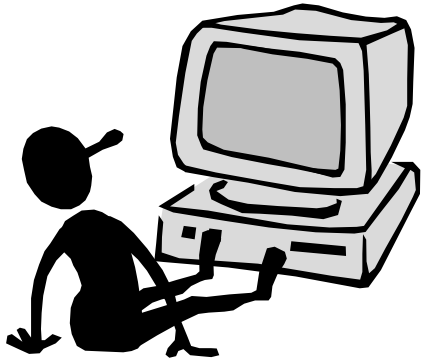
Introduction

- **You'll find a list of the terms and acronyms used in this presentation in the appendixes.**
- **Concerning the documents referred to in this presentation:**
  - ✓ **Unless otherwise stated, you can download the documents from www.houmollerconsulting.dk/facts-findings/.**
- **This PowerPoint presentation is animated**
  - ✓ **It's strongly recommended to run the animation when viewing the presentation.**
- **On most computers, you can start the animation by pressing *F5*.**
  - ✓ **Now the presentation moves one step forward, when you press *Page Down*. It moves one step backward, when you press *Page Up*.**



Moving towards a renewable energy future

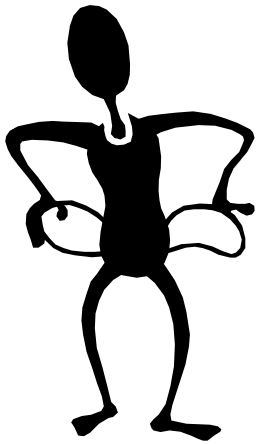
Reforming EU's day-ahead and intra-day electricity trading

- **This presentation discusses how to adapt EU's day-ahead and intra-day trading to a world dominated by renewable energy.**
- **The presentation argues EU must adapt a version of nodal pricing.**
  - ✓ **Because the new electricity business needs <u>local price signals</u>.**

- **Unless specified, the presentation only discusses trading of electrical energy**
  - ✓ **However, the conclusions can also be applied to the TSO's markets for capacity.**
  - ✓ **More information on capacity: see the PowerPoint presentation *Capacity markets and The Single European Electricity Market*.**

Reforming EU's electricity trading

- **EU's current day-ahead and intra-day trading allow trades, which the grid cannot sustain.**
- **This forces the TSOs to redispatch inside bidding zones**
  - ✓ **This is an expensive solution**
    - **In 2017, the German redispatch costs were € 1.1 billion.*)**
  - ✓ **Further, it means the prices created by the trading do not reflect the value of electricity**
    - **Hence, the day-ahead and intra-day prices are unreliable**
      - **Distorted prices are very costly for society**
        - **Although the size of the losses inflicted by distorted prices are hard to estimate.**



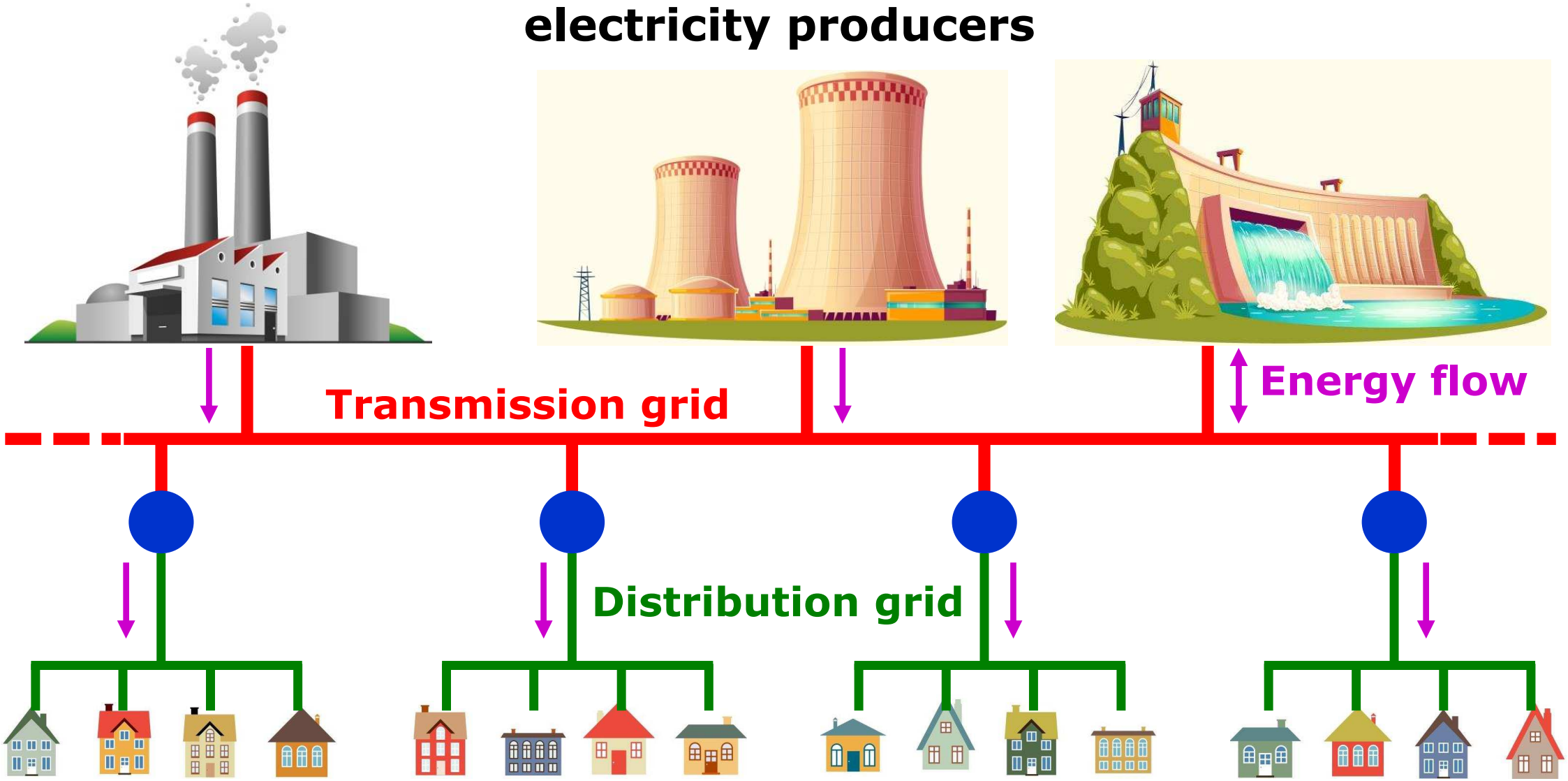
***) source** https://www.montelnews.com/en/story/europe-risks-costly-mistake-with-redispatch-markets--study/954861

The beginning of a new age

- EU's current day-ahead and intra-day trading systems were devised 20-25 years ago.
- Back then, the electricity supply system was dominated by big, central power stations.

- The problem: these old trading systems do not fit the modern world.
- We are moving towards a more decentralised electricity supply system
  - ✓ Where many small electricity producers feed electricity to the distribution grid
    - Solar cells and on-shore wind turbines, for example.
- Simultaneously, the demand side is changing. For example, due to
  - ✓ Electrical vehicles and prosumers.

The old electricity supply system



The new electricity business

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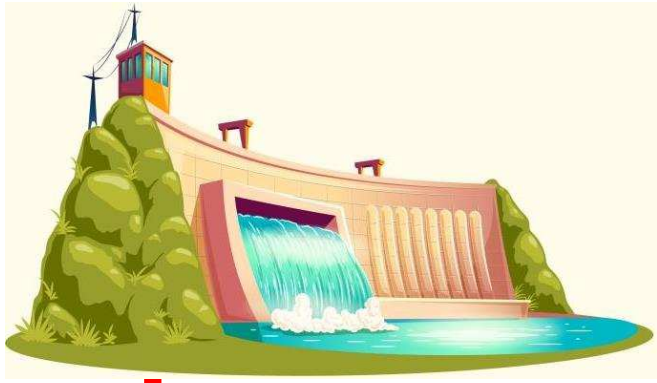
Battery storage

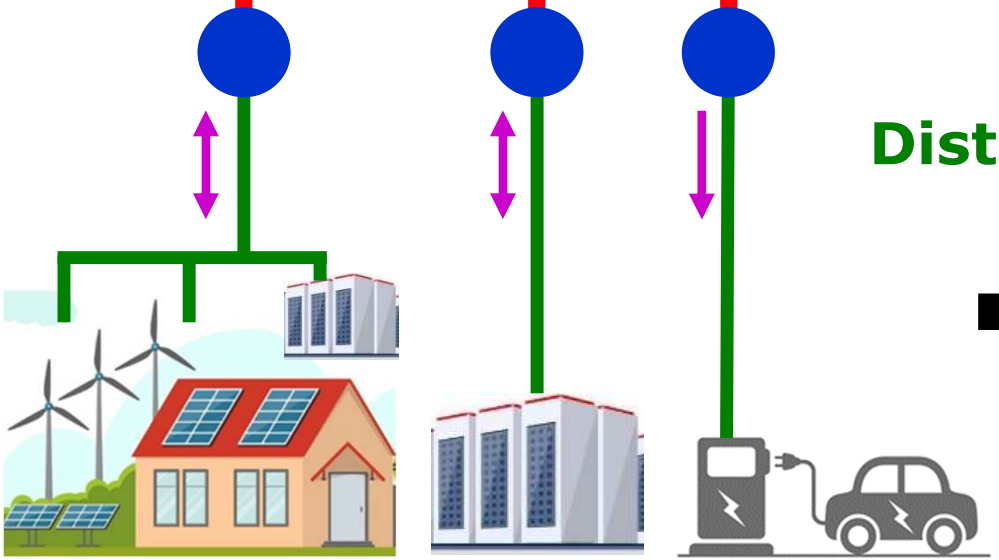
electricity producers

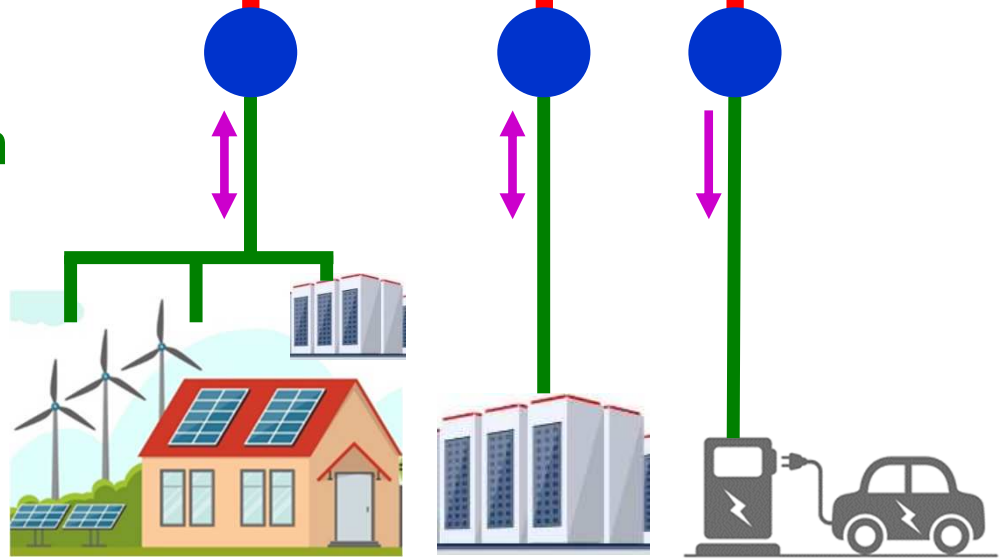


Energy flow

Transmission grid

Distribution grid





electricity producers, consumers and prosumers

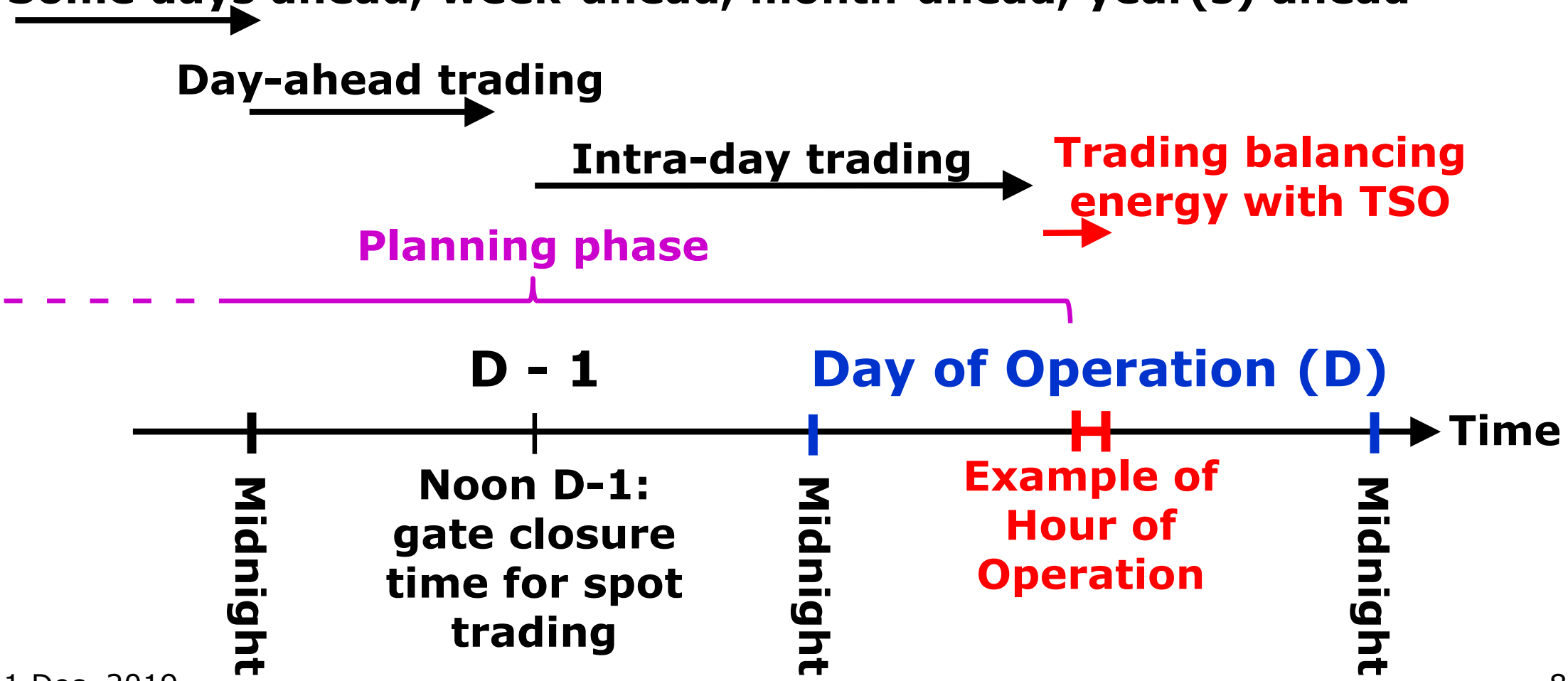
Trading electricity in EU

- **At the following slide, we consider trading of electrical energy for one, given Hour of Operation.**

Time line for trading electrical energy in EU

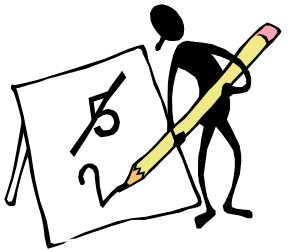
Day of Operation:
The day where the electrical energy is produced and consumed.
Hour of Operation:
The hour where the electrical energy is produced and consumed.

Long-term contracts (physical and financial):
Some days ahead, week-ahead, month-ahead, year(s) ahead

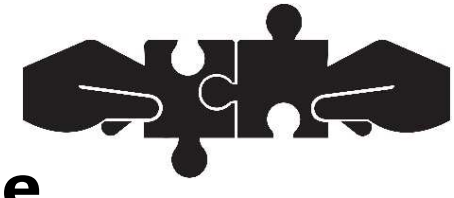


Reliable prices for electricity

- At every point in time, a reliable price means
  - ✓ The price contains all available price-relevant information
    - For the area in question.
- New flexibility platforms will be helpful



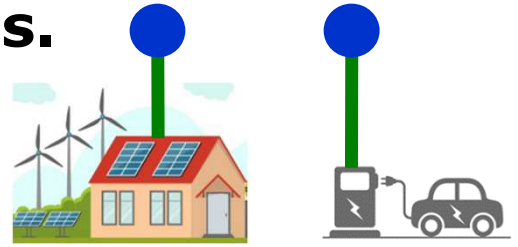
  - ✓ As they can help adjust the prices when new information emerges.
  - ✓ For example, information not available when the spot prices were set
    - New weather forecasts, unplanned outages, etc.
- However, flexibility platforms should <u>not</u> be used to fix dysfunctional day-ahead and intra-day trading systems.
- Instead of this sticking-plaster approach, we must reform the day-ahead and intra-day trading systems
  - ✓ Fitting them to the new electricity business.



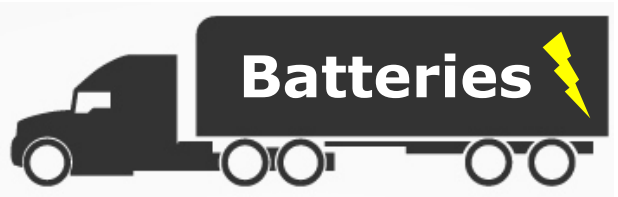
- More information on reliable spot prices: see the PowerPoint presentation *Europe's electricity markets*.

Consequences of the new electricity business

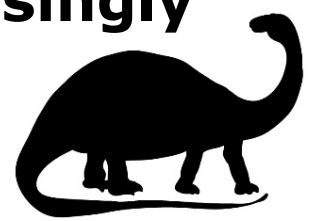
- **For the new electricity business, the value of electricity can vary greatly within short distances.**



- **Therefore, the new system needs <u>local prices</u>.**
- **For example, local prices can be used for *smart grid* technologies**
  - ✓ **Providing flexibility <u>where</u> and <u>when</u> it is needed.**

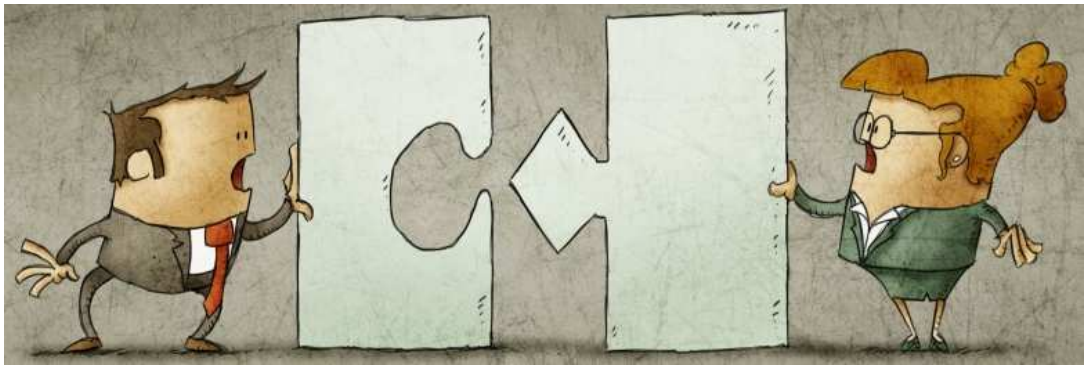


- **Local day-ahead prices can be used to decide the next day's location of movable battery storage, for example.**
- **The current spot prices and intra-day prices are increasingly becoming irrelevant**



  - ✓ **As they do not reflect the value of electricity**
    - **Because they do not reflect the <u>local variations</u> in the value of electricity.**

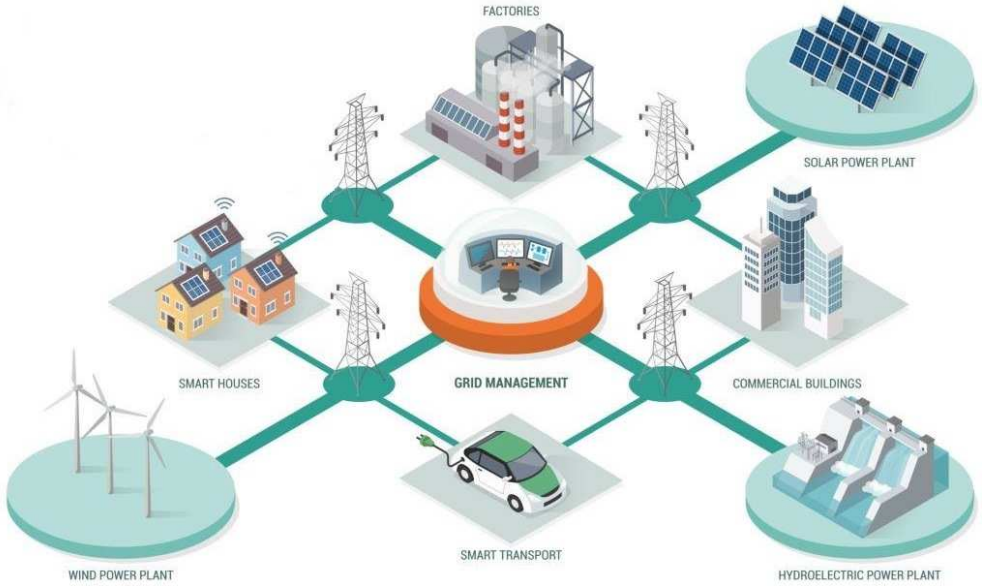
The new electricity business
Plus unreformed trading systems



- **If the spot and intra-day trading systems are <u>not</u> reformed:**
- **We'll need flexibility platforms to ensure, producers and consumers of electricity do <u>not</u> react to the signals from the spot prices and intra-day prices**
  - ✓ **As this could play havoc with the electricity system.**
- **In this case, the spot and intra-day prices do not have much socio-economic value**
  - ✓ **They are reduced to toys for traders.**

Congestion management during the planning phase – 1
Electrical energy

- ***During the planning phase, there's no need for elaborate, manual congestion management, if the trading systems reflect the grid geography***
  - ✓ **Meaning: the day-ahead and the intra-day trading systems must take the actual grid bottlenecks into account.**
  - ✓ ***Otherwise, neither system can produce reliable prices*.**

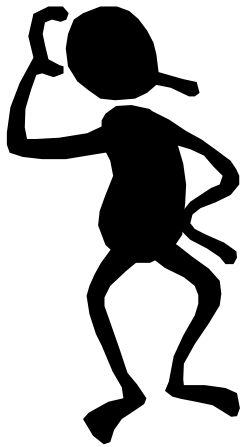


- **For trading systems adapted to the green society:**
  - ✓ **The congestion management will be done automatically by the capacity modules of the day-ahead trading system and the intra-day trading system, respectively.**
  - ✓ **With the actual grid bottlenecks taken into account by both systems.**

Congestion management during the planning phase – 2 Electrical energy

- **With this approach, for the intra-day trading, the new flexibility platforms become competitors to the current operators of the intra-day trading platform XBid.**
- **As they will offer market players an additional entrance to XBid**
  - ✓ **More information on intra-day trading: see the PowerPoint presentation *Intra-day trading for The Single Electricity Market*.**
  - ✓ **Further, the flexibility platforms may be used by the TSOs for the trading of balancing energy**
    - **And perhaps balancing capacity, too.**

Nodal pricing versus zonal pricing



Nodal or zonal pricing? – 1

- Zonal pricing and nodal pricing is explained in the appendix.
  - ✓ As can be seen in the appendix: with nodal pricing, you split the coupled region into many, very small bidding zones (so-called ”nodes”).
- Once every day, you run the calculation. The calculation decides the geographical areas having the same day-ahead prices

  - ✓ Thereby, the decision on which areas will have the same day-ahead prices is left to the market.
  - ✓ In contrast: with the zonal system’s relatively large, pre-set zones, you may argue the zonal system is planned economy.

  - ✓ For other commodities, we do not have rules dictating the commodity must have the same whole-sale price for given geographical areas.

Redispatching inside a zone with sub-areas A and B

Example for one hour of tomorrow

For simplicity, exchange of energy with other zones is ignored

A

At price 50 €/MWh, the producers in A have a planned production 2000 MWh bigger than A's consumption

Redispatching in A: TSO must sell 500 MWh to players in A – thereby reducing the energy surplus with 500 MWh. The TSO's sale price is 48 €/MWh.

Planned energy flow: 2000 MW

Grid capacity: 1500 MW

Redispatching in B: TSO must buy 500 MWh from players in B – thereby reducing the energy deficit with 500 MWh. The TSO's purchase price is 53 €/MWh.

B

At price 50 €/MWh, the producers in B have a planned production 2000 MWh smaller than B's consumption

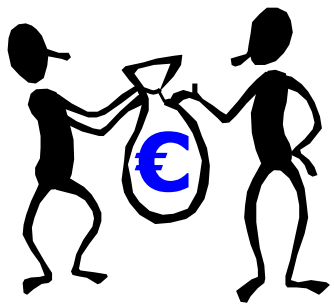
Zone's spot price: 50 €/MWh

The TSO's redispatching costs (buying at 53, selling at 48):
(53 - 48) €/MWh * 500 MWh = 2500 €

The true day-ahead prices in A and B are 48 and 53 €/MWh

Nodal or zonal pricing? – 2

- Because the zonal system typically has large bidding zones, the TSOs often must pay for redispatching inside a zone
  - As the zone's common spot price often creates a planned production surplus in one part of the zone and a planned production deficit in another part of the zone.
    - ✓ And the grid cannot transport the energy between the two parts of the zone.
- However, when this happens, the zone's spot price is unreliable
  - ✓ The redispatching prices are the true market prices.
- The zonal system's large zones simplifies price hedging
  - ✓ And price hedging is important for retailers, who have customers preferring fixed price contracts.
- However, via the grid fees everybody pay for the redispatching
  - ✓ Therefore, the zonal system forces consumers, who prefer spot price contracts, to subsidize consumers, who prefer fixed price contracts
    - As the fixed price consumers do not themselves pay the full cost of the hedging.



- Similar, when intra-day trading ignores grid bottlenecks.

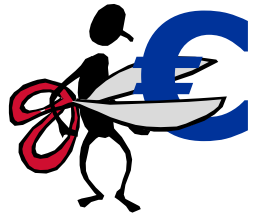
Nodal pricing: the commercial players' settlement of imbalances with the TSO

At the outset, we'd have to establish an imbalance settlement per node

- **However, this would place a big burden on the retailers.**
- **As they would have to produce a consumption forecast for their customers at each node**
  - **Thereby, it would also create a huge entrance barrier for new retailers.**

Hence, we'll have to make a settlement for a larger area

- **Using an average of the area's nodal prices as the starting point for the settlement.**
- **This could give wrong incentives, if players can foresee, this will give imbalance prices better than the nodal prices for given nodes**
  - **However you can deal with this by installing systems ensuring imbalances are never economic advantageous.**



- **For a greener society, a shift to a one-price system for imbalances may not be wise…**

Nodal pricing: price hedging

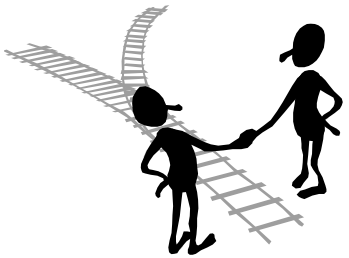
Electricity derivatives – hedging with financial contracts

- **You'll never get liquidity in financial contracts using the day-ahead price at a single node as the underlying reference.**
- **Hence, as the underlying reference for financial contracts:**
  - ✓ **You must use the average of the nodal prices for larger areas.**
- **Thereby, those who prefer fixed price contracts, will themselves:**
  - ✓ **Either bear the remaining risk that their nodal price deviates from the average price.**
  - ✓ **Or pay for having this risk removed also.**
    - **With the zonal system, all grid users pay for this risk (via payment for redispatching)**
      - **Even consumers who have spot contracts.**

- **More information on price hedging and electricity derivatives: see the PowerPoint presentations**
  - ✓ ***Financial prices and spot prices – annual contracts 2002-2017*.**
  - ✓ ***Financial prices and spot prices – quarter contracts 2006-2017*.**

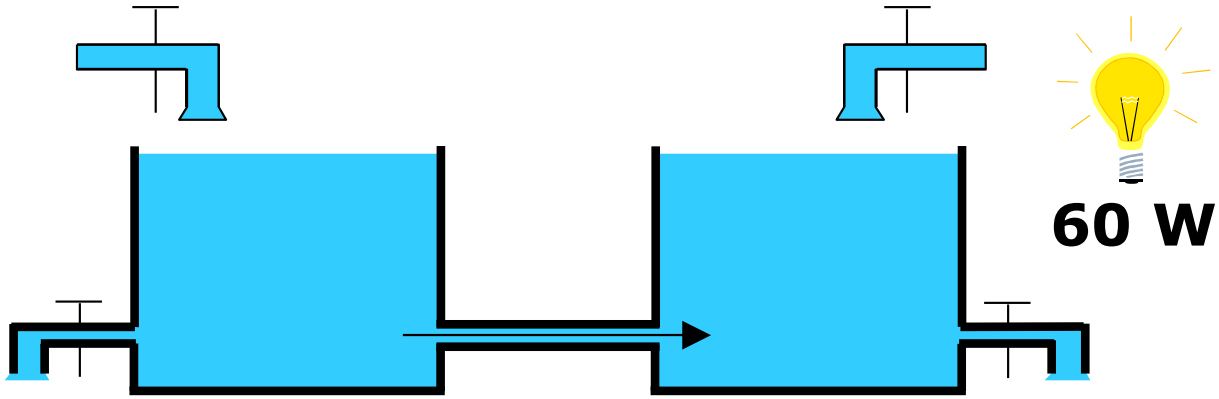
Combination of nodal and zonal pricing

- **Assume we adapt a version of nodal pricing, where the price for each node is set by double auction**
  - ✓ **Hence, we do not use the original nodal system's shadow price principle.**
  - ✓ **Instead, we use the same calculation principle as for the standard zonal pricing**
    - **In this case, the difference between the two systems virtually disappears**
      - **The remaining difference is the size of the zones**
        - **Where the "adapted nodal pricing" has very small zones and the standard zonal pricing has large zones.**



- **With this "adapted nodal pricing", the two systems can co-exist in the same market coupling**
  - ✓ **As some countries in the coupled region will need the "adapted nodal pricing" (i.e. very small zones), whereas other countries can do with the standard zonal pricing (i.e. larger zones).**

Appendix 1 Concepts and units



60 W

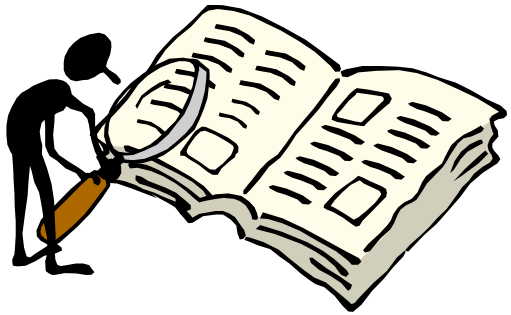
Energy consumed during an hour: 60 W * 1h = 60 Wh

Concept	***Explanation***	***Unit***	***Water analogy***
Power	**Flow: how much energy per second?**	**W (Watt)**	**Flow: how much water is passing by per second?**
Energy	**The amount (for example, during an hour)**	**Wh (Watt-hour)**	**The amount (for example, during an hour)**
Capacity	**The ability to change a flow**	**W (Watt)**	**The ability to change a flow**

Appendix 2 Settlement of imbalances

Production and consumption	Imbalance settlement	Trading: buy and sell energy

- **Settlement of imbalances is the glue between**
  - ✓ **The physical world, where electricity is produced and consumed.**
  - ✓ **The financial system, where electricity is traded.**
- **In EU, the TSOs are responsible for the imbalance settlement.**
- **<u>Example</u>: consider an owner of a wind farm and a given Hour of Operation. For this hour, assume the owner has sold 100 MWh to the market.**
  - ✓ **Assume the windfarm actually produces 110 MWh.**
  - ✓ **In this case, the TSO buys the extra 10 MWh.**
  - ✓ **In a two-price system: if the surplus production was helpful for the electricity system, the TSO pays the market price for the extra 10 MWh**
    - **Hence, compared with the market price, no reward for the surplus production, even if the electricity system needed extra energy during this hour.**
  - ✓ **If the surplus production was harmful for the electricity system, the TSO pays a price lower than the market price.**
  - ✓ **In a one-price system: if the surplus production was helpful for the electricity system, the TSO pays a price higher than the market price.**
    - **Hence, a reward for helping the system, although the TSO did not ask this player for assistance.**
  - ✓ **If the surplus production was harmful for the electricity system, the TSO pays a price lower than the market price.**
- **Similar for a retailer, who buys an amount of energy, which does not correspond to the consumption of the retailer's customers.**
- **For more information: see the PowerPoint presentation *Capacity markets and the Single European Electricity Market* and the PDF document *The Liberalized Electricity Market*.**



Appendix 3
Terminology and acronyms

Terminology and acronyms – 1
As used in this presentation

- ***Bidding zone*** **A geographical area, within which the players can trade electricity day-ahead without considering grid bottlenecks.**
- ***Border*** **Means a border between two bidding zones.**
  - ✓ **Hence, it need not be a border between two countries. It may be a border between two bidding zones inside a country.**
- ***Coupled region*** **A geographical area, in which you have a common IT system calculating the area's spot prices and day-ahead plans for the cross-border energy flows by using:**
  - ✓ **The market players' spot bids.**
  - ✓ **Information on the day-ahead cross-border trading capacities.**
- ***Double auction*** **A calculation method whereby an exchange's price is set by using the exchange's supply curve and the exchange's demand curve. See the PowerPoint presentation "Maximizing the economic value of market coupling and spot trading" and the PDF document "The Liberalized Electricity Market".**
- ***Electricity*** **Short for electrical energy.**
- ***Fixed price contract*** **See *spot contract*.**
- ***Flexibility*** **In this document, this means the ability to change production or consumption of electricity with short notice.**
- ***Flow*** **Short for *energy flow*.**

Terminology and acronyms – 2
As used in this presentation

- ***Flow-based zonal market coupling*** **A version of zonal market coupling, where the market coupling calculation includes a simplified load flow calculation. Thereby, the calculation tries to take into account the complicated flows of a meshed grid.**
- ***Hour of Operation*** **The hour where the electricity is produced and consumed.**
- ***Implicit auction*** **The common term for market coupling and market splitting.**
- ***Market coupling*** **A day-ahead congestion management system, you can have on a border, where two electricity exchanges meet. The day-ahead plans for the cross-border energy flows are calculated using the market players' spot bids and information on the day-ahead cross-border trading capacity. See the PowerPoint presentation "Maximizing the economic value of market coupling and spot trading" and the PDF document "The Liberalized Electricity Market".**

  For simplicity, in this presentation, the term *market coupling* is used for both market coupling and market splitting.
- ***Market splitting*** **A day-ahead congestion management system, you can have on a border, where you have the same electricity exchange on both sides of the border. The day-ahead plans for the cross-border energy flows are calculated using the market players' spot bids and information on the day-ahead cross-border trading capacity. See the PowerPoint presentation "Maximizing the economic value of market coupling and spot trading" and the PDF document "The Liberalized Electricity Market".**

  For simplicity, in this presentation, the term *market coupling* is used for both market coupling and market splitting.

Terminology and acronyms – 3
As used in this presentation

Nodal pricing **With this system, the coupled region is divided into very small sub-areas called "nodes"**

For example, a node may be the sub-area supplied by a given distribution grid.

A node's whole-sale price is set by calculating the cost of supplying a small <u>extra</u> volume of electrical energy to the node

Example for a given hour – if a node's demand is 1000 MWh: the node's price is set by calculating the cost of supplying one extra kWh (thereby increasing the node's supply to 1000.001 MWh). Hence, <u>the nodal price is a shadow price</u>.

In the nodal calculation, the complexities of energy flows in a meshed grid is taken into account. Thereby, nodal pricing is an alternative to flow-based zonal market coupling.

Apart from the nodal system's shadow price principle, you may say nodal pricing deviates from zonal pricing in this way:

By splitting the coupled region into very small sub-areas, the nodal pricing abandons large, (politically set?) bidding zones.

Terminology and acronyms – 4
As used in this presentation

- ***Prosumer*** **A player who is both a producer and a consumer of a commodity.**
- ***SIDC*** **See XBid.**
- ***Spot bid*** **A purchase bid or a sales offer submitted to a spot exchange.**
- ***Spot contract*** **A consumer having this contract with a retailer, pays the retailer the spot price plus the retailer's mark-up. Hence, the consumer's price is tracking the spot price.**

  The consumer's price can track the hourly spot price, if the consumer has a meter measuring the consumption per hour.

  This contrasts with a fixed price contract, where the consumer has a fixed electricity price for a long period (a year, for example). In practice, with a fixed price contract, the consumer's price is tracking the market's forecast of the whole-sale price, as the price is fixed before the delivery period.
- ***Spot exchange*** **In this document, a spot exchange is an electricity exchange where**
  - ✓ **Electrical energy is traded day-ahead.**
  - ✓ **The exchange's day-ahead prices are calculated by means of double auction.**

  See the PowerPoint presentation "Maximizing the economic value of market coupling and spot trading" and the PDF document "The Liberalized Electricity Market".
- ***Spot price*** **A day-ahead price used by a spot exchange (or the spot exchange's associated clearing house) to settle the participants' trading at the exchange.**

  The spot price is calculated using double auction.

  See the PowerPoint presentation "Maximizing the economic value of market coupling and spot trading" and the PDF document "The Liberalized Electricity Market".

Terminology and acronyms – 5
As used in this presentation

- ***TSO*** **Transmission System Operator.**

  In EU, each TSO has two tasks:

  - ✓ **Operate the high-voltage grid (the transmission grid) in the TSO's so-called control area.**
  - ✓ **Be responsible for the security of supply in the TSO's control area.**

  Most EU Member States have only one TSO. Hence, the TSO's control area is the whole country.

  However, some Member States have more than one TSO (e.g. Germany).

- ***XBid*** **A European intra-day trading platform. As of 19 November 2019, the name is SIDC (Single Intra-Day Coupling).**
- ***Zonal market coupling*** **A market coupling, where the coupled region is divided into relatively large bidding zones.**

  Further, for each zone, the zone's day-ahead exchange prices are calculated by means of double auction (i.e. it's spot prices).
- ***Zone*** **Short for *bidding zone*.**

Thank you for your attention!

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