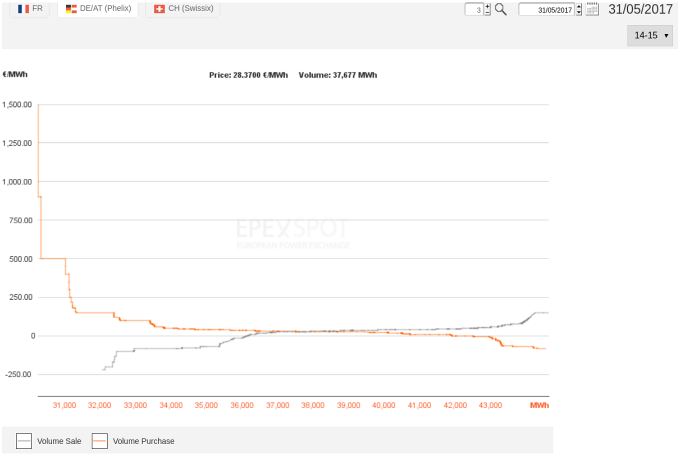
A **spot market** is so-called because delivery is "on the spot" i.e. now, as opposed to futures.

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: 3000 €/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:



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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.

Source: epexspot.com

Product description

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

Type of orders:

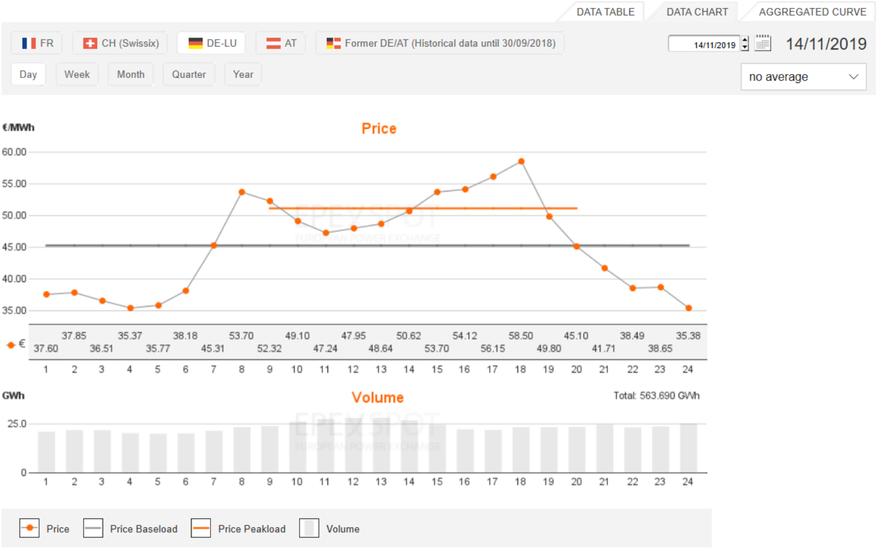
-Individual hours
Orders contain up to 256 price/quantity combinations for each hour of the following day. Prices must be between -500 €/MWh an 3000 €/MWh. The 256 prices are not necessarily the same for each hour. A volume – whether positive, negative or nil – must be entered at the price limits. A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

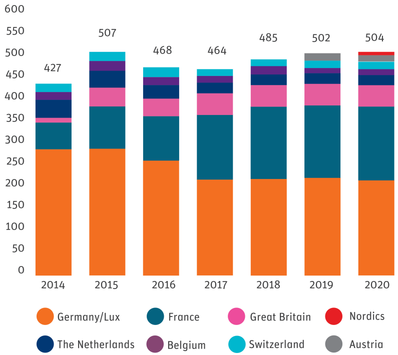
Source: epexspot.com

EPEX spot day results



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.

Source: epexspot.com

Intraday market

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

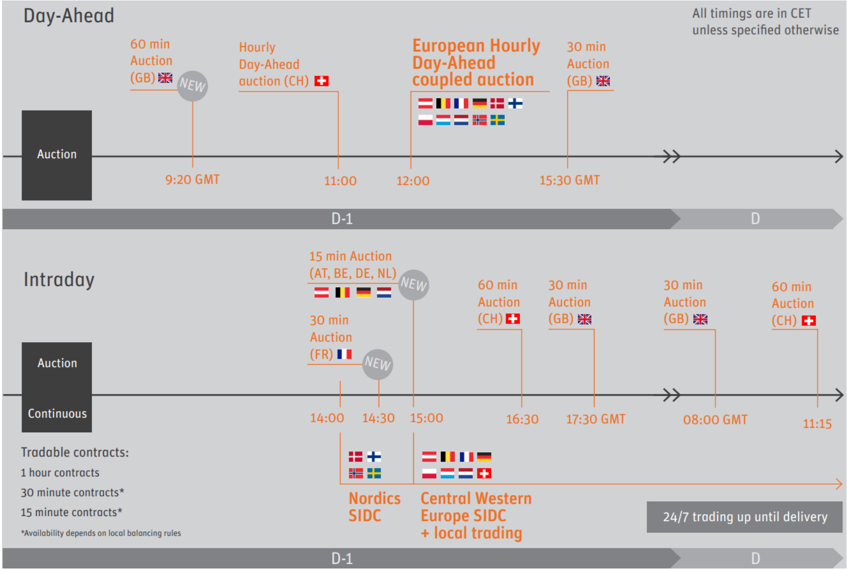
The intraday market serves for adjusting trading positions based on corrected forecasts closer to real-time.

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

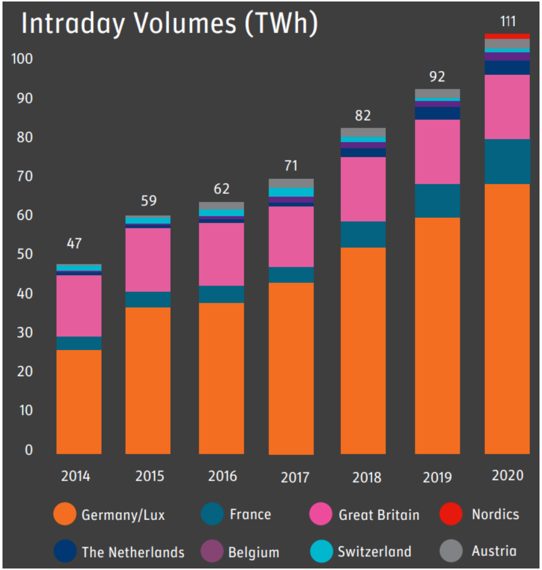
Continuous: as soon as two entered bid and ask orders match, the trade is executed (cf. shares and bitcoin trading).

Intraday market



Source: EPEX Spot brochure

Intraday market volumes have been increasing



Source: epexspot.com

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
- 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

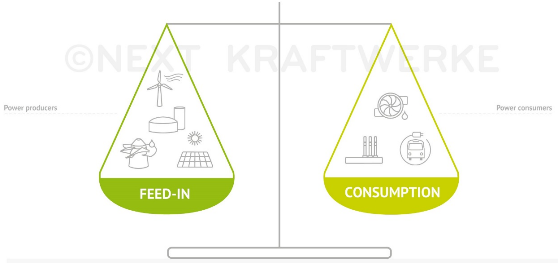
Balancing group: Linking the virtual and physical worlds

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

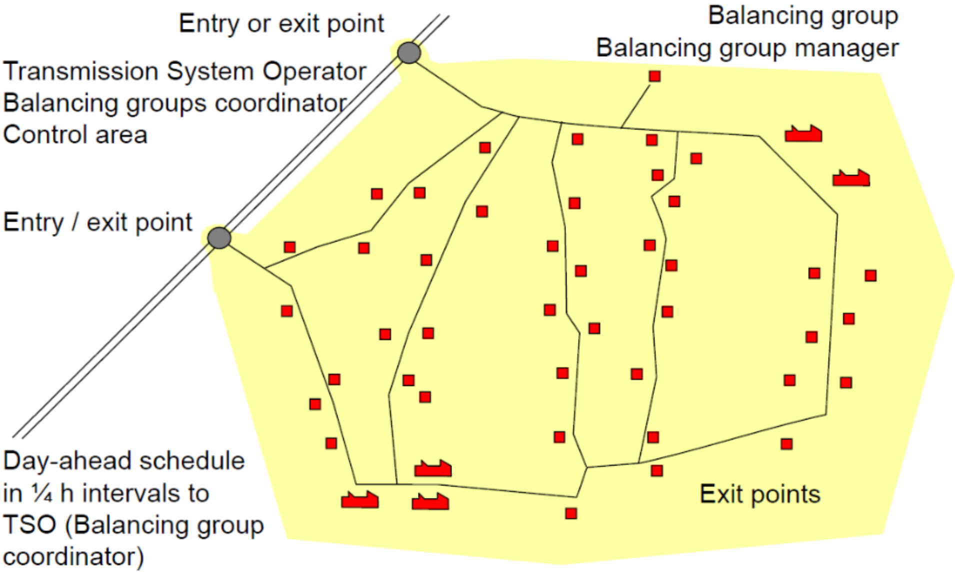
Depending on the nature and composition of a balancing group, the BGR transmits to the TSO forecasted load or generation and/or buy and sell amounts.

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.

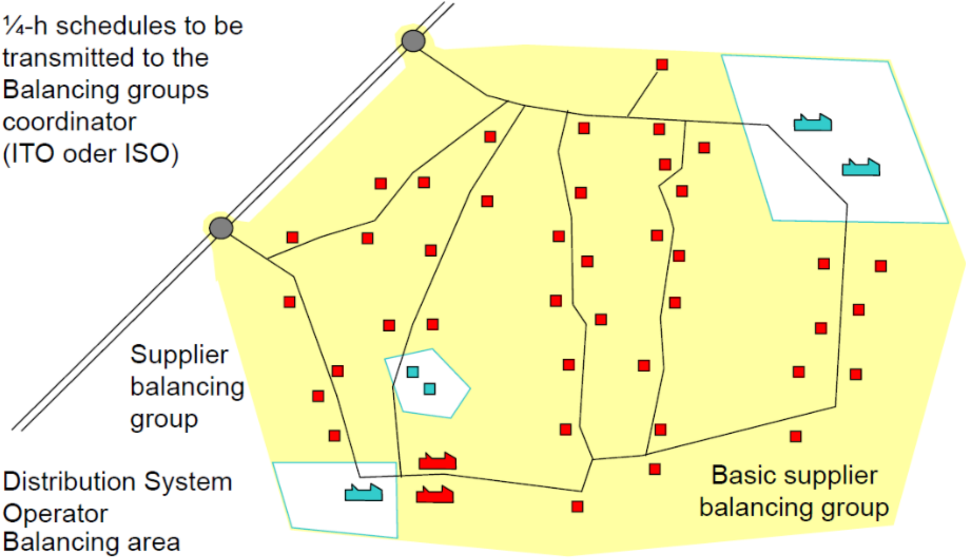


Market roles and processes at TSO level



Market roles and processes at DSO level

¼-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

Tasks of the balancing group management

Time

Day-ahead delivery

before 12:00 h	The balancing group manager (BGM) forecasts a load schedule for each of the 96 ¼ hours of the next day
until 12:00 h	Based on a predefined trading strategy, bid and ask orders are submitted to the energy exchange (EPEX)
12:30 h	EPEX informs market participants on their trading result
until 15:00 h	BGM informs wholesale customers about trading results. The BGM submits the day ahead schedule to the Transmission System Operator TSO. Intraday trade may be used to reduce expected imbalances

Delivery day

00-24:00 h	Customers and BGM control the power generation and consumption devices according to the schedule. Stochastic deviations are covered by the TSO in form of balancing energy
Following day	Financial settlement of trade results between BGM and EPEX

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.

Risk is a source of uncertainty about the future.

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 bnefits 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 forgoe 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 forgoe 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.

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 • 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		
• 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.

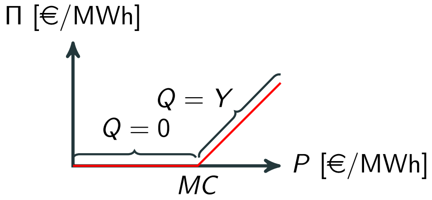
Source: Stoft et al, 1998

Generator hedges price risk

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

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

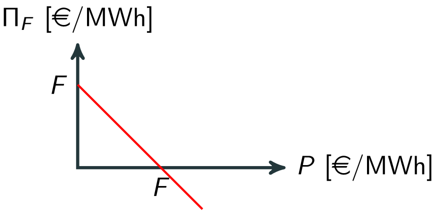
If $P < MC$ it doesn't run $Q = 0$ and if $P > MC$ it runs at maximum capacity $Q = Y$.



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).

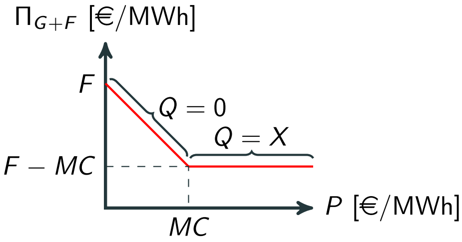
Futures allow to hedge without distorting real-time incentives

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:



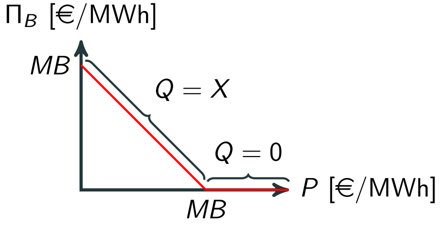
Considerations are similar for consumers.

Assume a linear benefit function $B(Q) = MB \cdot Q$, consumption capacity $Q \leq Y$.

It maximises net benefit:

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

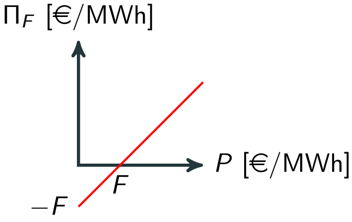
If $P > MB$ it doesn't consume $Q = 0$ and if $P < MB$ it consumes at max capacity $Q = Y$.



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).

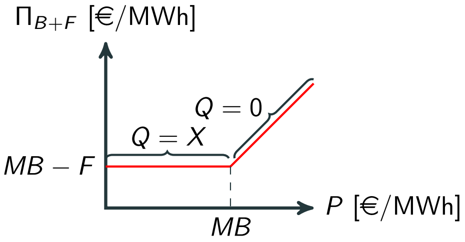
Futures allow to hedge without distorting real-time incentives

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:



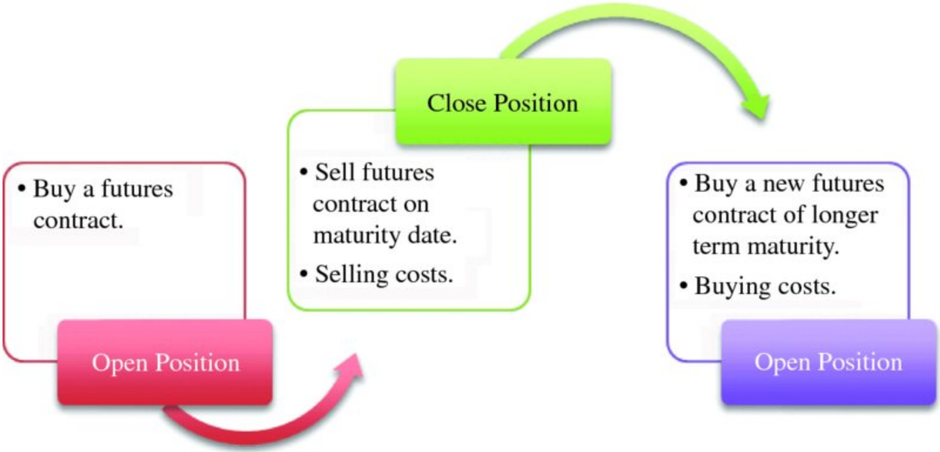
End of futures contract

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 his 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. 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

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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.

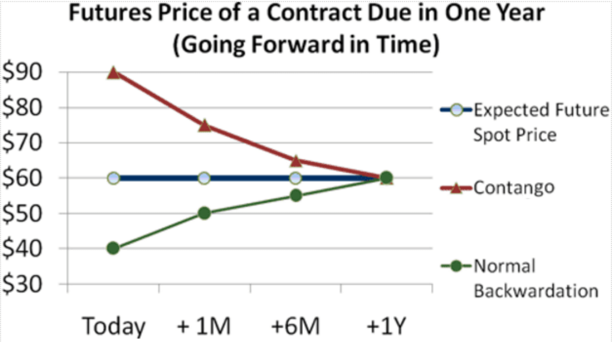
Source: Trading Technologies

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.

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:

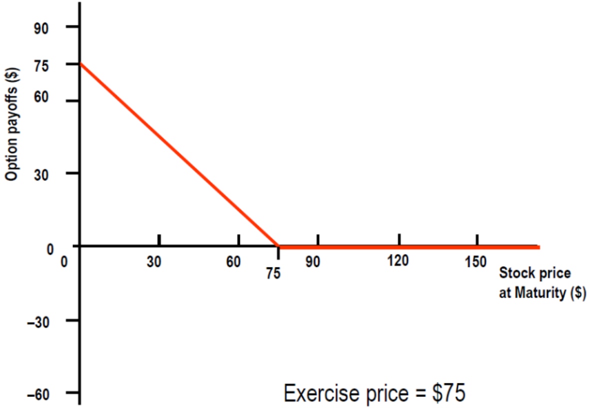
Strike Price	Call Option Premium	Put Option Premium
30	5.00	0.01
35	0.53	0.60
40	0.01	6.00

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

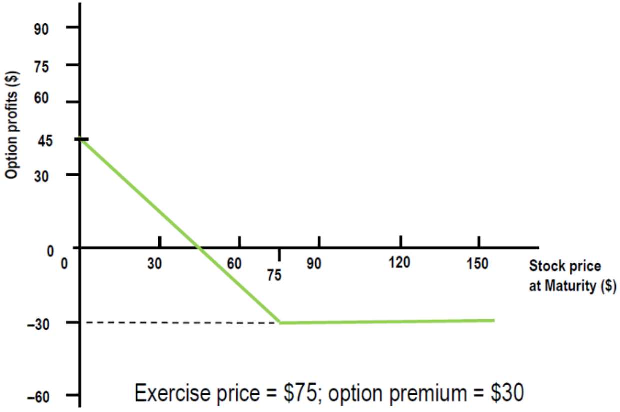
Put Option Payoff

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.



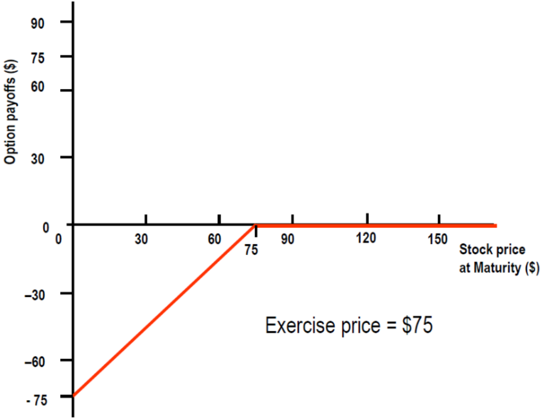
But remember we still have to pay the option premium which offset the payoff. We will make a loss if the spot price is below $45.

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



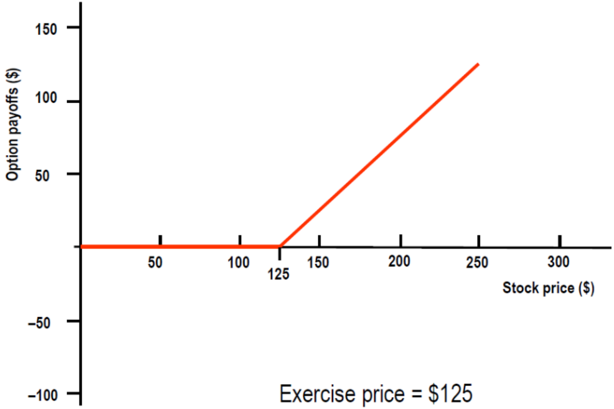
Put Option Writer Payoff

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



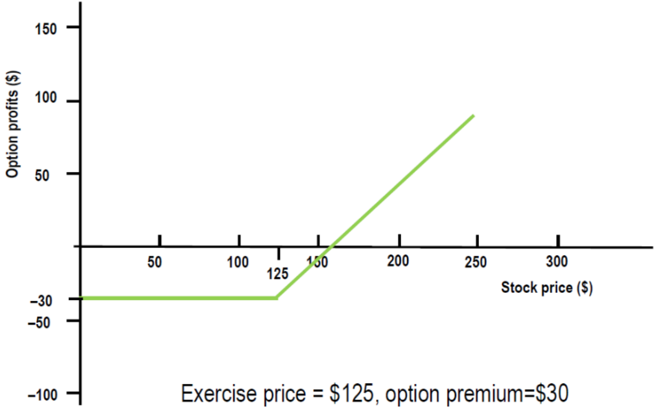
Call Option Writer Payoff

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.



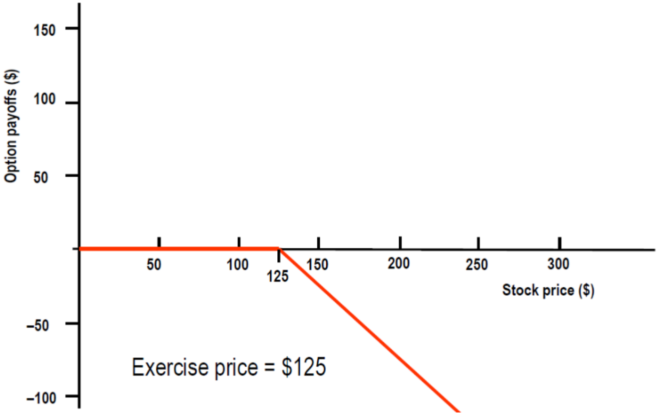
Call Option Writer Payoff

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



Call Option Writer Payoff

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



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.

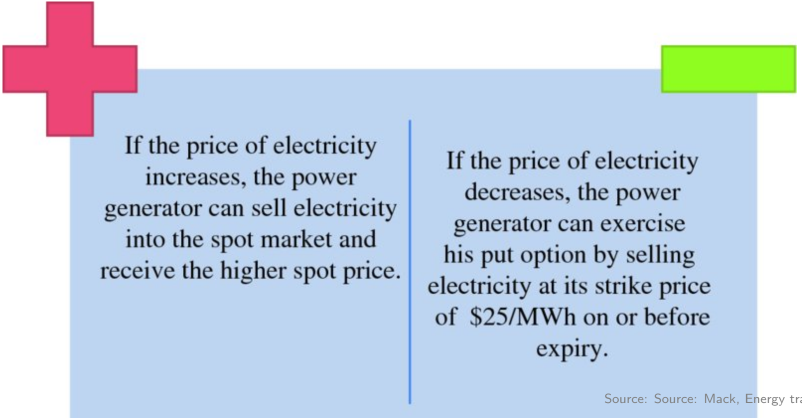
A put option is in-the-money if strike price $>$ spot price.

NB: Options allow you to keep choices open.

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

Generator hedging with put options

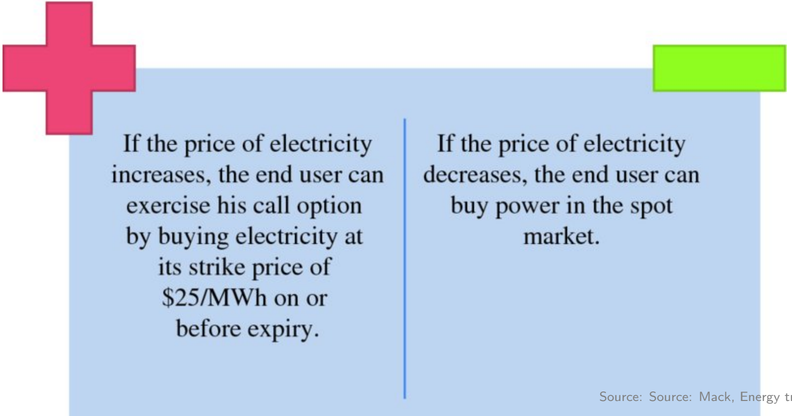
A power generator uses put options to guarantee a minimum selling price for its generated electricity. Suppose the electricity futures contract price is \$25/MWh. The power generator wishes to receive at least \$25/MWh for the physical sale of power. To accomplish this, the power generator purchases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