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Robert Schuman Centre for Advanced Studies

Florence School of Regulation

Electricity Markets: the Wholesale Market

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Florence School of Regulation
Summer School on
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Florence, June 28th – 2nd July, 2010

Outline

- Electricity and other Traded Products
- Trading in Liberalised Electricity Markets
- Design of Organised Wholesale Electricity Markets
- Financial Derivatives Markets

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- **Electricity and other Traded Products**
- Trading in Liberalised Electricity Markets
- Design of Organised Wholesale Electricity Markets
- Financial Derivatives Markets

Products and Services

- Different products and services are identified in a liberalised electricity market
 - Scheduled energy
 - Balancing energy
 - Tertiary reserve
 - Frequency control
 - Primary reserve
 - Secondary reserve
 - Reactive power for voltage regulation
 - Black-start capabilities
 - Generation capacity for long term adequacy
- Ancillary Services

Ancillary Services

- Ancillary Services – interconnected operations services identified as necessary for transmission
- Primary (Frequency) Control – maintenance of the balance between generation and demand using turbine speed generators
- Secondary (Load-Frequency) Control – centralised automatic function to regulate the generation in a control area in order to:
 - maintain exchanges with other control areas at the programmed levels
 - return the frequency to its set value in case of a (major) frequency deviation, thus restoring primary control reserve
- Tertiary Control – automatic or manual change of working point of generators (mainly by re-scheduling) to restore an adequate secondary control reserve
- Black-start Capability – the ability of a generating unit to start operating and delivering power without assistance from the electric system
- Reactive Power – the portion of the electricity that establishes and sustains the electric and magnetic fields of alternating-current equipments, and directly influences the electric system voltage

Trading Mechanisms

- Ancillary services are provided by TSOs
- Resources for the provision of ancillary services can be:
 - Provided directly by the TSO (e.g. Voltage control through capacitors)
 - Supplied by grid users according to licence conditions (e.g. Primary reserve)
 - Procured by the TSO through long-term contracts (e.g. Black start capability)
 - Procured by the TSO through dedicated markets (e.g. Secondary reserve)
- Ancillary services are public goods (they cannot be provided selectively to grid users)
- Balancing energy is also traded in a dedicated market/mechanism
- Generation capacity for long-term adequacy can be traded in different ways (bilaterally or in a centralised market)

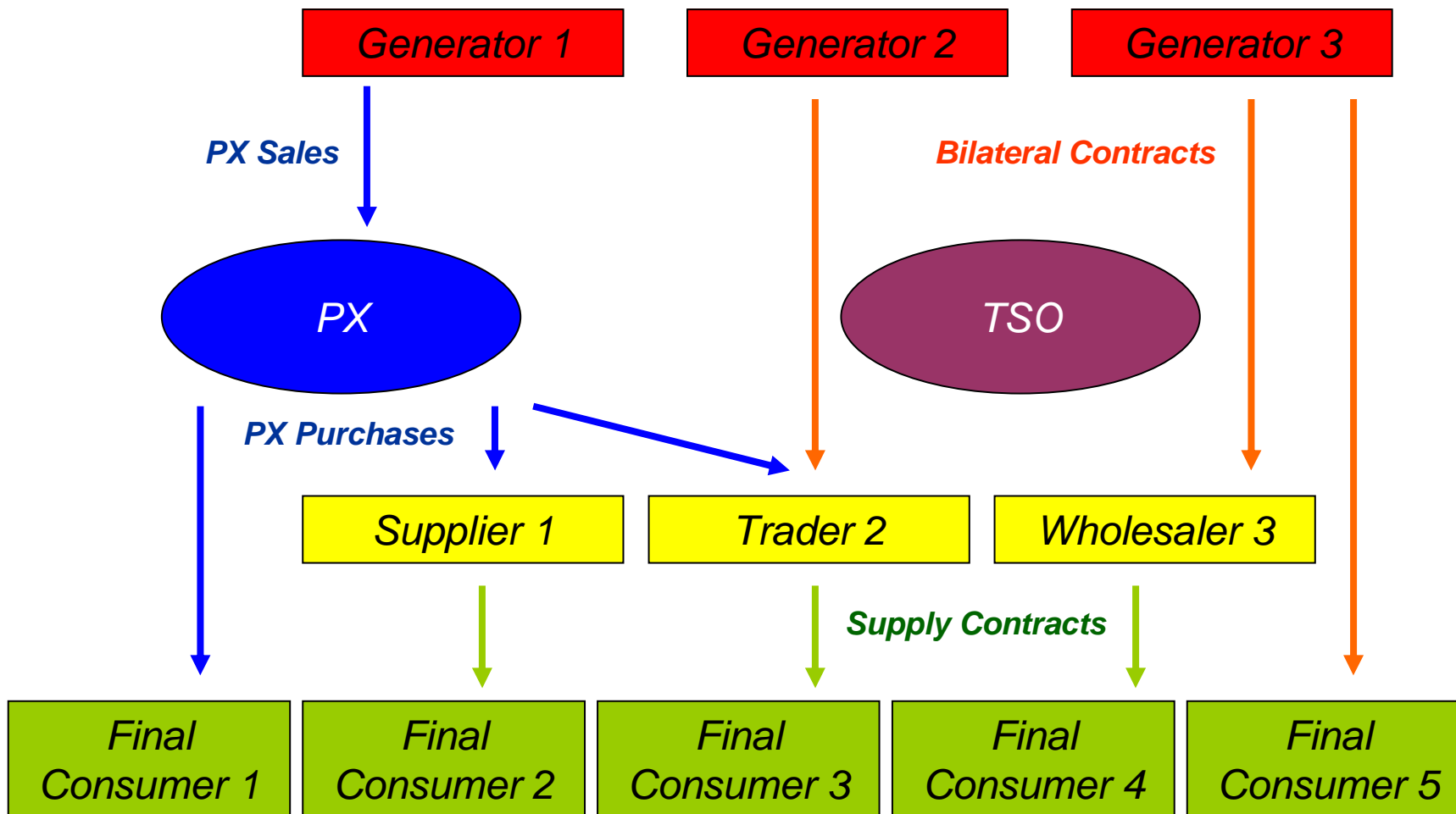
Outline

- Electricity and other Traded Products
- **Trading in Liberalised Electricity Markets**
- Design of Organised Wholesale Electricity Markets
- Financial Derivatives Markets

Trading opportunities (1)

- Generally, trading can be conducted through:
 - Bilateral Over-the-Counter (OTC) contracts
 - Organised markets (Power Exchanges - PXs)

Commercial Relationships in Liberalised Electricity Markets



Trading opportunities (2)

- Bilateral contracts may be:
 - Customised
 - Respond to the requirements of the counterparties
 - Reduce basis risk ...
 - But requirements of the counterparties may not always be compatible
 - Standardised
 - Standard features and clauses
 - Easier to negotiate
 - Easier to trade in a secondary market
- Brokers may facilitate the conclusion of bilateral contracts by matching counterparties with compatible requirements

Bilateral Over-the-Counter vs. Power Exchange Trading

Properties	Trading Method	
	Over-the-Counter	Power Exchange
Anonymity of Trading	No	Yes
Counterparty	Bilateral	Central Counterparty
Counterparty Risk	Yes, unless Cleared	No
Trading Method	Continuous Trading	Typically Central Auction

Bilateral Contracts: the EFET Example

- General Agreement (GA) governing Individual Contracts (ICs)
- GA customisation through the Election Sheet (ES)
- IC could be:
 - Fixed price
 - Floating price
 - Call Option
 - Put Option
- ICs confirmed through a Confirmation of Individual Contract (CIC)
- Cross Border Annex (jurisdiction and taxation issues)

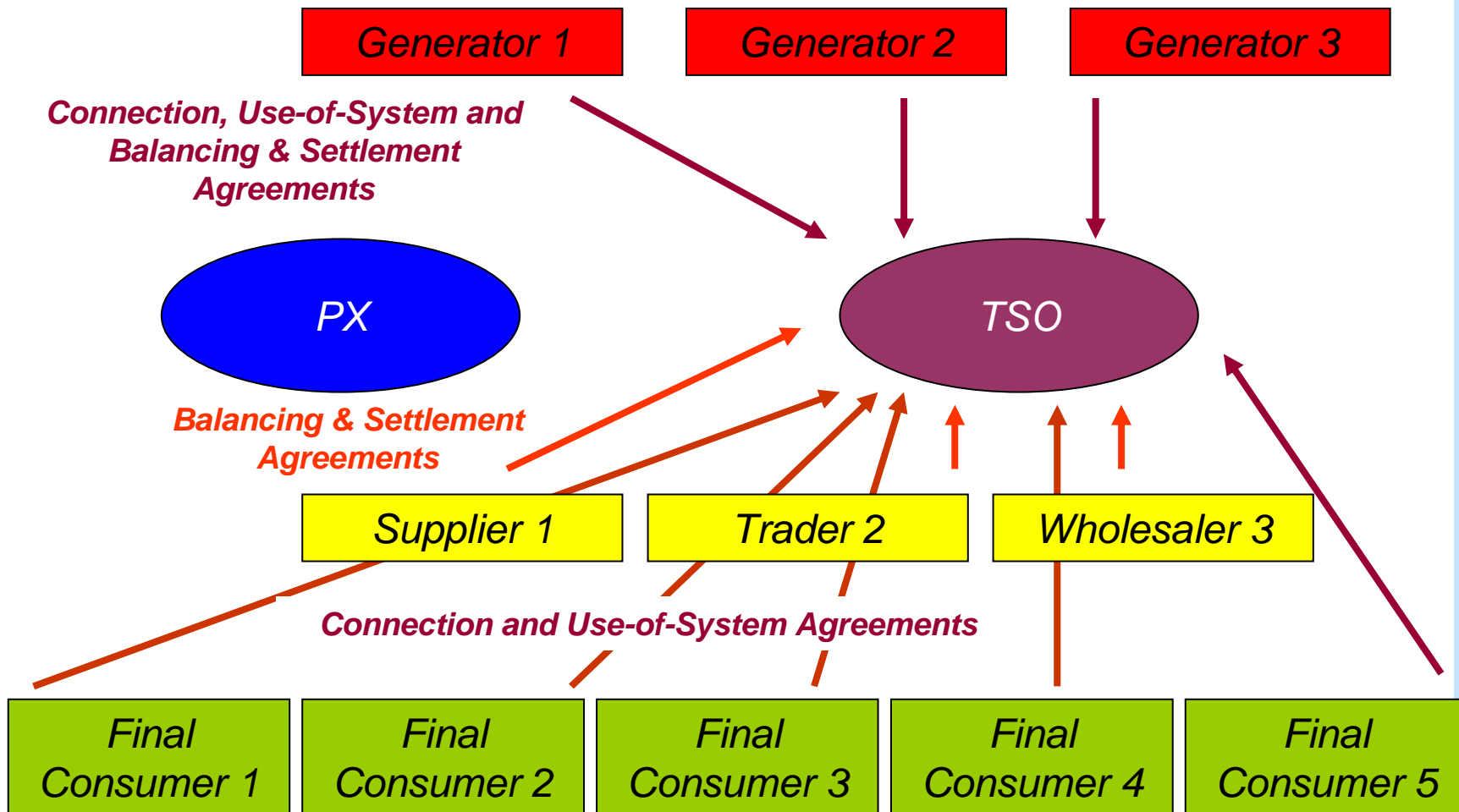
Trading and delivery (1)

- Trading results in long/short positions
 - Long positions assign the right/obligation to withdraw power from the grid
 - Short positions assign the right/obligation to inject power into the grid
 - Long and short positions resulting from trading should be balanced (injections = withdrawals) in each delivery period

Trading and delivery (2)

- “Gate Closure” is the deadline for trading electricity to be delivered in a specified period
- Gate Closure could be from one or more days to one hour or less before delivery time
- By Gate Closure, balanced (injections and withdrawal) positions are declared (possibly through balance responsible agents) to the relevant TSO (scheduling). (The PX may itself be a balance responsible agent)
- At Gate Closure the TSO takes over the management of electricity flows over the network
- Deviations of actual injections/withdrawals from positions attract imbalance charges and are settled with the TSO

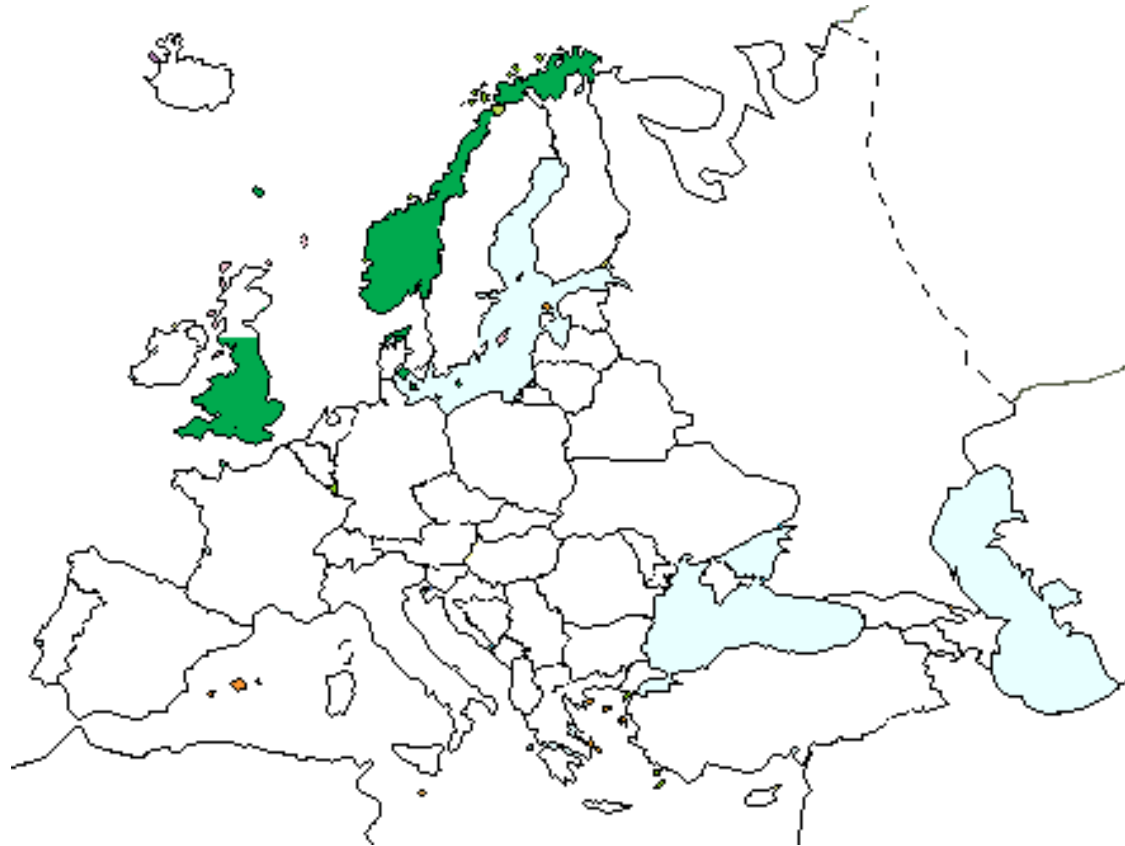
Technical Relationships in Liberalised Electricity Markets



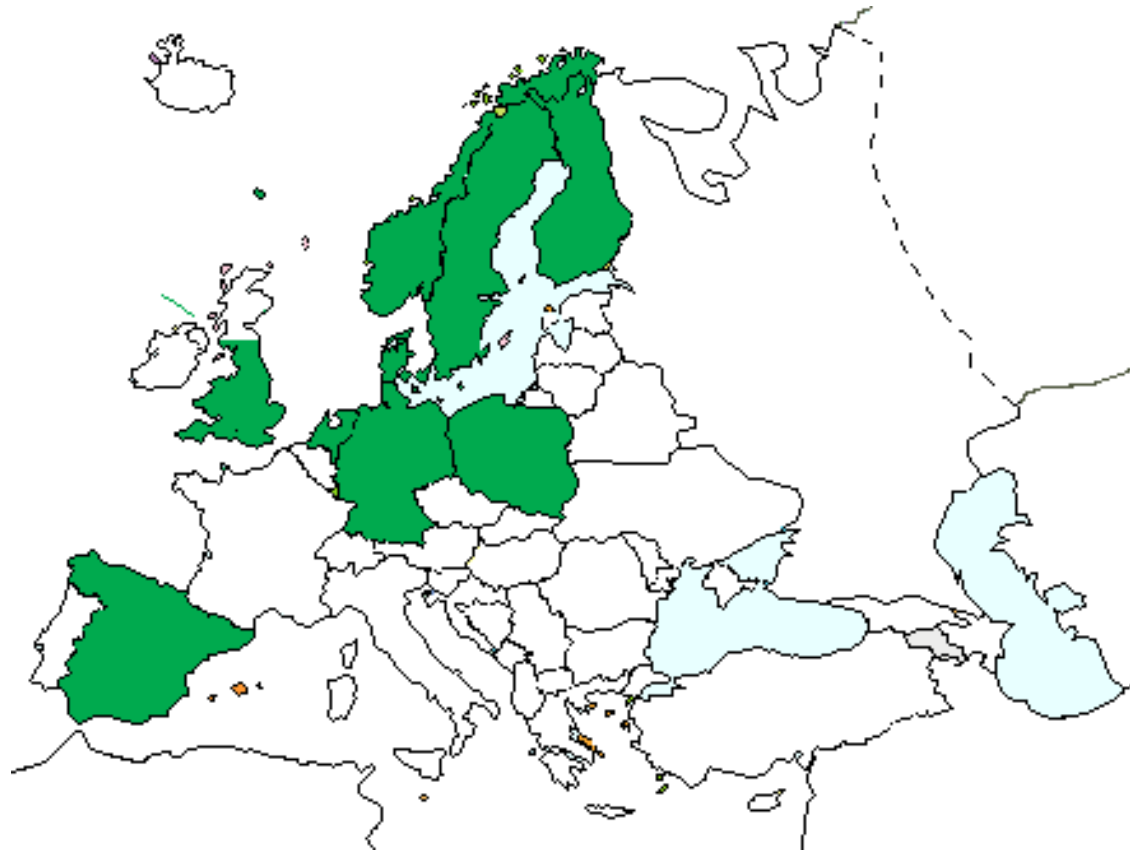
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Power Exchanges operating in Europe in 1995

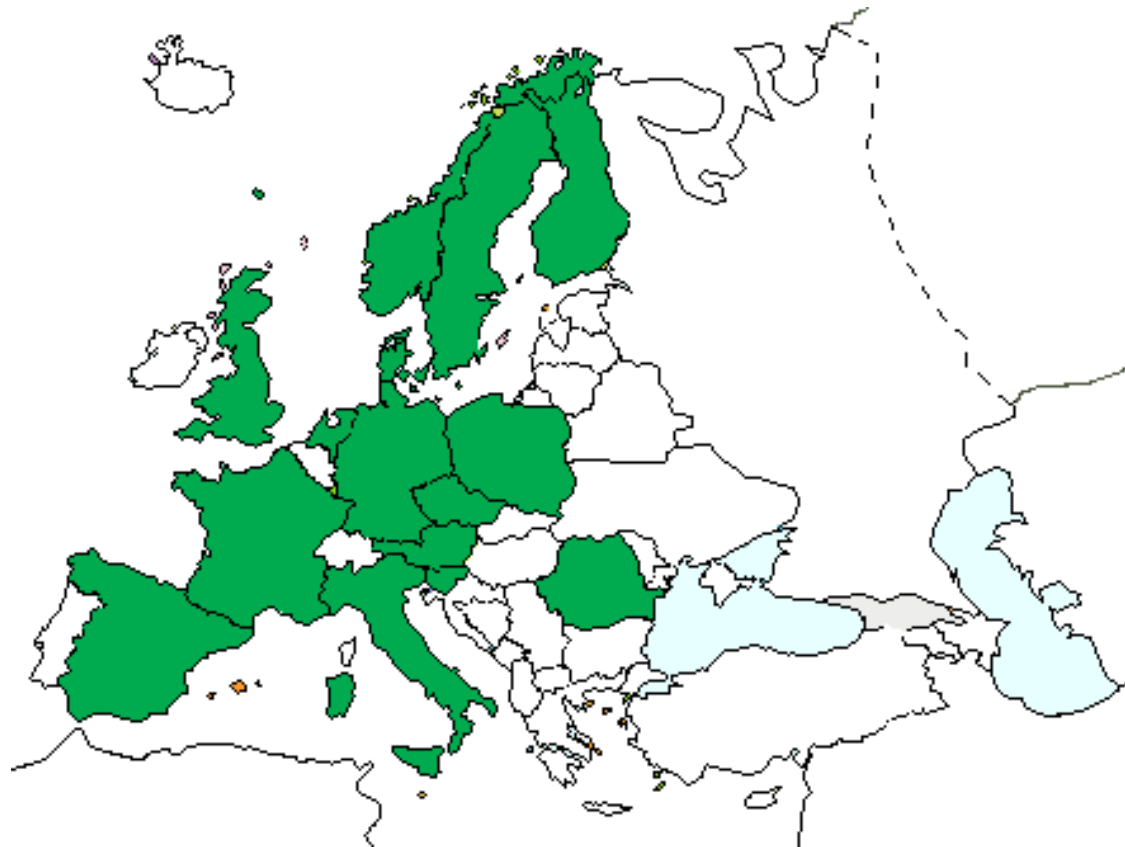


Power Exchanges operating in Europe in 2000



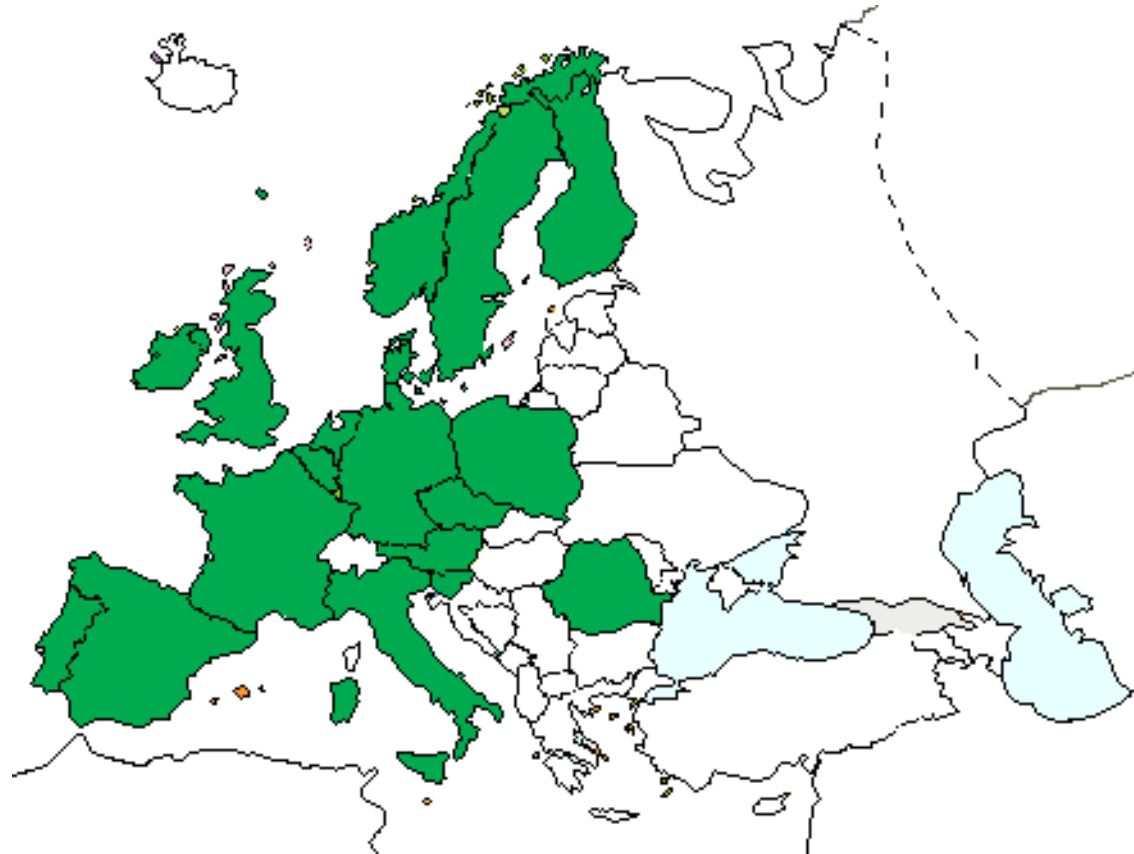
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Power Exchanges operating in Europe in 2005



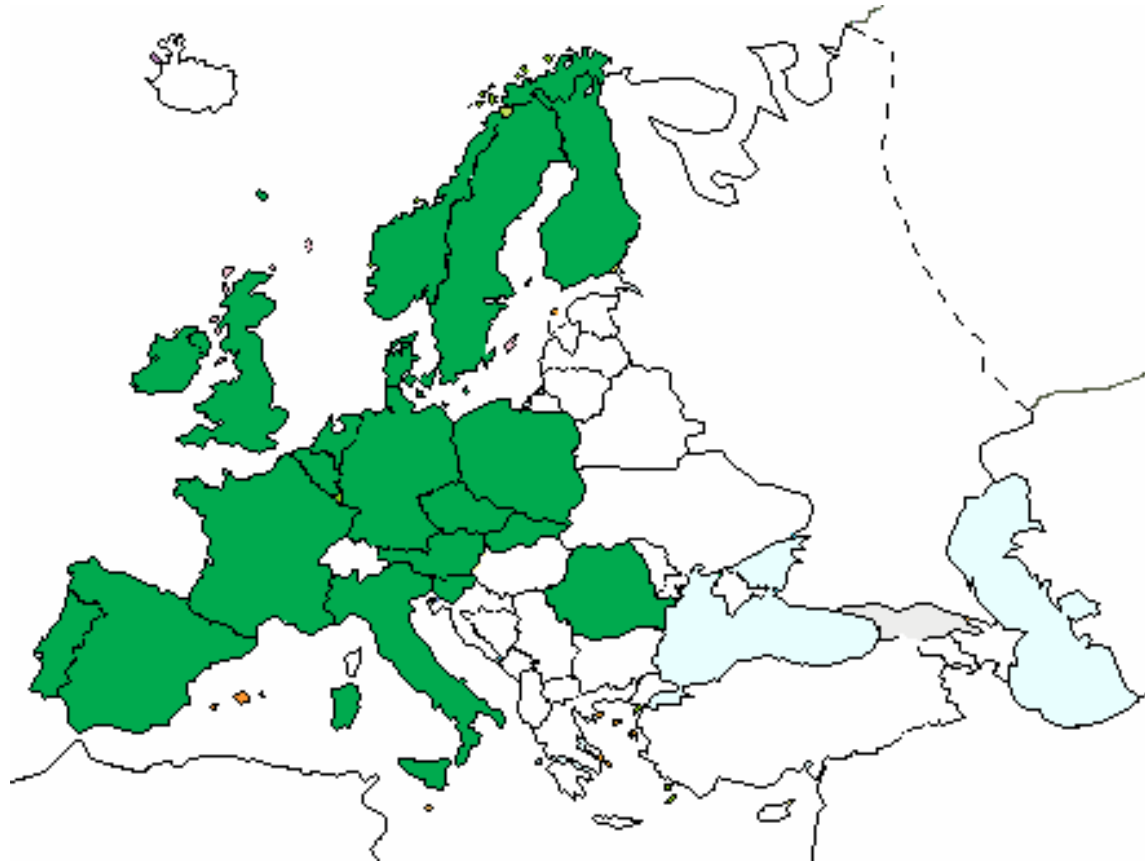
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Power Exchanges operating in Europe in 2008



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Power Exchanges operating in Europe in 2010



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Development of European Power Exchanges (1)

- 1990:** **England and Wales** Pool starts operating
- 1993:** StatnettMarked starts operating in **Norway**
- 1996:** StatnettMarked becomes NordPool and extends to **Sweden**
- 1998:** NordPool extends to **Finland**
Omel starts operating in **Spain**
- 1999:** APX starts operating in **The Netherlands**
- 2000:** NordPool extends to **Denmark**
EEX and LPX start operating in **Germany**
Gielda Energie starts operating in **Poland**
- 2001:** E&W Pool is replaced by NETA. AutomatedPX and UKPX start operating
Powernext starts operating in **France**
Opcom starts operating in **Romania**

Development of European Power Exchanges (2)

- 2002:** Borzen starts operating in **Slovenia**
EXAA starts operating in **Austria**
OTE starts operating in the **Czech Republic**
EEX and LPX merge and establish the new EEX (Liepzig)
- 2003:** APX takes over AutomatedPX in the UK
- 2004:** GME starts operating in **Italy**
APX takes over UKPX, APX UK's operations are branded as UKPX
- 2005:** NETA is extended to Scotland under BETTA
- 2006:** Belpex starts operating in **Belgium**
- 2007:** Mibel integrates the markets of Spain and **Portugal**
The Single Electricity Market starts operating in the **Republic of Ireland** and **Northern Ireland**
- 2008:** EEX and Powernext merge spot trading into EPEX Spot (Paris)
- 2009:** SEPS, the Slovak TSO, launches a PX in **Slovakia**

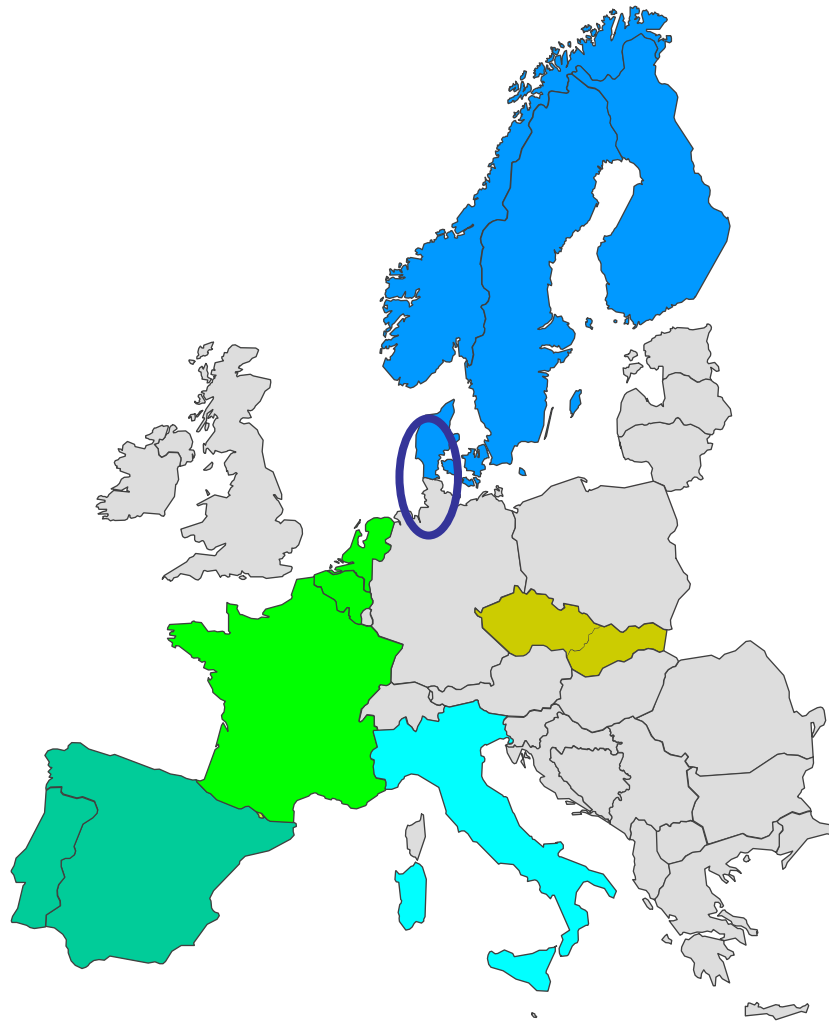
European Power Exchanges



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Source: EEX

Current Regional Markets




REGIONAL IMPLICIT AUCTIONS		
	Nordic and DK East to Ger on Kontek & CBO DK West - Ger	Market splitting/NTC
	TLC	Price coupling/ATC
	Iberian Peninsular	Market splitting/NTC
	Czech Rep - Slovakia	Price coupling/ATC
OTHER IMPLICIT MARKET REGIONS		
	Italy	Market splitting (internal market boundaries)/NTC

No congestion (common price areas):

Austria – Germany

Rep Ireland – N. Ireland

 “Cross Border Optimization” mechanism between DK West (Jutland) and Germany

System Level Benefits

- **Efficient, merit-order dispatch**
according to offers submitted to the PX.
- **Separation between generation and supply**,
the two potentially-competitive activities in the electricity sector, which, in many countries, are still characterised by (vertically-integrated) dominant players.
- **Greater transparency in price setting.**
Prices reflect market conditions and thus vary hour by hour. PX prices are published daily and provide a reliable reference.
- **Easier entry into the market by new players.**
Non-discriminatory access to wholesale power. New entrants in the generation business may sell power at fair prices. New entrants in the supply business may buy wholesale power at fair prices.
- **Increased security of supply.**
Promotion of generation capacity availability and load management at peak times. More accurate price signals on the relationship between demand and supply.

Participants Level Benefits

- **Market-place** where electricity is available at market prices
- **Greater flexibility** in generation and consumption strategies (revision of scheduled generation or consumption close to real time)
- **Guaranteed payment** of electricity through a central counterparty and guarantee requirements

Characterisation of Power Exchanges

- Market participation
- Trading timing
- Traded products / trading periods
- Bid and offer format
- Trading methods / pricing criteria

Market participation

- Participation can be:
 - Compulsory - in a gross market ("Pool")
 - Voluntary – in a net market
- All PXs in the EU are voluntary
 - Participation may be compulsory for some types of trading (e.g. inter-zonal trading in Nordic countries should be effected through Nord Pool)
 - Some entities may be required to use PXs for part of the energy they trade (e.g. the Single Buyer in Italy)
 - Regulation may favour participation in a PX (e.g. capacity payments in Spain)
- Active participation of demand (load/LSE) and supply (generators)

Trading timing

- PXs are generally centred around a Day-Ahead Market (DAM), where electricity is traded the day before the day of delivery
- Longer-Term Markets are generally based on financial products
- Some PXs also provide Adjustment Markets for modifying commitments deriving from the outcome of the DAM:
 - improving on suboptimal results of the DAM
 - reflecting new information (unplanned outages, ...)
- Current Adjustment Markets:
 - NordPool: Elbas Market
 - Spain: six Intra-day Market sessions, each covering the remaining delivery periods of the day of delivery
 - Italy: Adjustment Market immediately after the DAM
 - Germany/France: continuous trading

Traded products / trading periods

- Non-storability → electricity at different times is a different product
- Some aggregation into delivery periods inevitable (for practical reasons)
- Electricity is traded
 - typically hourly (energy to be delivered in a specific 60-minute delivery period),
 - half-hourly (UKPX)
 - 15-minute periods
- Blocks: Hourly energy for a predefined set of contiguous hours (Nord Pool, OMEL, EEX, Powernext, Borzen, UKPX, EXAA) or a set defined by individual participants (APX – effectively similar to setting a minimum revenue requirement – see “bid and offer format”)

Bid and offer format (1)

- Bid:
 - one or more quantity-price pairs, each specifying the maximum price at which the participant is willing to buy the corresponding quantity of electricity
- Offer:
 - one or more quantity-price pairs, each specifying the minimum price at which the participant is willing to sell the corresponding quantity of electricity

Bid and offer format (2)

- Simple bids/offers:
 - Bids and offers are submitted independently for each delivery period
 - The market equilibrium for a delivery period is determined independently from the market equilibrium for other delivery periods
- Complex bids and offers:
 - Bids and offers specify constraints covering more than one delivery period
 - The market equilibrium for different delivery periods are interrelated

Bid and offer format (3)

- Types of complex bids/offers:
 - Generators:
 - Minimum revenue requirement (OMEL)
 - Ramp constraint (OMEL)
 - Generators and load/LSE:
 - Block bids/offers: bids/offers for a number of consecutive delivery periods:
 - standardised (Nord Pool, OMEL, EEX, Powernext, Borzen, UKPX, EXAA)
 - defined by the market participant (APX)

Bid and offer format (4)

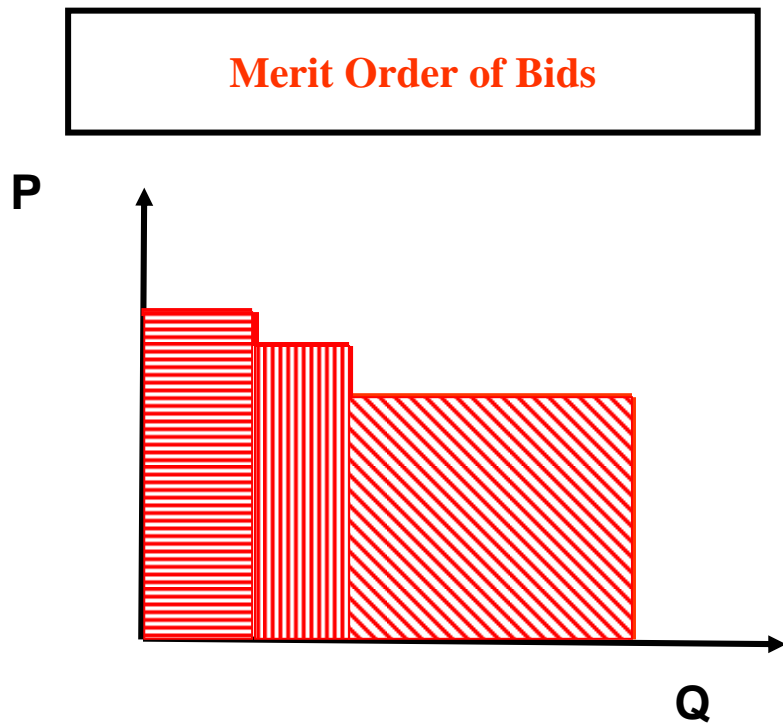
PROS and CONS of Simple and Complex Bids/Offers

- Simple Bids/Offers:
 - Simpler and more transparent determination of the market outcome
 - Offers only imperfectly reflect generators' costs → generators bear some risk and → market outcome may be suboptimal/technical unfeasible
 - Subsequent (adjustment) markets may provide opportunities to modify commitments arising from the outcome of simple-bids/offers DAMs
- Complex bids:
 - Offers may reflect actual costs more accurately → reduced risk for generators and → optimal/feasible market outcome easier to achieve
 - Computationally more complex and less transparent determination of market outcome

Trading methods / pricing criteria (1)

- Auction-based trading:
 - Bids and offers for each delivery period are submitted by a specified deadline
 - Merit orders are compiled:
 - Bids are ranked in descending price order
 - Offers are ranked in ascending price order
 - The (equilibrium) market outcome is defined by the equilibrium market price (EP)
 - The EP is the price at which the cumulative quantity specified in the merit order of bids is equal to the cumulative quantity specified in the merit order of offers
 - Bids specifying a price not lower than the EP are accepted
 - Offers specifying a price not higher than the EP are accepted
 - Accepted bids and offers are valued at:
 - the EP (single-price auctions)
 - the price specified in each bid/offer (discriminatory or “pay-as-bid” auctions)
 - Possibility of several rounds of bidding

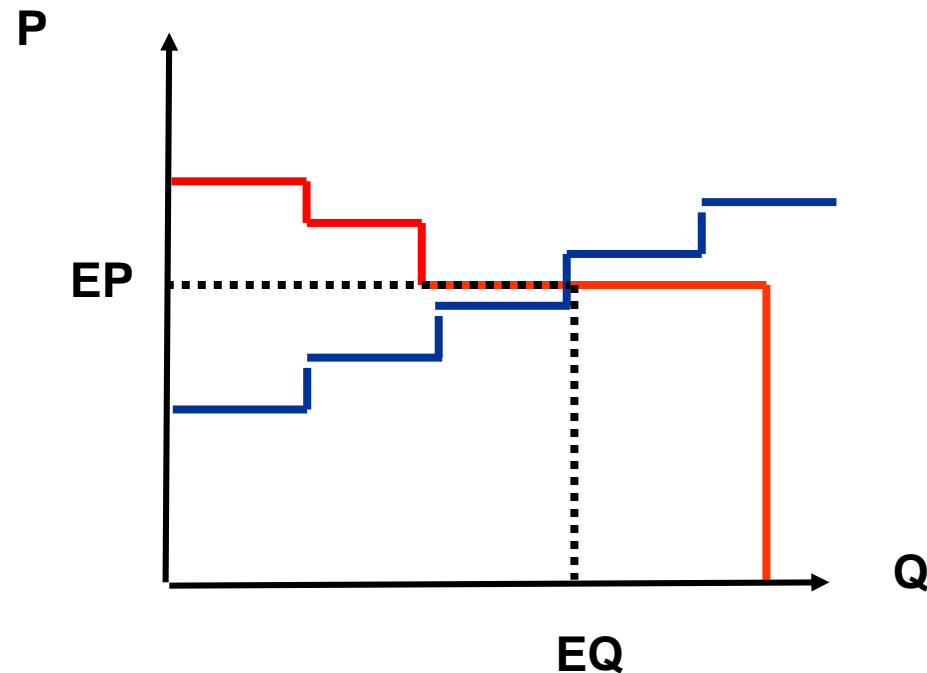
Trading methods / pricing criteria (2)



Merit Orders

Trading methods/pricing criteria (3)

EP = Equilibrium Price
EQ = Equilibrium Quantity

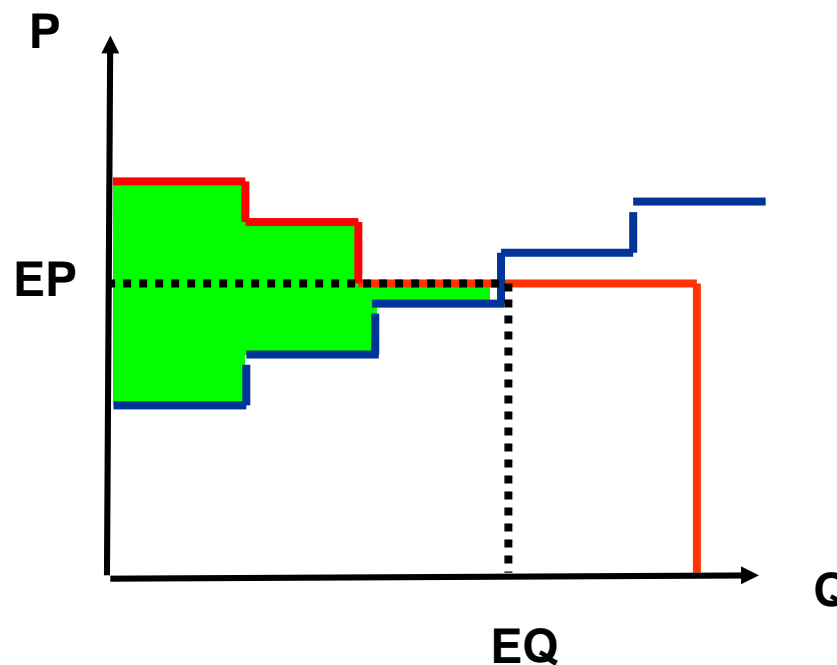


Market Equilibrium

Trading methods / pricing criteria (4)

EP = Equilibrium Price
EQ = Equilibrium Quantity

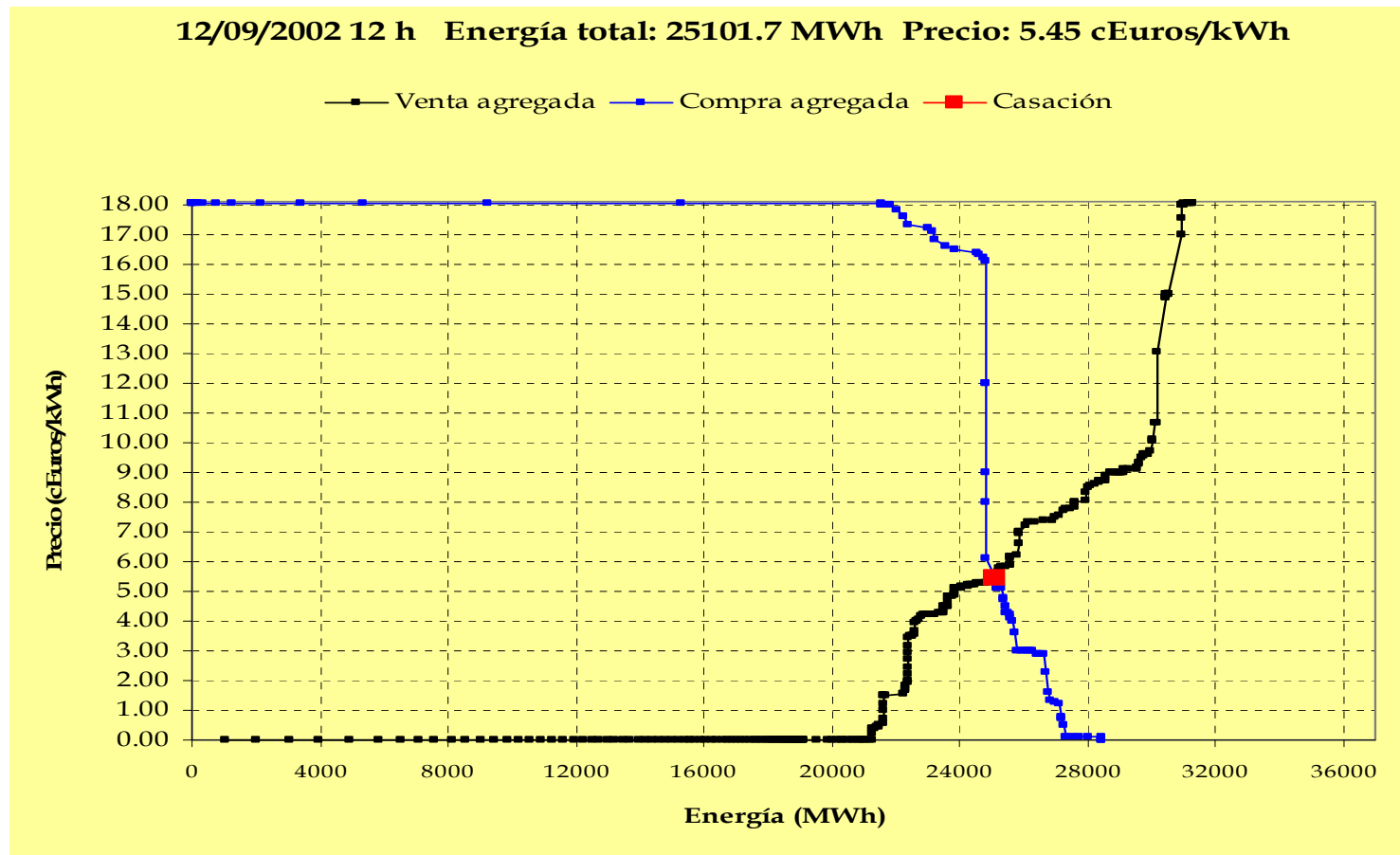
 = Economic value of transactions



**The Market maximises
the economic value of transactions**

Trading methods / pricing criteria (5)

Example from the Spanish PX (OMEL)



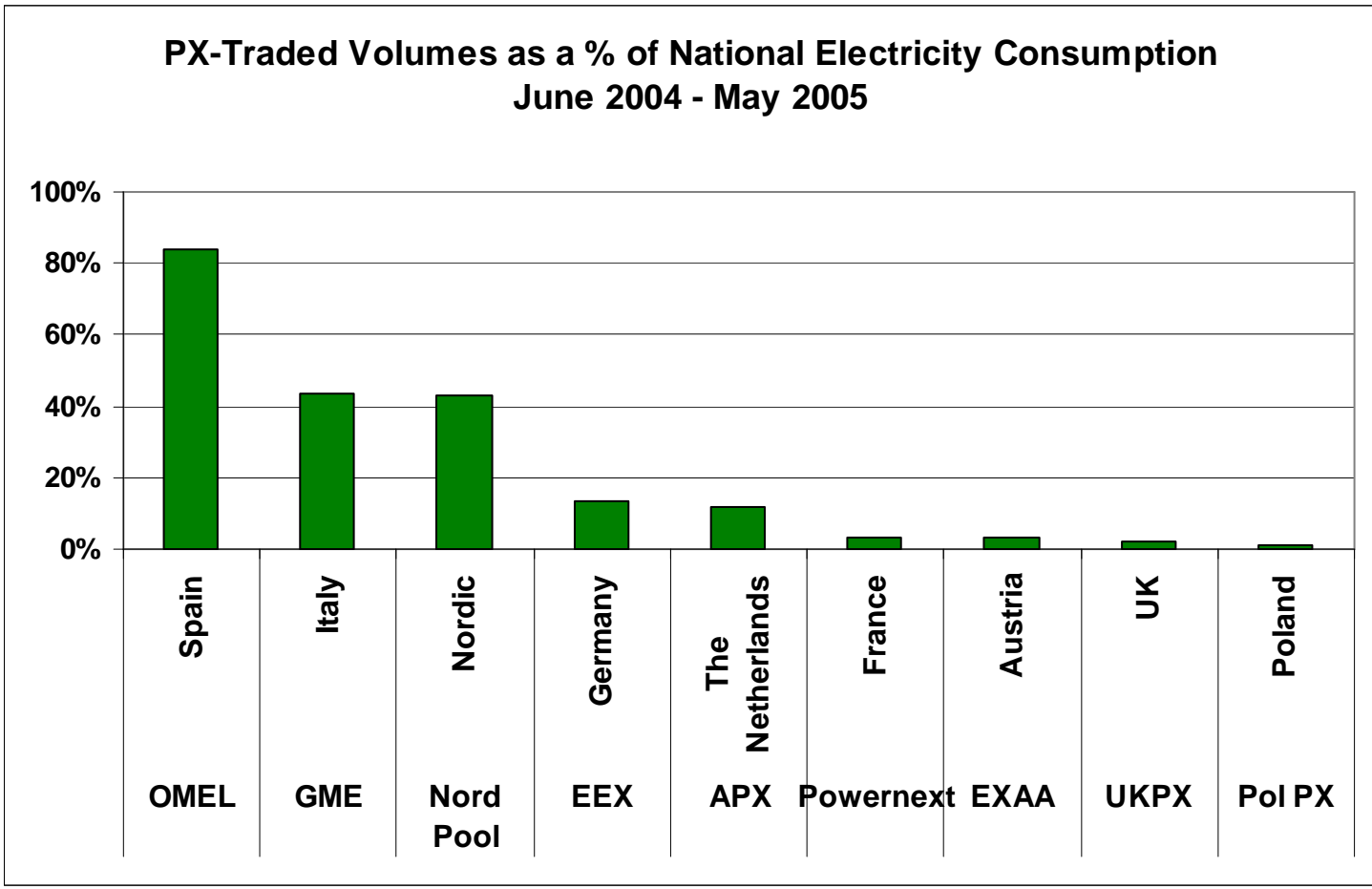
Trading methods / pricing criteria (6)

- Continuous bilateral trading
 - Bids and offers for a specified delivery period are submitted at any time during the trading session
 - As soon as it is submitted, each bid/offer is matched, if possible, with offers/bids already submitted for the same delivery period and specifying compatible quantities and prices
 - The execution price of a transaction is generally the price specified in the bid/offer submitted earlier
 - If no match can be found, bids/offers are held and shown in the “trading book” to be matched with offers/bids submitted later in the same trading session

Trading methods/pricing criteria (7)

- **PROs of trading methods/pricing criteria**
- Auction-based trading
 - Maximises value of transactions → facilitates efficient dispatching
 - Single equilibrium price reference
 - Allows integrated congestion management
- Continuous bilateral trading
 - Analogous to financial markets trading
 - Participants can “see” the market before trading

Traded Volumes



Outline

- Electricity and other Traded Products
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- **Financial Derivatives Markets**

Financial (derivatives) trading

- Prices in liberalised electricity markets vary from trading period to trading period, as a result of demand – supply interaction and transmission capacity
- Participants are exposed to the risks resulting from the variability of revenues/costs from selling/buying electricity
- As in the financial markets, electricity derivative instruments provide risk hedging
- Types of instruments:
 - Forwards
 - Futures
 - Options

Forward, Future and Option Contracts

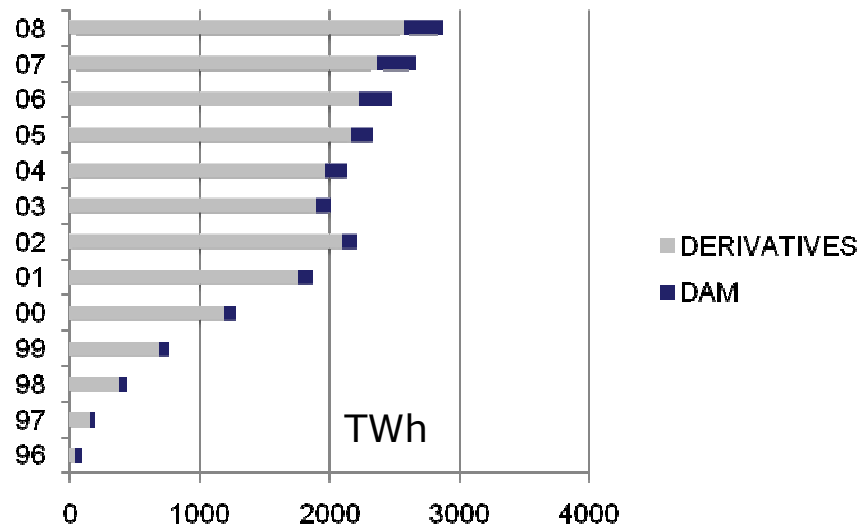
- **Forward contracts** commit the buyer to purchase and the seller to deliver a specified quantity of electricity at a specified time in the future, at a pre-determined price (delivery price)
- **Future contracts** are standardised forward contracts traded in organised and regulated exchanges
- **Option contracts** confer the buyer, against the payment of a fee, the right, but not the obligation, to purchase (“call options”) or to sell (“put options”) a specified quantity of electricity at a specified time in the future, at a pre-determined price (strike price)
- Electricity-based derivatives instruments can require:
 - Physical settlement, involving the delivery of electricity
 - Cash settlement, involving an equivalent cash payment (equal to the difference between the market price and the delivery/strike price)
- Most traded electricity-based derivative instruments are cash-settled

Nord Pool Traded Products

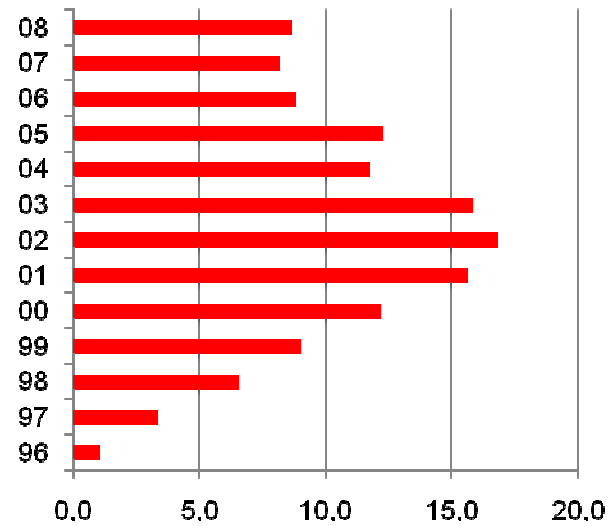
Product	Ref. Price	BL/PL	D	W	M	Q	Y
Futures (D, W)/ Forwards (M, Q, Y)	Nordic	BL	5 nrst	6 nrst	6 nrst	10 nrst	5 nrst
		PL		5 nrst	2 nrst	3 nrst	1 nrst
	Germany	BL		4 nrst	3 nrst	3 nrst	2 nrst
		PL		4 nrst	3 nrst	3 nrst	2 nrst
	Netherlands	BL		4 nrst	3 nrst	3 nrst	2 nrst
CfD	Denmark W Denmark E Finland Norway Sweden				2 nrst	3 nrst	3 nrst
European Options	Nordic	BL			13 nrst	9 nrst	4 nrst

Nord Pool (3)

Traded volumes and Churn Ratio



CHURN = DER/DAM



Electricity Derivatives: NordPool

Base load contracts	
Products	<ul style="list-style-type: none"> - futures - day (Nordic only)/week - forward - month/quarter/year - European option (Nordic only) - contracts for difference (CfD)
Min contract size	1 MW
Min tick size	0.01
Currency	EUR
Reference price	<ul style="list-style-type: none"> - Nordic: the official Nordic underlying day-ahead price as published by Nord Pool Spot - Germany: the official German underlying day-ahead price as published by EEX - Holland: the official Dutch underlying day-ahead price as published by APX - Monday through Sunday inclusive 0.00 to 24.00
Peak load contracts	
Products	<ul style="list-style-type: none"> - futures - week - forward - month/quarter/year
Min contract size	1 MW
Min tick size	0.01
Currency	EUR
Reference price	<ul style="list-style-type: none"> - Nordic: the official Nordic underlying day-ahead price as published by Nord Pool Spot - Germany: the official German underlying day-ahead price as published by EEX - Monday through Friday inclusive 08.00 to 20.00

EEX Traded Products

Product	Ref. Price	BL/PL	Settl.	D	W	M	Q	Y
Futures	Phelix(*)	BL	Financial			7 nrst	7 nrst	6 nrst
		PL	Financial			7 nrst	7 nrst	6 nrst
	Germany	BL	Phys. ⁽¹⁾			7 nrst	7 nrst	6 nrst
	Germany	PL	Phys. ⁽¹⁾			7 nrst	7 nrst	6 nrst
	France	BL	Phys. ⁽²⁾			7 nrst	7 nrst	6 nrst
	France	PL	Phys. ⁽²⁾			7 nrst	7 nrst	6 nrst
Options	Phelix Futures	BL	Financial			10 nrst	11 nrst	6 nrst
		PL	Financial			10 nrst	11 nrst	6 nrst

(*) – Physical electricity index – simple average of hourly prices on EEX
 (1) – Delivery in the RWE control area
 (2) – Delivery in the RTE control area

Electricity Derivatives: EEX

Contract Specifications

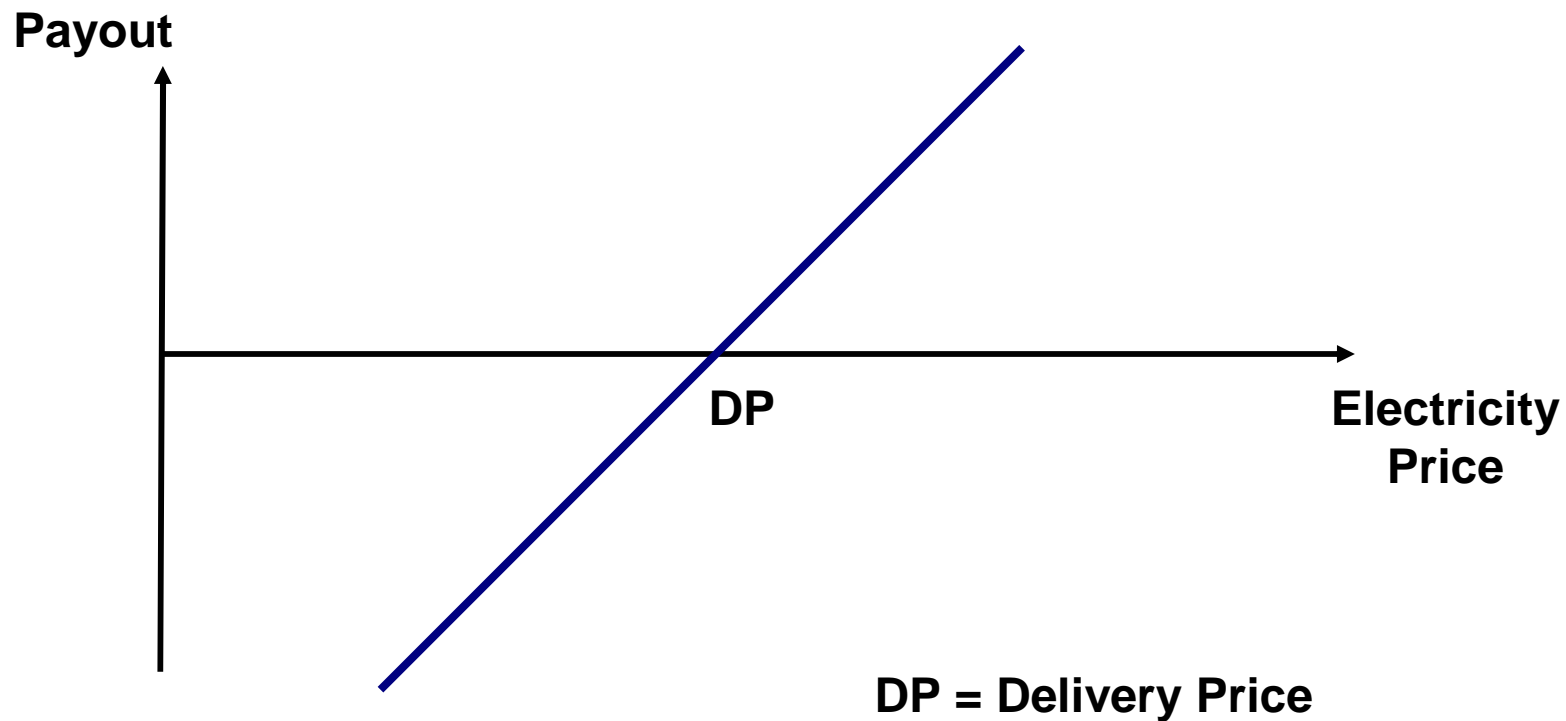
	Derivatives Market
Contract	Future on the future average price of the Spot Market (Phelix)
Maturity	the current month, the following 6 months, 7 quarters and 6 years
Settlement	financial settlement (cash settlement)
Quotation	in €/MWh to two decimal points
Transaction fees	0.015 €/MWh exchange fee 0.005 €/MWh clearing fee 0.005 €/MWh OTC clearing

Value and Valuation of Derivatives (1)

- At any point in time:
 - there is only “one” forward/future contract for a specified maturity (the horizon to the time of delivery). Forward/future contracts with different delivery prices are homologous, up to a fixed monetary amount
 - there are many option contracts with different strike prices
- Non-storability of electricity makes:
 - valuation using no-arbitrage approach unrealistic
 - valuation of derivatives contract more complex and dependent on risk attitude of participants

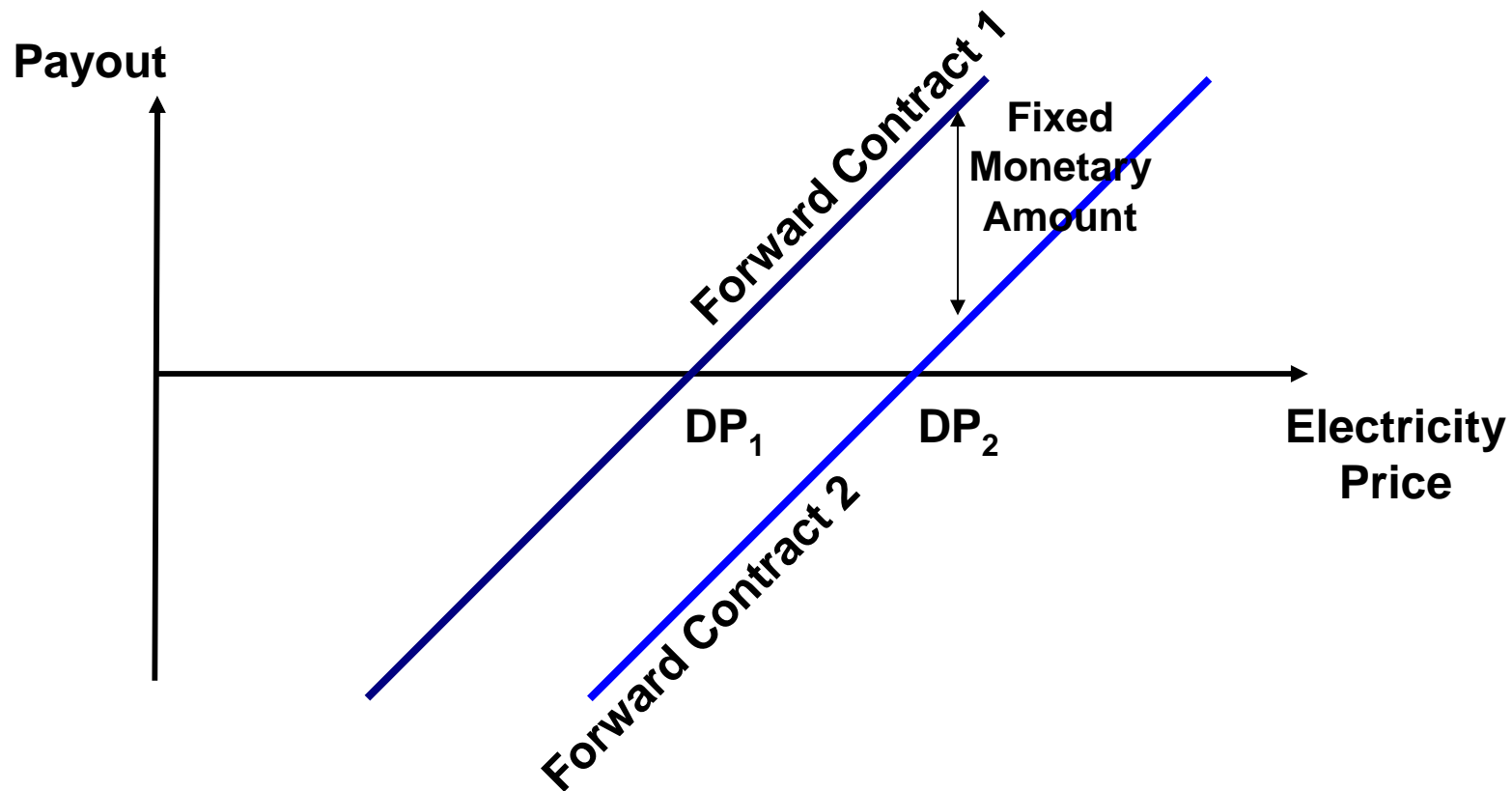
Value and Valuation of Derivatives (2)

Value/Payout Profile of Forwards/Futures (Long Position)



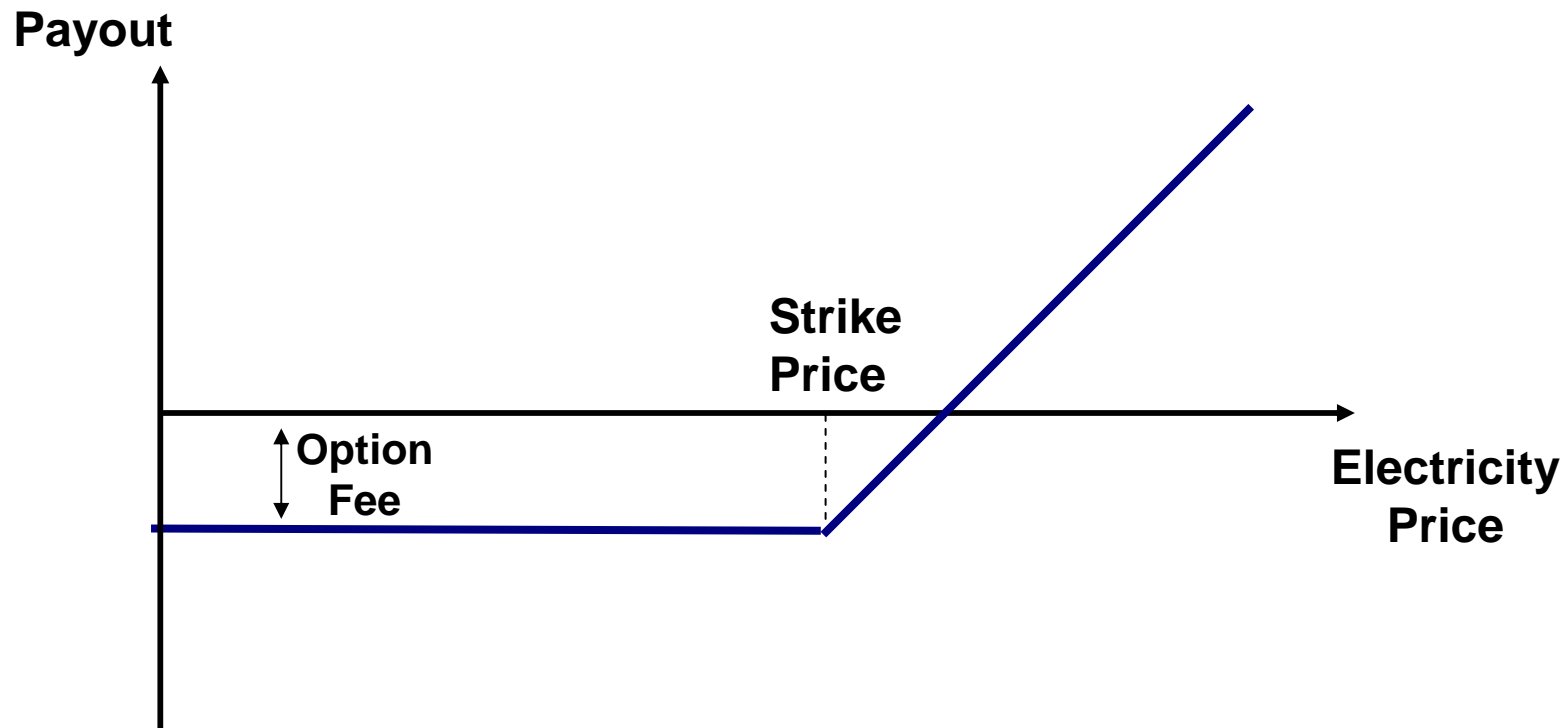
Value and Valuation of Derivatives (3)

Value/Payout of Forwards/Futures with Different Delivery Prices



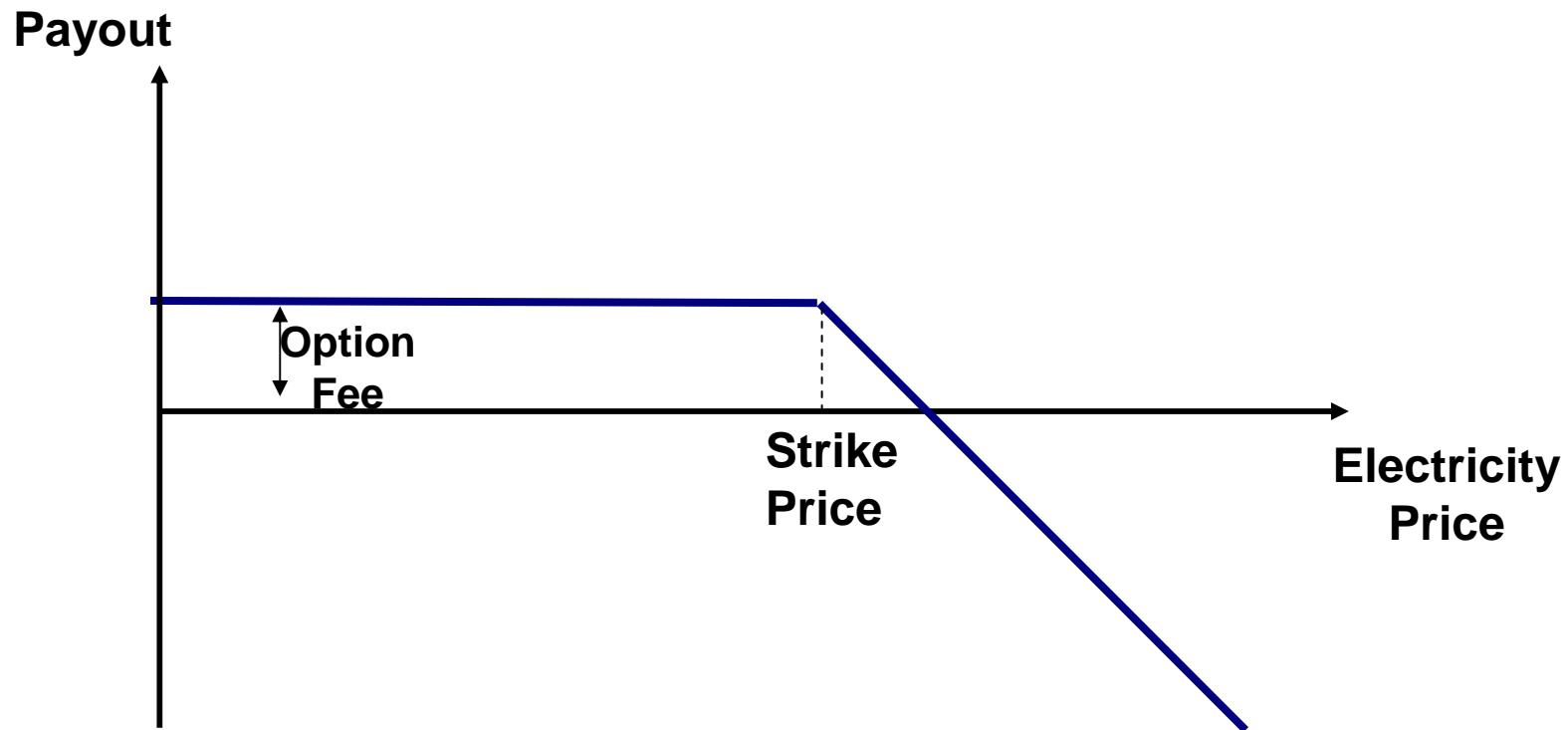
Value and Valuation of Derivatives (4)

Value/Payout Profile of Call Options (Long Position)



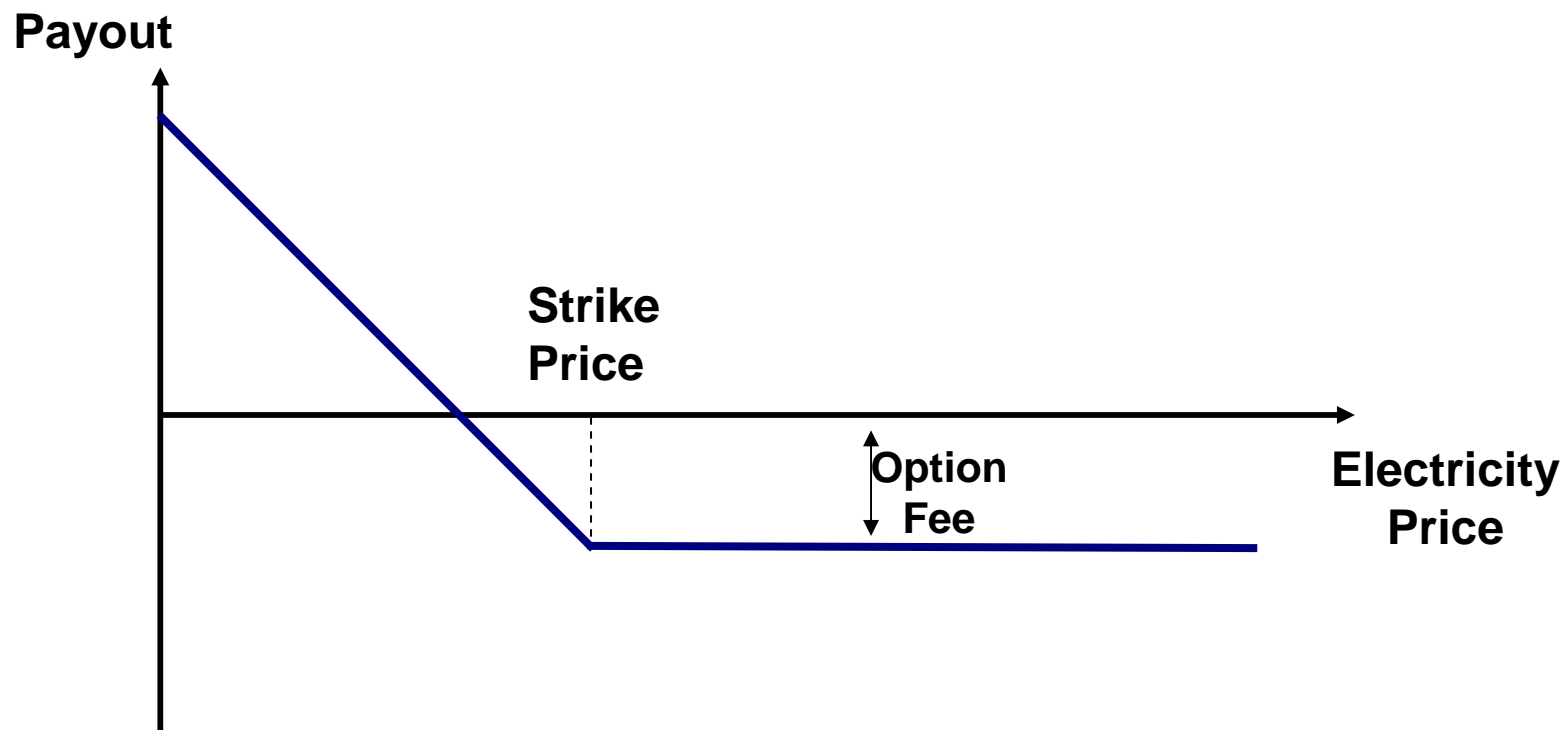
Value and Valuation of Derivatives (5)

Value/Payout Profile of Call Options (Short Position)



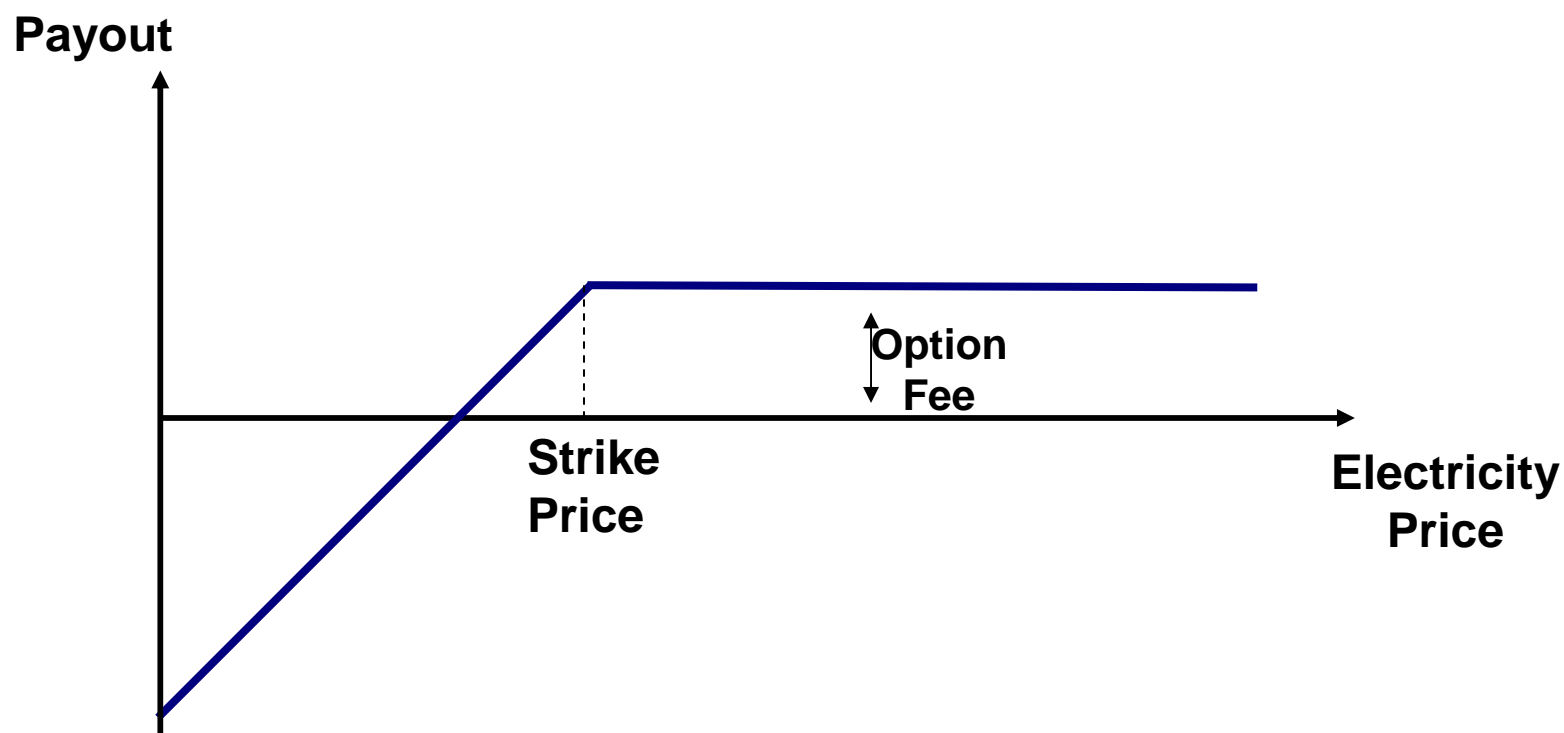
Value and Valuation of Derivatives (6)

Value/Payout Profile of Put Options (Long Position)



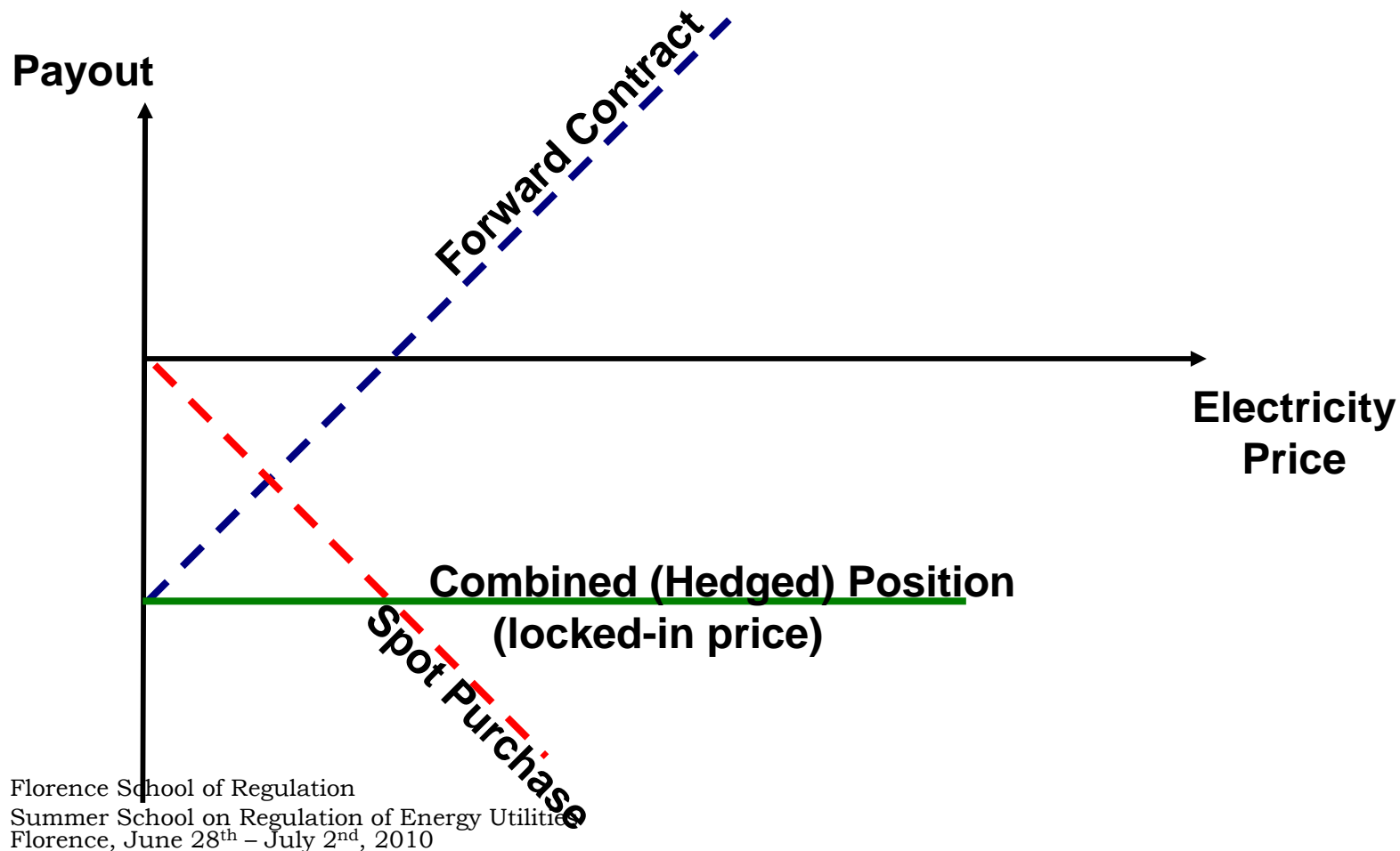
Value and Valuation of Derivatives (7)

Value/Payout Profile of Put Options (Short Position)



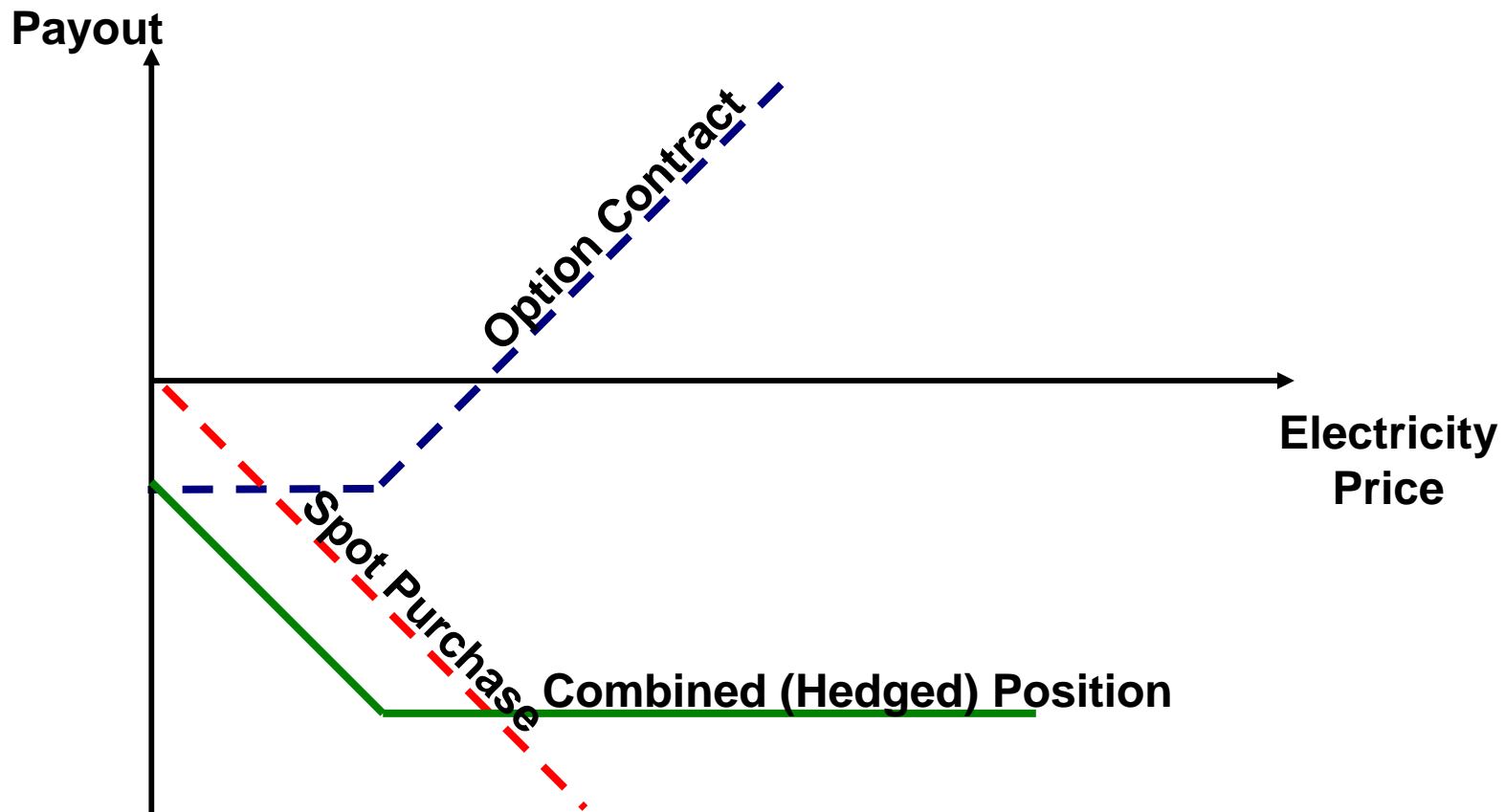
Value and Valuation of Derivatives (8)

Hedging a Long (Purchase) Position in the Spot Market with a Long Position in a Forward Contract



Value and Valuation of Derivatives (9)

Hedging a Long (Purchase) Position in the Spot Market with a Long Position in a Call Option Contract



Value and Valuation of Derivatives (10)

Value and valuation of electricity derivatives contracts

- For storable commodities, at any time t , the delivery price of a “zero-value” forward/future contract with maturity T ($F(t,T)$) is linked to the current spot price ($S(t)$)

$$F(t,T) = S(t) e^{(r-y)(T-t)}$$

where

r = continuously compounded annual interest rate at time t for maturity T

y = convenience yield (=return from ownership – carry/storage costs)

Value and Valuation of Derivatives (11)

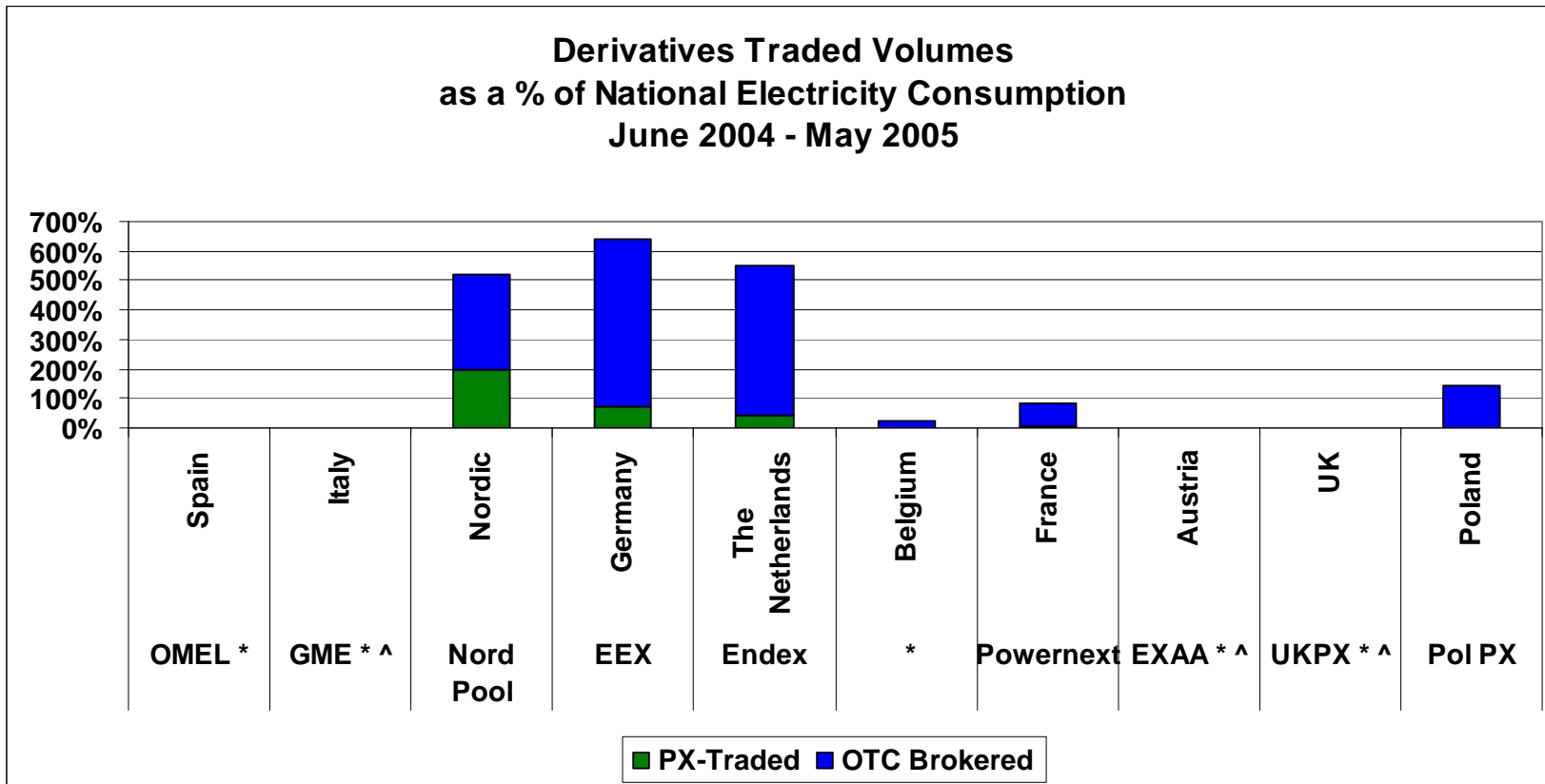
$$F(t,T) = S(t) e^{(r-y)(T-t)}$$

- This relationship is derived from the assumption of no arbitrage between two strategies (which have equivalent value at time T):
 - Strategy A – Buy and hold a forward contract and a monetary amount equal to the NPV of the delivery price
 - Strategy B – Buy and hold the underlying commodity
- The valuation of forwards/futures using the no-arbitrage condition cannot be used for electricity forwards/futures, as Strategy B cannot be pursued

Electricity Derivatives Trading in Europe

- Electricity derivatives are traded on:
 - NordPool (futures and options)
 - EEX (futures and options)
 - Endex NL (futures)
 - Giielda Energii (futures)
 - Powernext (futures)
 - Borsa Italiana
- Futures contracts on the difference between equilibrium prices in different areas/markets:
 - NordPool: “Contracts for Differences” between zonal prices and the (unconstrained) system price

Electricity Derivatives Traded Volumes



* - No PX-trading of derivatives. ^ - Data on OTC Brokered volumes not available



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Electricity Markets: the Wholesale Market

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**End of the Presentation
Thank you for your attention**