



Europa-Universität
Flensburg

DEEM

Yangon, 11th of October 2017

Energy Economics

1. Foundation of Energy Economics

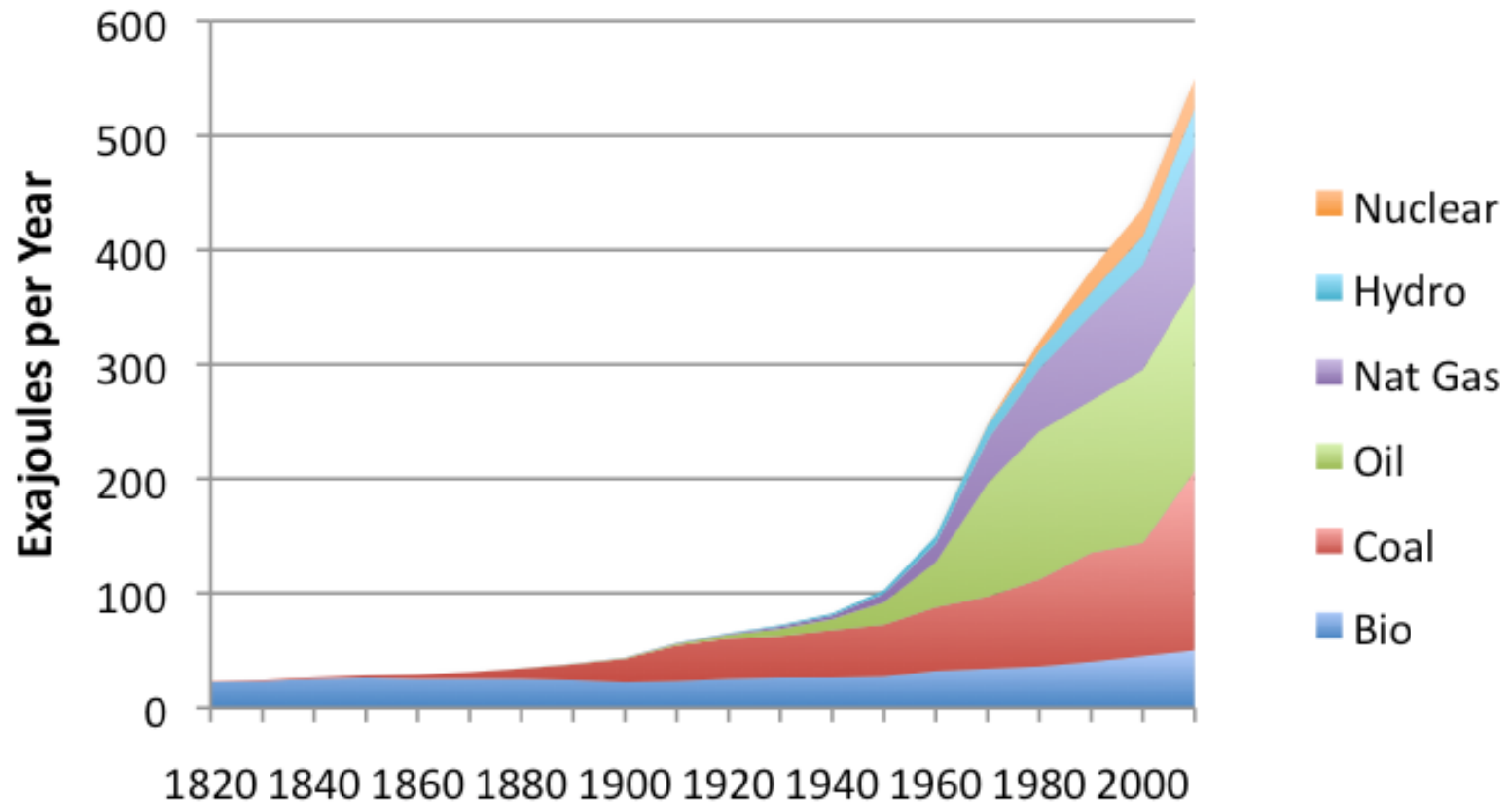
2. World Energy Market for

- Oil
- Coal
- Gas
- Electricity

3. Market Mechanisms

Foundation of Energy Economics

World's Primary Energy Consumption



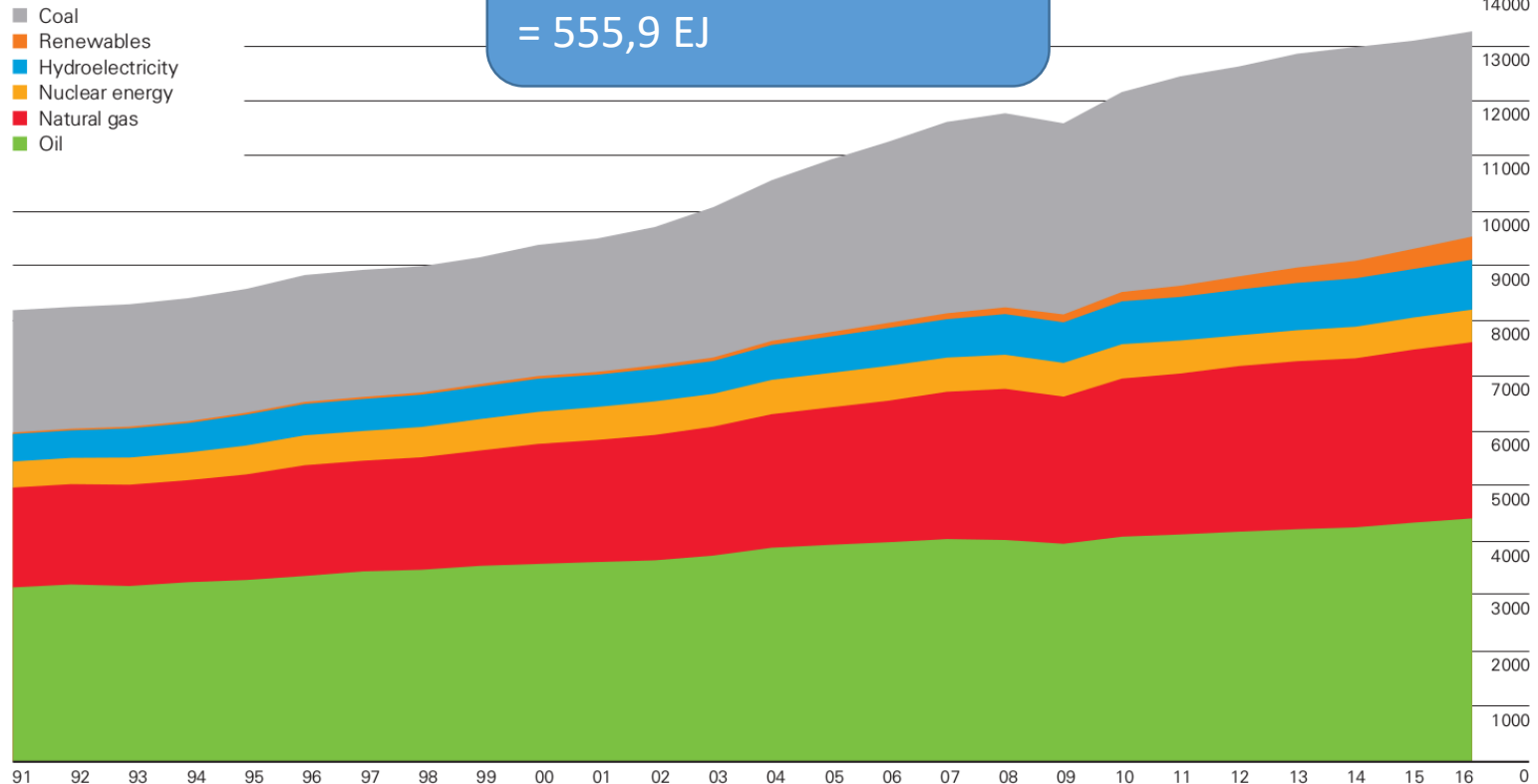
Historic development of energy use (supply)

- Renewable energy without competition until 1700 (mostly biomass, some wind)
- Hard coal use since 1709
- Crude oil use since around 1860
- Natural gas since
 - about 1920 in the United States
 - about 1945 in Europe
- Nuclear energy since 1944 (commercial use since about 1960)
- New solar energy since about 1980

World's Primary Energy Consumption

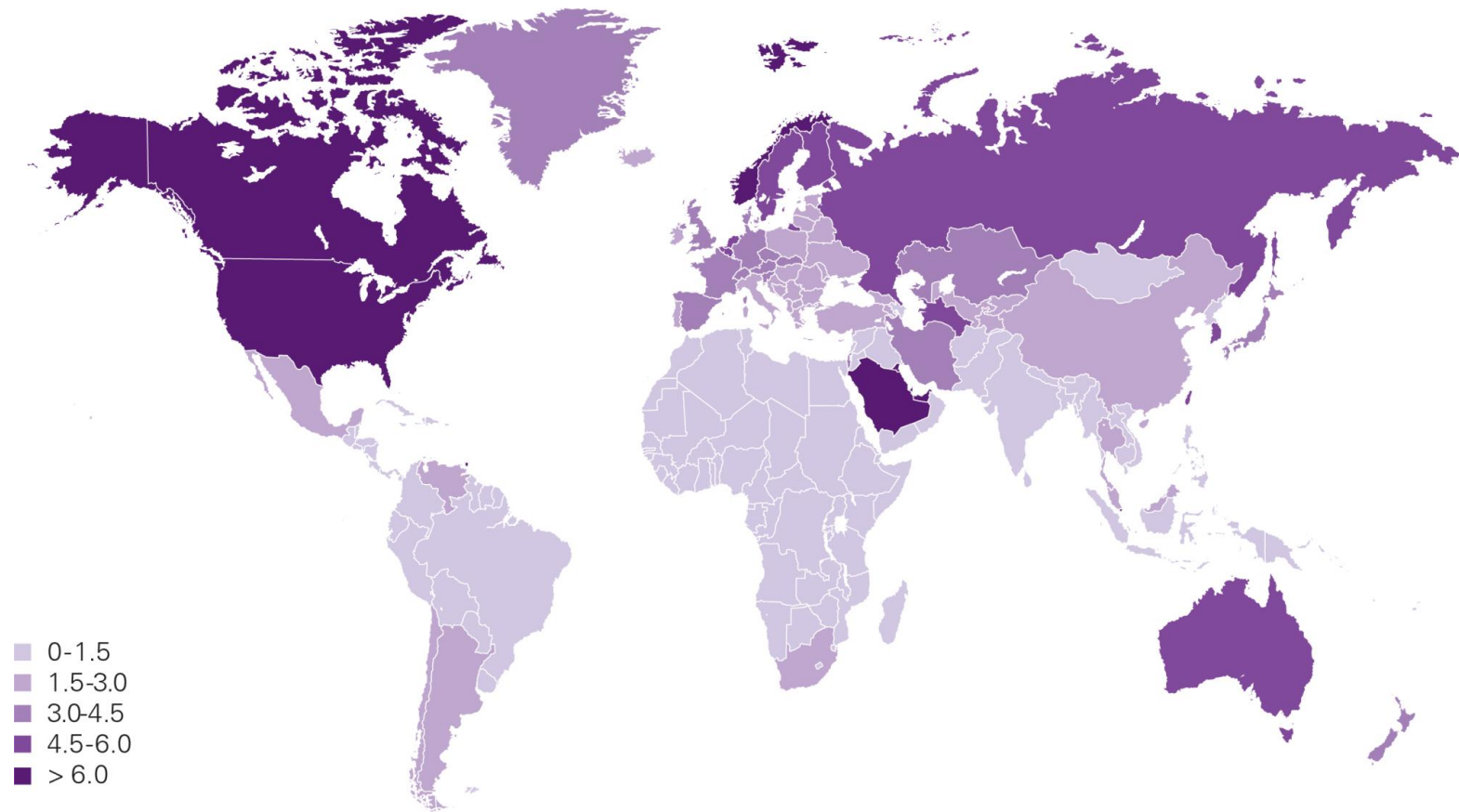
World consumption
Million tonnes oil equivalent

13276,3 Mtoe in 2016
= 154.400.000 GWh
= 555,9 EJ



Source: BP Statistical Review of World Energy 2017, p. 10

Primary Energy Consumption per Capita [toe]



Source: BP Statistical Review of World Energy 2013, p. 43

Primary Energy Consumption per Capita

- Today typical primary energy consumption varies heavily among the worlds countries
- **European** countries like **e.g. Germany** consume ~ **6000 W**
- **Myanmar** currently consumes currently ~**400 W** with **heavy growth rates**

Some of most used Energy Units

kWh

EJ

mmBTU

Mtoe

Tcf

ktce

kcal

BOE

Conversion Factors of Energy Units

1. Prefixes for orders of magnitude

Kilo = k = 10^3 = thousand
 Mega = M = 10^6 = million
 Giga = G = 10^9 = billion

Tera = T = 10^{12} = trillion
 Peta = P = 10^{15} = 1000 trillions
 Exa = E = 10^{18} = 1 000 000 trillions

2. Conversion factors

	kJ	kcal	kW h	kg ce	kg oe	m³ nat. gas	btu
1 kilojoule (kJ)	-	0,2388	0,000278	0,000034	0,000024	0,000032	0,947817
1 kilocalory (kcal)	4,1868	-	0,001163	0,000143	0,0001	0,00013	3,96832
1 kilowatt hour (kWh)	3.600	860	-	0,123	0,086	0,113	3.412,140
1 kg hard coal equivalent (kg ce)	29.308	7.000	8,14	-	0,7	0,923	27.778,620
1 kg oil equivalent (kg oe)	41.868	10.000	11,63	1,428	-	1,319	39.683,200
1 m ³ natural gas	31.736	7.580	8,816	1,083	0,758	-	30.079,900
1 btu	1,055	0,252	0,00029	0,000036	0,000025	0,000034	-

3. Other international units

1 barrel (b) oil = 159 l oil; 7,3 b = 1 t oil
 1 Mill. b / d (barrel per day) = 50 Mill. t / a (tonnes per year)

Source: BMWi 1995

Energy Content of Different Fuels

Fuel	Mass unit	Heating value kJ	Heating value kcal	Coal equivalent 1 kg coal
Hard coal	kg	29704	7095	1,014
Hard coal coke	kg	28650	6843	0,978
Hard coal birquette	kg	31401	7500	1,071
Brown coal	kg	8506	2032	0,290
Brown coal briquette	kg	19470	4650	0,664
Brown coal coke	kg	29935	7150	1,021
Coal dust and dry coal	kg	21569	5152	0,736
Hard brown coal	kg	14925	3565	0,509
Fire wood (1 cbm = 0,7 t)	kg	14654	3500	0,500
Peat	kg	14235	3400	0,486
Crude oil	kg	42421	10132	1,447
Petrol for cars	kg	43543	10400	1,486
Raw petrol	kg	43543	10400	1,486
Light aviation fuel	kg	43543	10400	1,486
Heavy aviation fuel	kg	42705	10200	1,457
Diesel	kg	42705	10200	1,457
Light heating oil	kg	40910	9771	1,396
Heavy heating oil	kg	41031	9800	1,400
Petroleum coke	kg	29308	7000	1,000
Liquid natural gas (LNG)	kg	45887	10960	1,566
Refinery gas	kg	45466	10859	1,551
Natural gas	m3	31736	7580	1,083
Crude oil gas	m3	40300	9625	1,375
Mining gas (Methane)	m3	15994	3820	0,546

Source: BMWi 1995

Why should Economics focus on Energy?

- Useful energy is a scarce resource and the provision of energy induces costs. Therefore, energy is a subject of economics.
- Energy is a crucial production factor
 - Energy is an essential input to production, which can not be totally replaced by other production factors.

What Energy Economics is about?

- **Energy economics** is a broad field of study, which **studies human utilization of scarce energy resources** and energy commodities and includes:
 - The allocation of energy sources to competing uses
 - Market structures and regulatory structures
 - Environmental consequences and the sustainable use of energy
 - External costs of the use of energy
 - Economically efficient use of energy

Our Energy Sources

- fossil fuels
 - coal
 - oil
 - natural gas
- nuclear energy
- solar energy
 - direct solar energy
 - indirect solar energy
- geothermal and tidal energy

Fossil Fuels

Pros

- Cheap investment
- high energy density
- low risk of catastrophic accidents
- secondary fuels very convenient to use (e.g. petrol or heating oil)

Cons

- emission of greenhouse gases
- emission of air pollutants like SO₂, NO_x, particulates
- very limited resources (oil and natural gas)

Fossil Nuclear Energy

Pros

- no emission of air pollutants like SO₂, NO_x, particulates
- huge resources if nuclear fusion works
- relatively cheap excluding external costs/ cost of nuclear waste

Cons

- risk of catastrophic accidents
- radioactive contamination
- easy military abuse
- possible abuse by terrorists
- limited uranium resources for commercial reactors

Solar Energy

Pros

- unlimited availability
- huge resource
- environmentally friendly
- no emission of air pollutants like SO₂, NO_x, particulates (not biomass)
- no risk of catastrophic accidents
- can be installed in very small units

Cons

- intermittent nature (wind, direct solar)
- large areas needed per kW
- high material intensity
- relatively expensive in terms of investment

The Economic Problem

- The problem of scarcity
 - Normally finite resources available are insufficient to satisfy all human wants

oil
50.6 years

gas
52.5 years

coal
153 years

static length!

How do we satisfy unlimited wants with limited resources?

That's the task of economics!

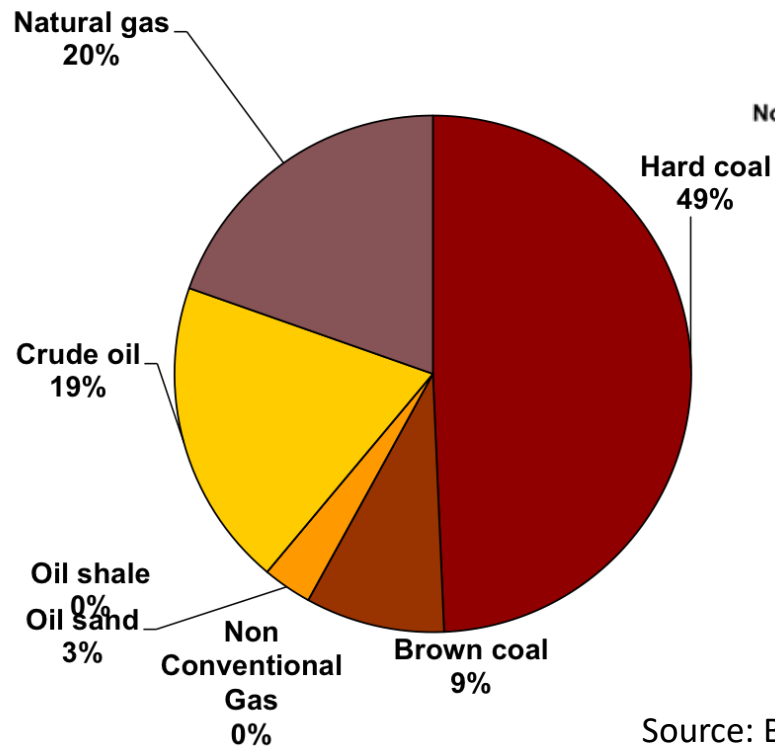
Reserves and Resources

- Reserve
 - the tonnage within the proved amount in place that can be recovered under present and expected economic conditions with existing available technology
- Resource
 - includes all additional discovered and undiscovered assumed/speculative quantities

Reserves and Resources

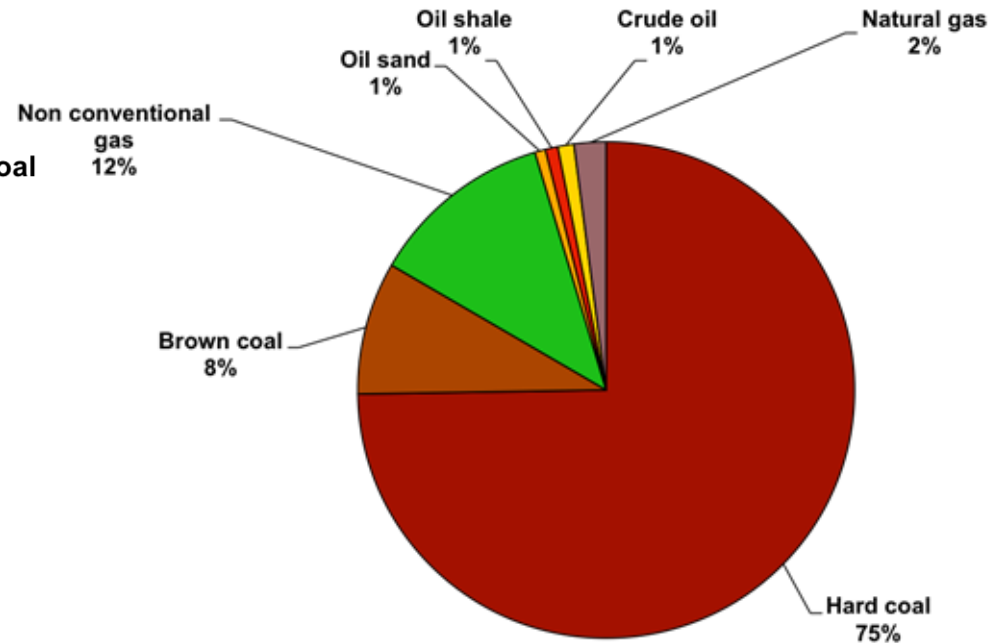
Reserves

2011: 37 600 EJ



Resources

2011: 581 800 EJ

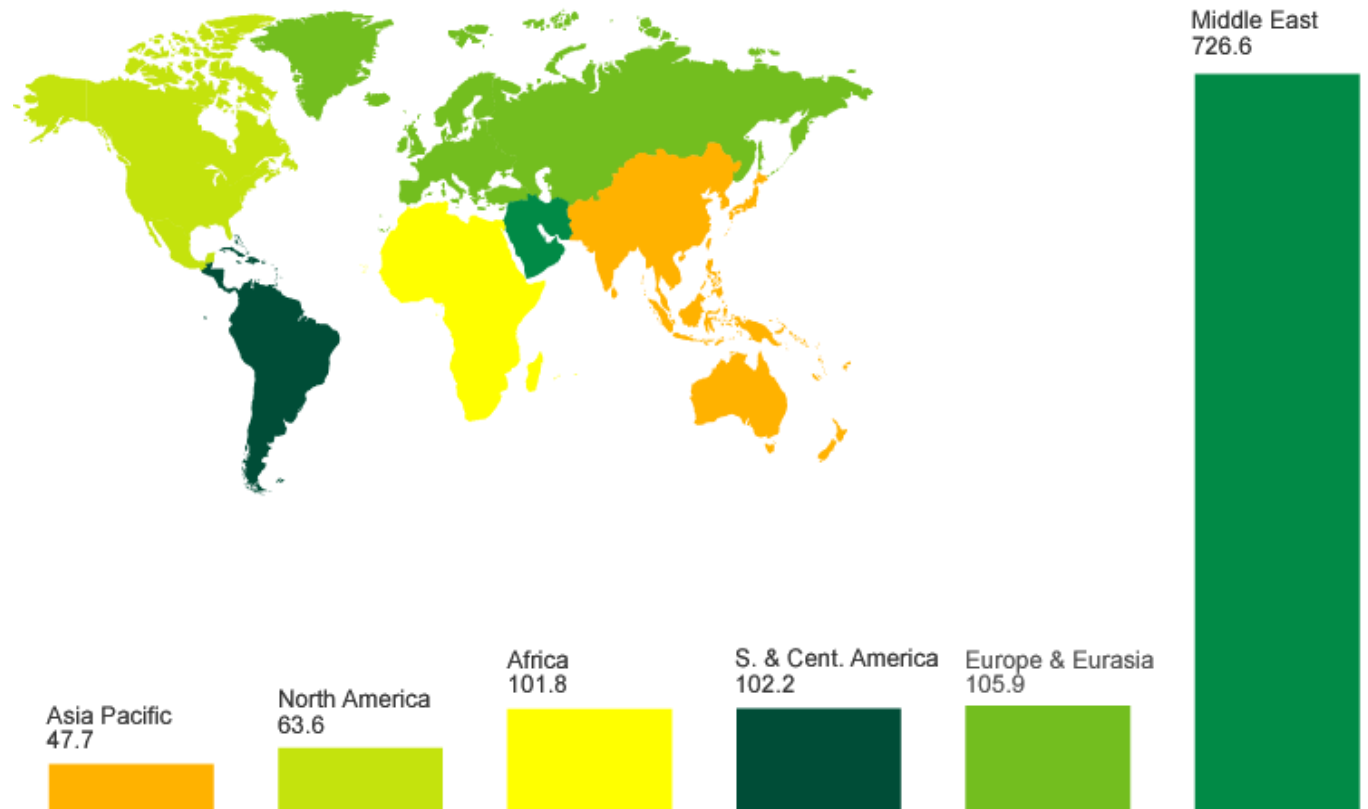


Source: BGR 2011, p. 15

World Market for Oil

World market for oil (the proved reserves in 10^9 barrels)

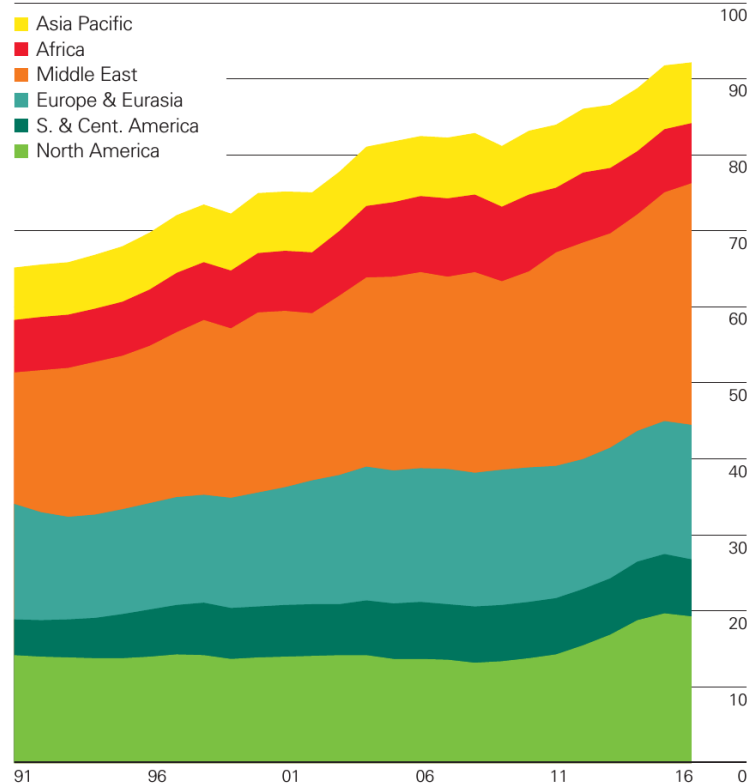
Thousand million barrels



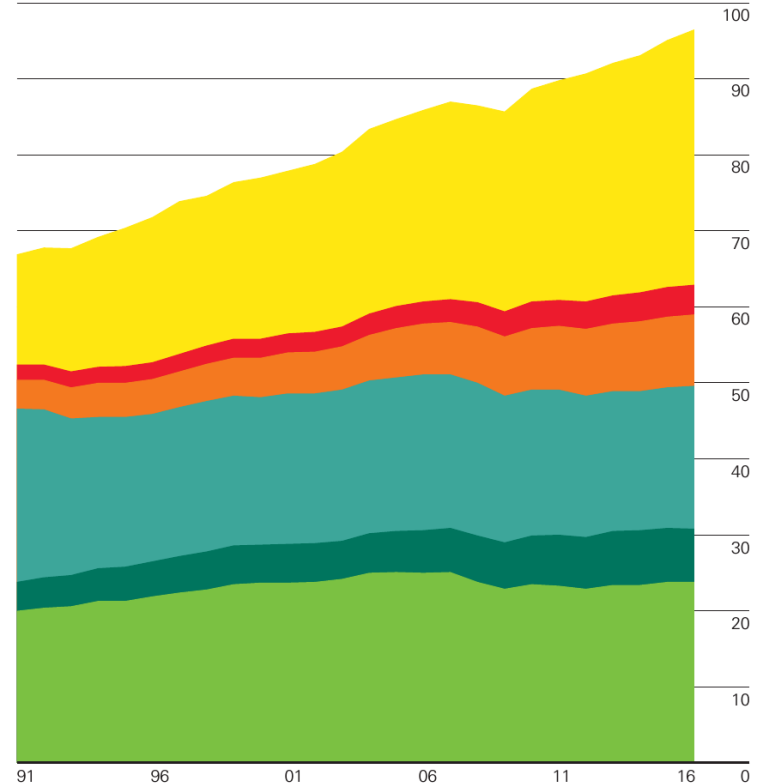
Source: BP Statistical Review of World Energy 2004

World market for oil (production and consumption by area in 10⁶ barrels/d)

Oil: Production by region
Million barrels daily



Oil: Consumption by region
Million barrels daily



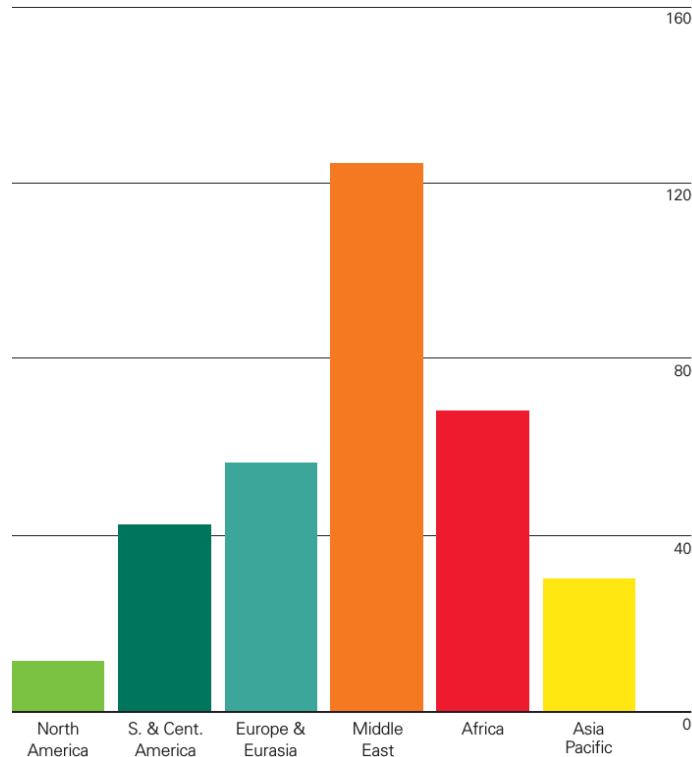
Source: BP Statistical Review of World Energy 2017, p. 18

World market for oil (reserves to production ratio)

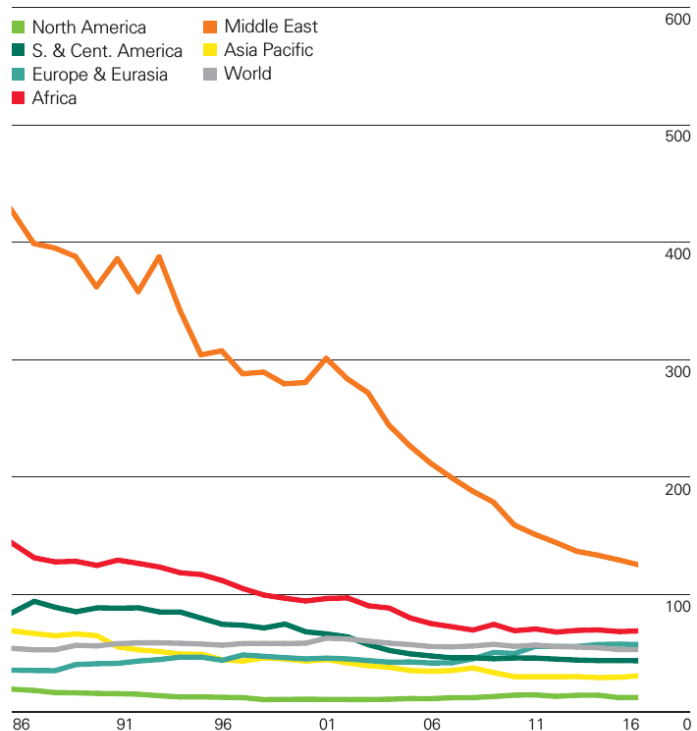
Reserves-to-production (R/P) ratios

Years

2016 by region



History

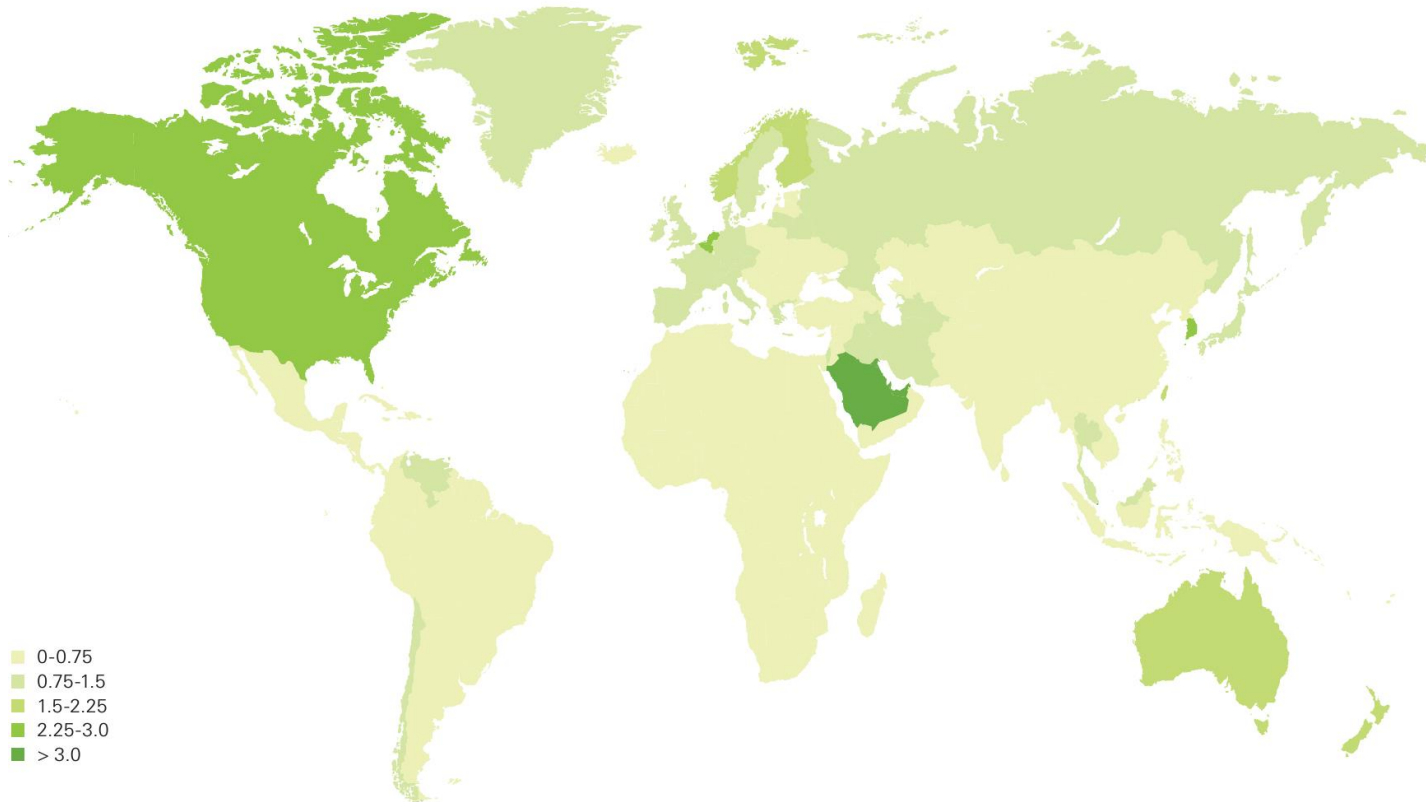


Source: BP Statistical Review of World Energy 2017, p. 27

World market for oil

(Consumption per capita 2016 in t/a)

Oil: Consumption per capita 2016
Tonnes

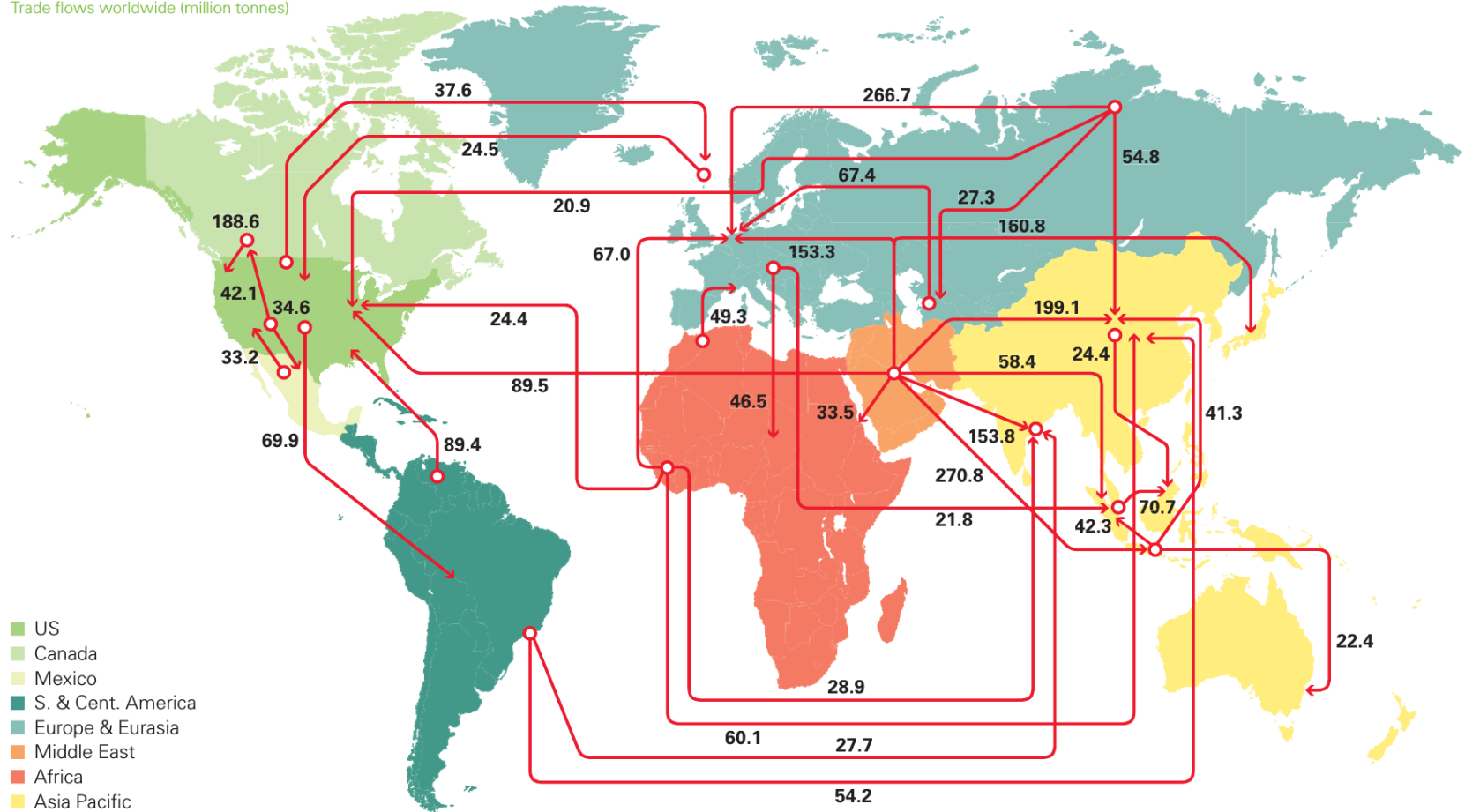


Source: BP Statistical Review of World Energy 2017, p. 18

World market for oil

Major trade movements 2016

Trade flows worldwide (million tonnes)



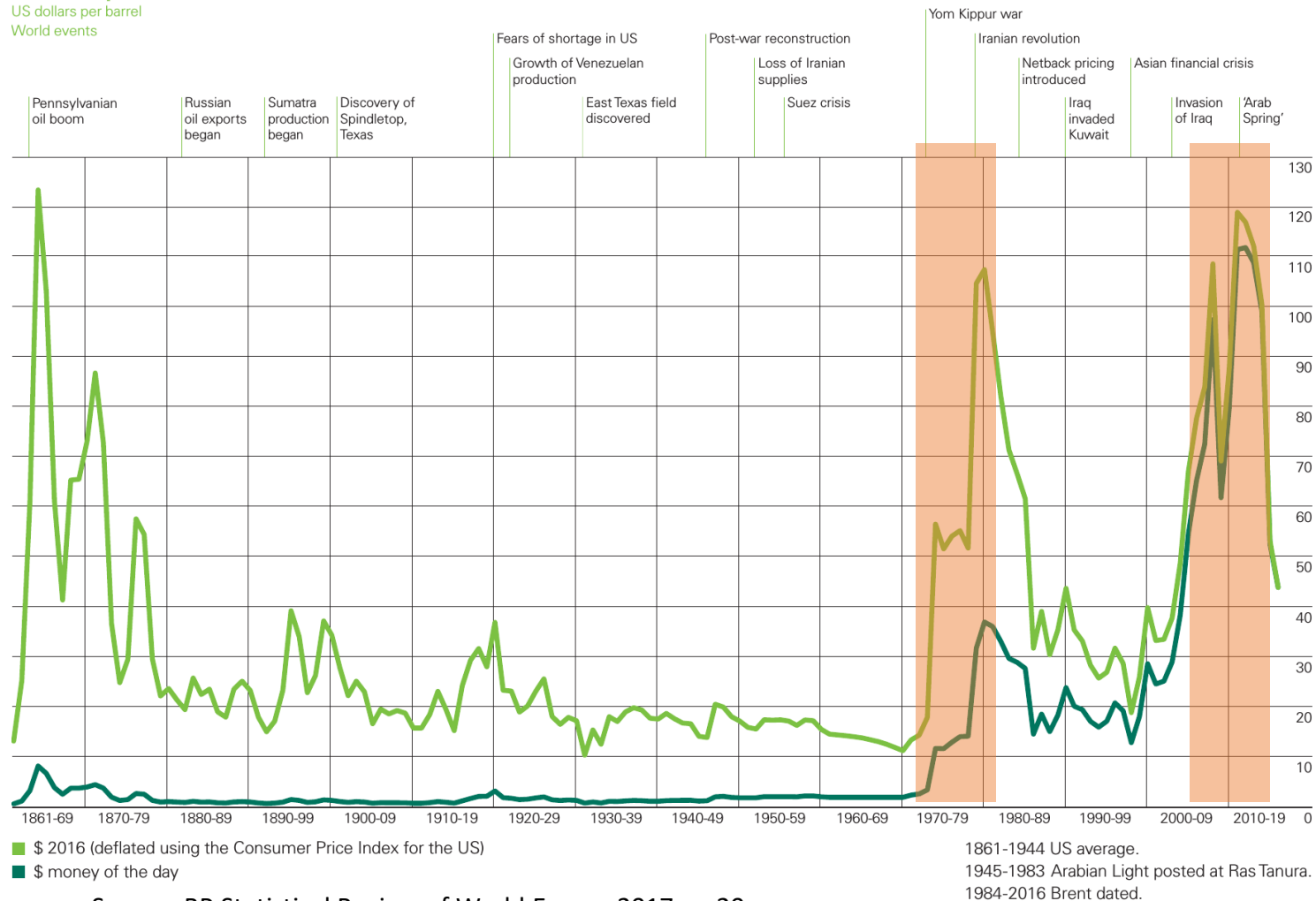
Source: BP Statistical Review of World Energy 2017, p. 25

World market for oil

Crude oil prices 1861-2016

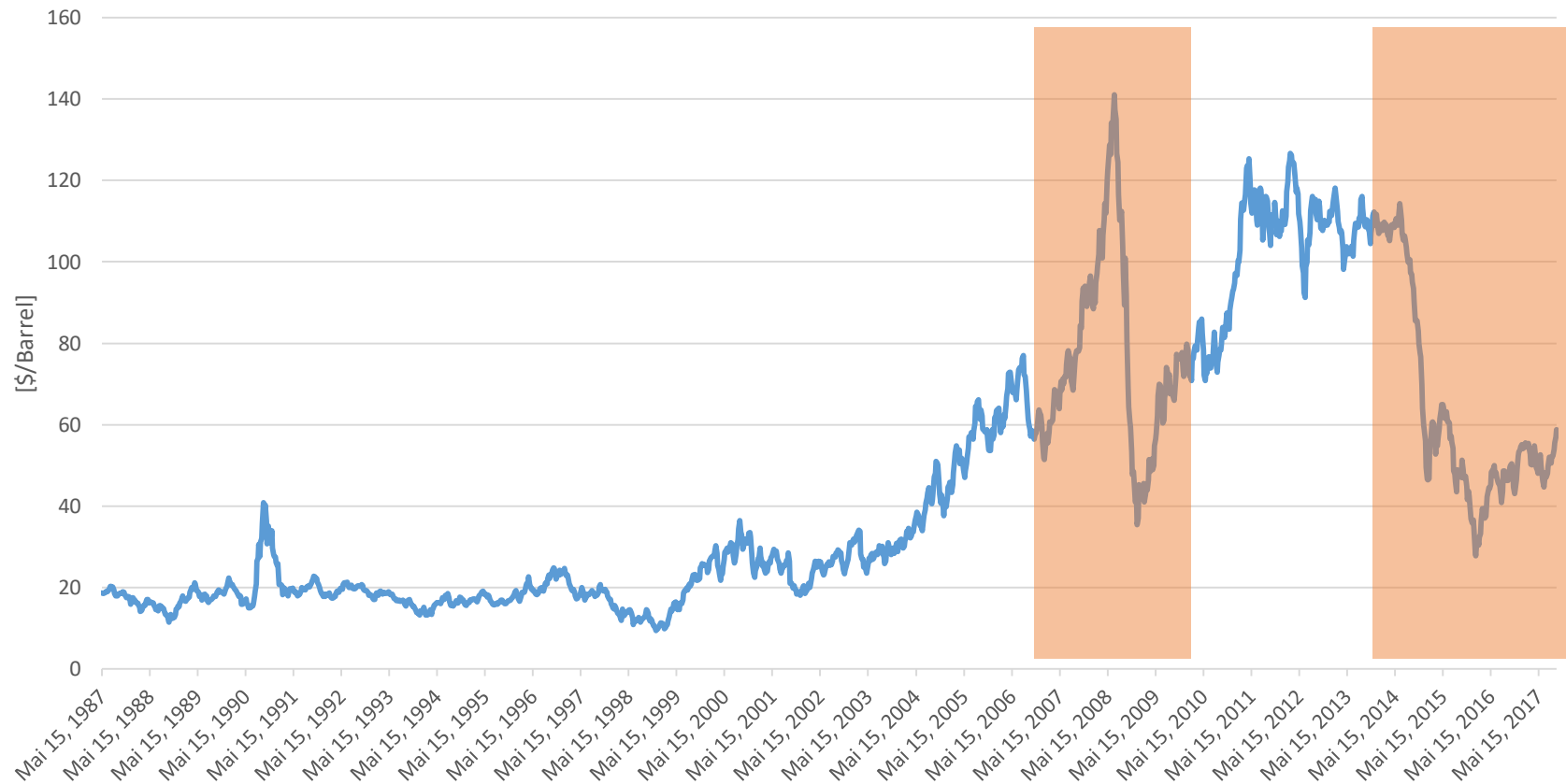
US dollars per barrel

World events



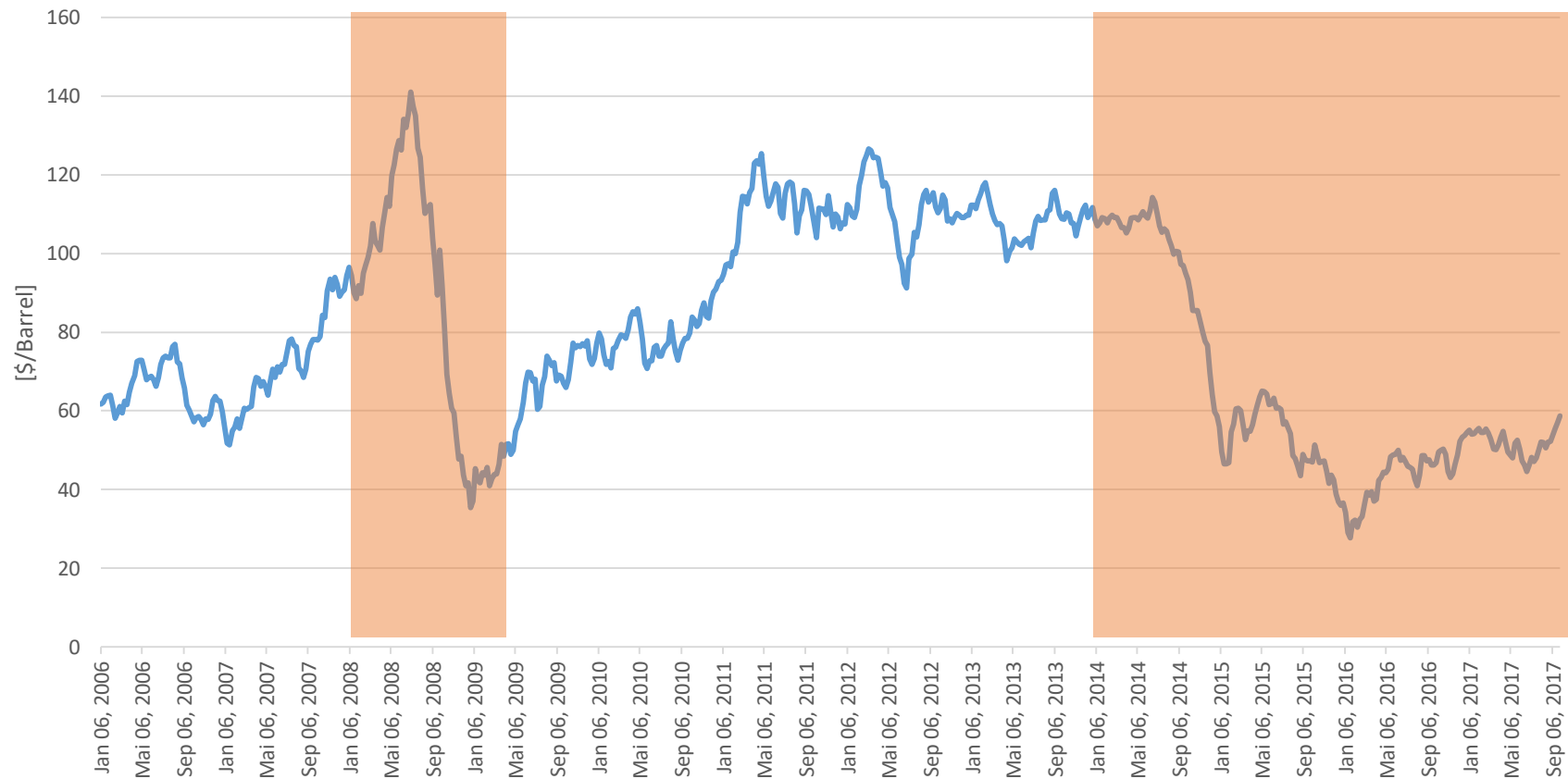
Source: BP Statistical Review of World Energy 2017, p. 20

World market for oil – Weekly Brent Price



Source: own illustration based on EIA 2017, URL:
<https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=m>

World market for oil – Weekly Brent Price



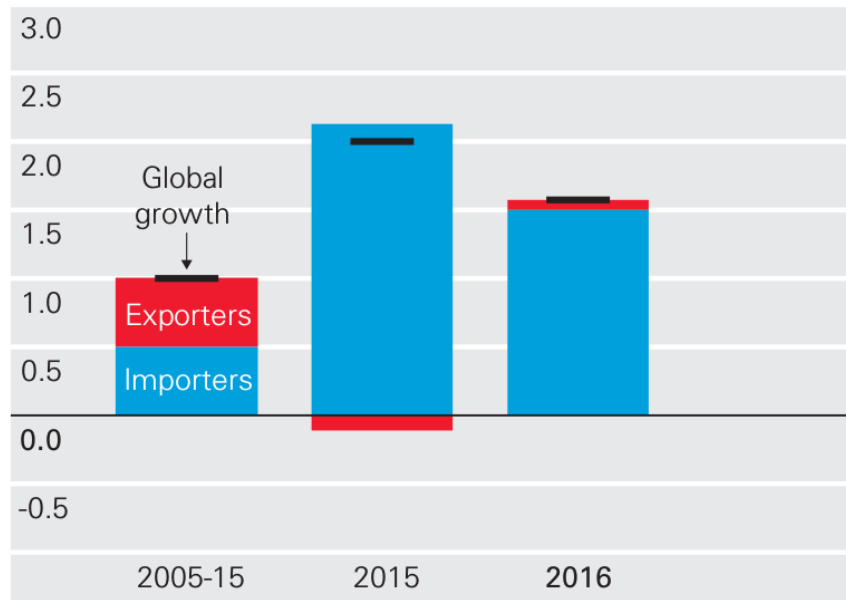
Source: own illustration based on EIA 2017, URL:
<https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=m>

Oil Markets Recent Developments

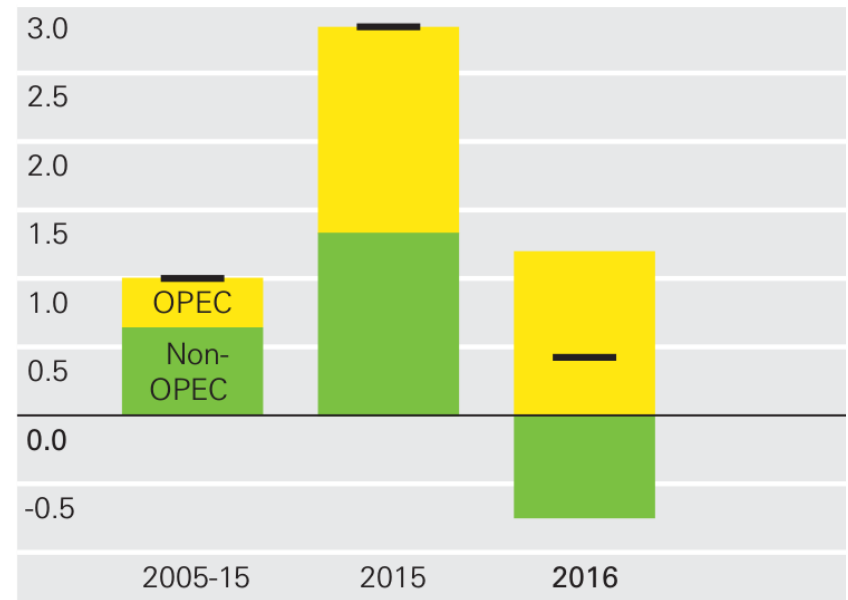
Oil market in 2015 and 2016

Consumption

Annual change, Mb/d



Production



Source: BP Statistical Review of World Energy 2017, p. 3

Recent Oil Markets Drivers

2014 Peak prices

- High Oil Prices made US tight oil production increase
 - High marginal cost of tight oil production
 - Fast reaction to prices compared to conventional oil
- Surprisingly OPEC increased oil production at the end of

2015 Low prices

- OPEC cutted production from November 2015
- Decreasing growth of US tight oil production due to continuing low prices
- Stocking up of OECD inventories

Recent Oil Markets Drivers

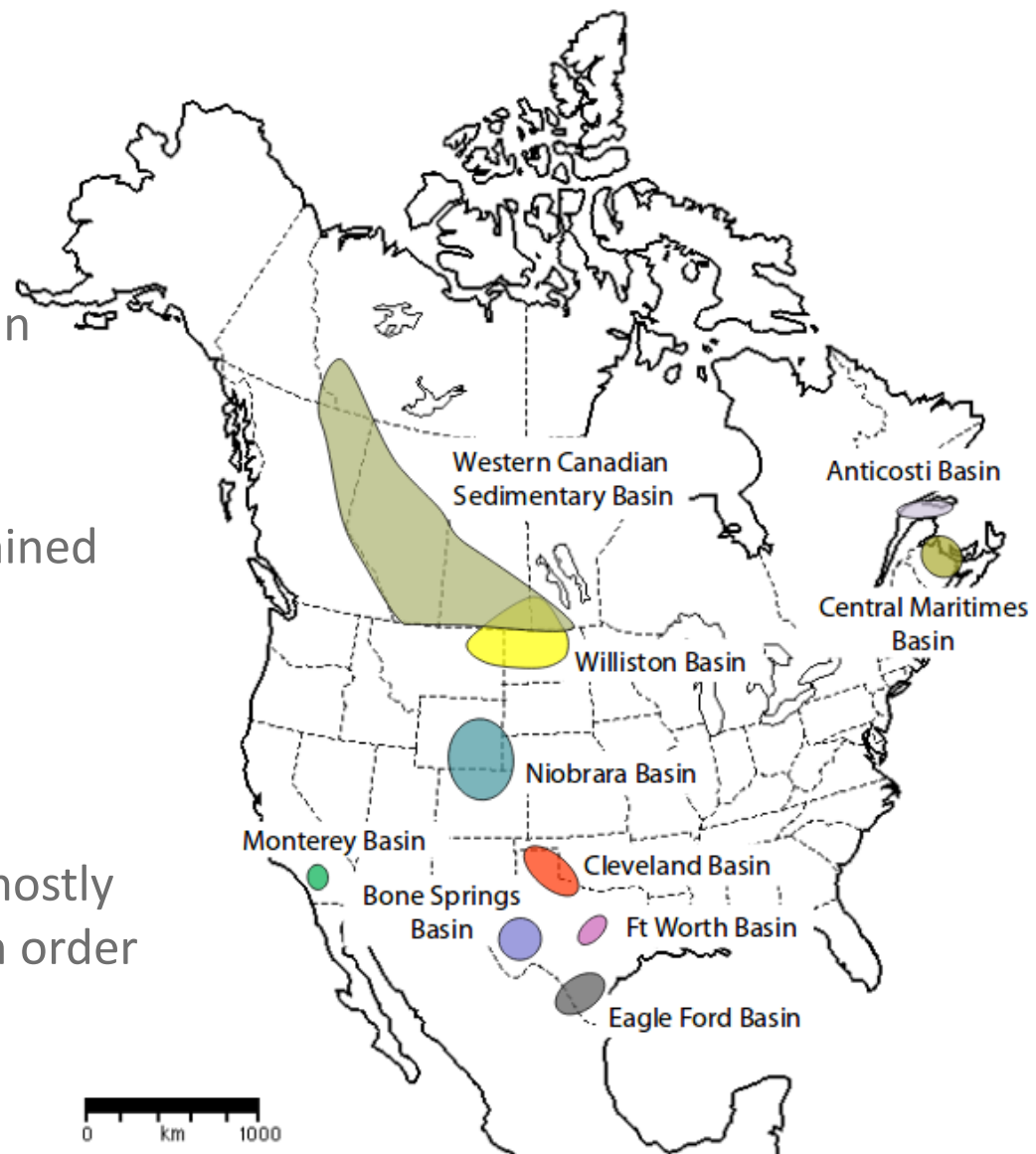
2016 Market Adjustment

2017: ?

- High Stock of inventories
- US tight oil increasing
- Prices increase due to lower OPEC production

(US) tight Oil

- Tight oil is light crude oil beared in permeable formations like e.g. sandstone
- Quality of tight oil source determined by
 - Porosity
 - Permeability
- Hydraulic fracking/fructuring is mostly used to crack stone formations in order to increase permeability

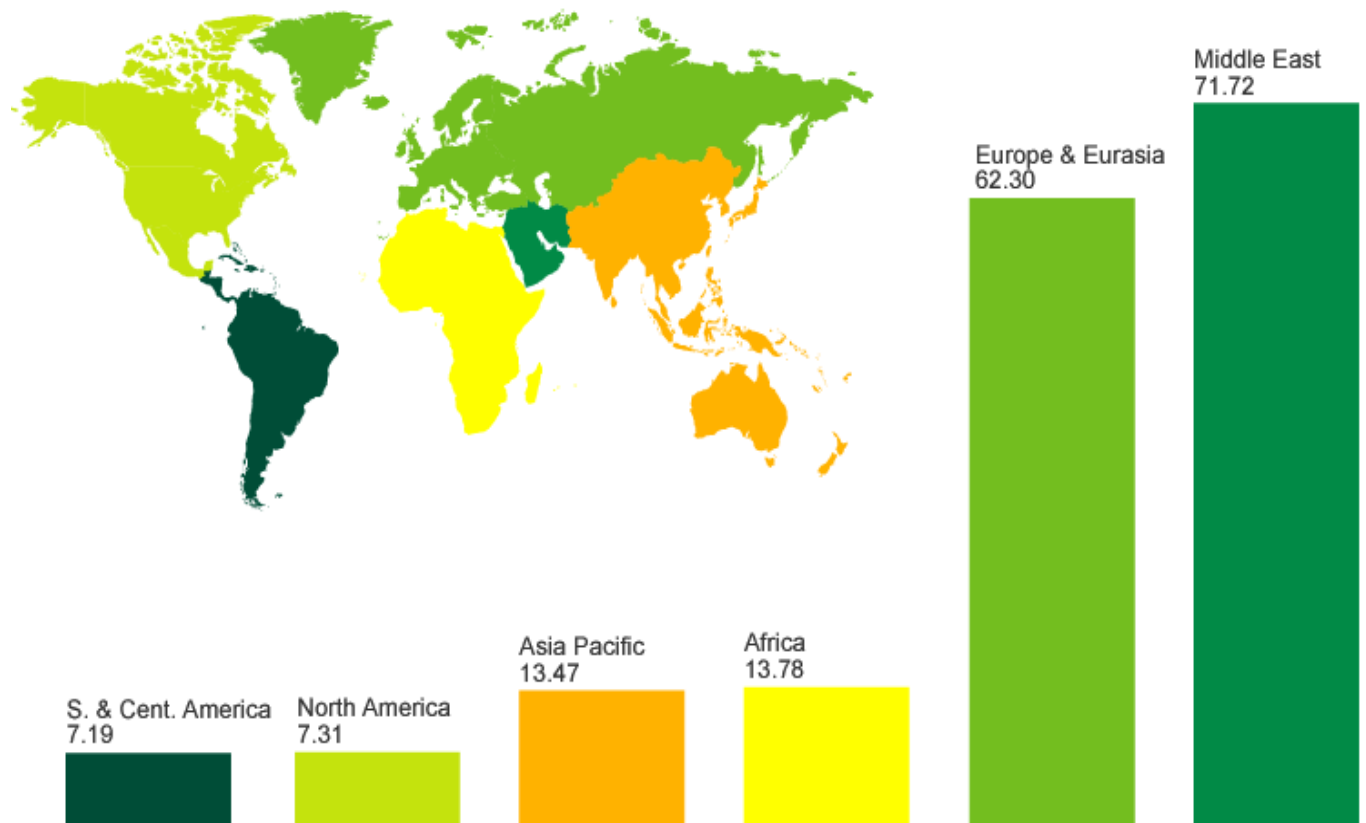


Source: CSUR n.d., Understanding tight oil,
URL:http://www.csur.com/sites/default/files/Understanding_TightOil_FINAL.pdf



World Market for Gas

World market for natural gas (proved reserves 10^{12} m³)

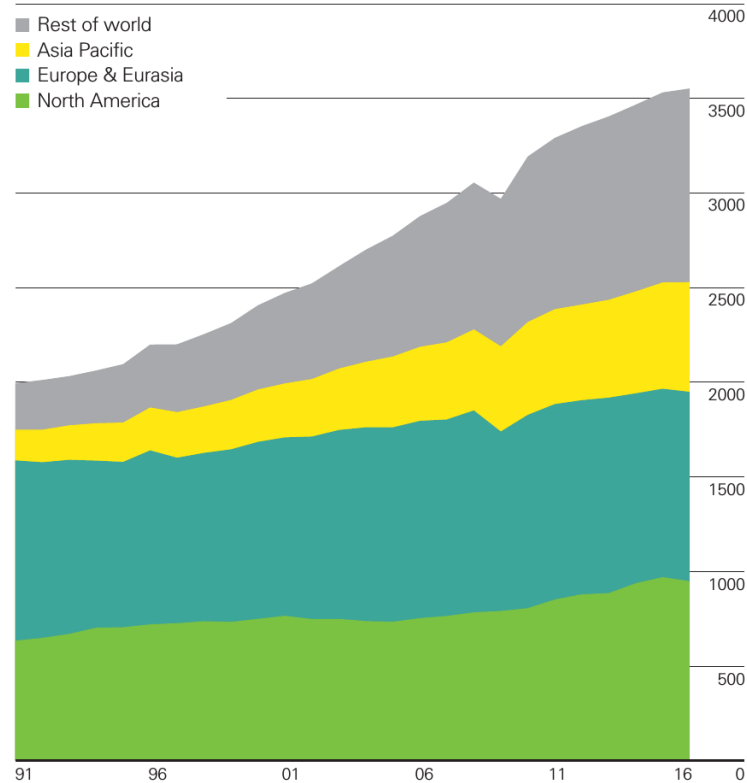


Source: BP Statistical Review of World Energy 2004

World market for natural gas

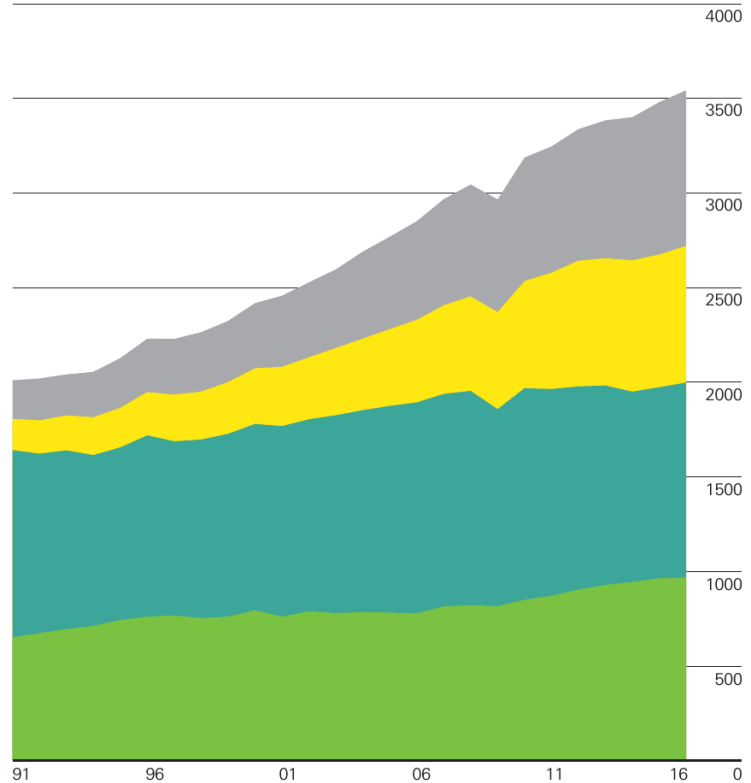
Natural gas: Production by region

Billion cubic metres



Natural gas: Consumption by region

Billion cubic metres



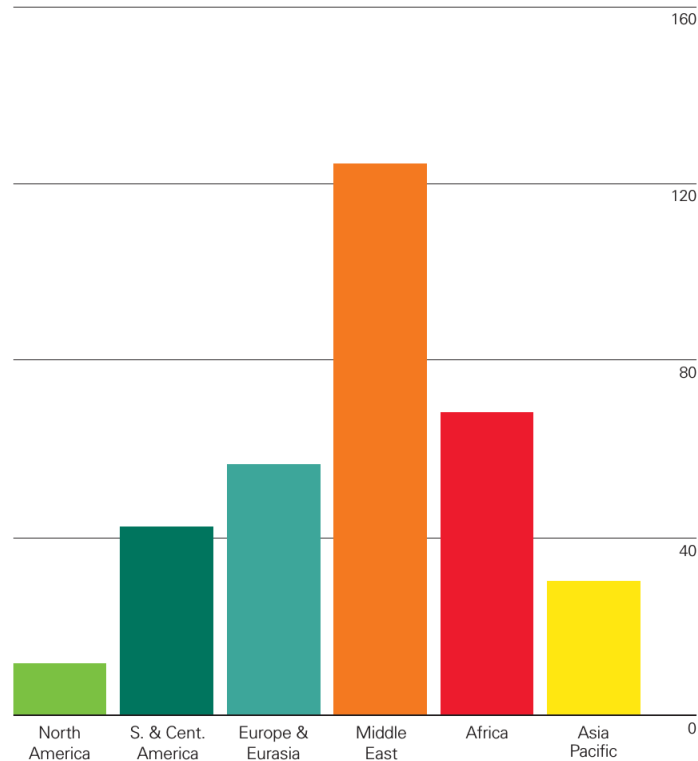
Source: BP Statistical Review of World Energy 2017, p. 32

World market for natural gas (reserve to production ratios)

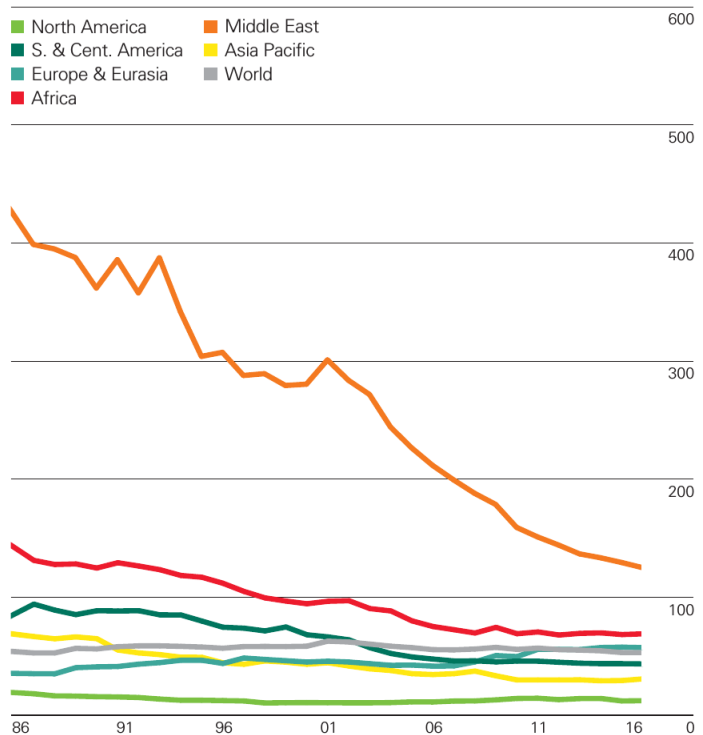
Reserves-to-production (R/P) ratios

Years

2016 by region



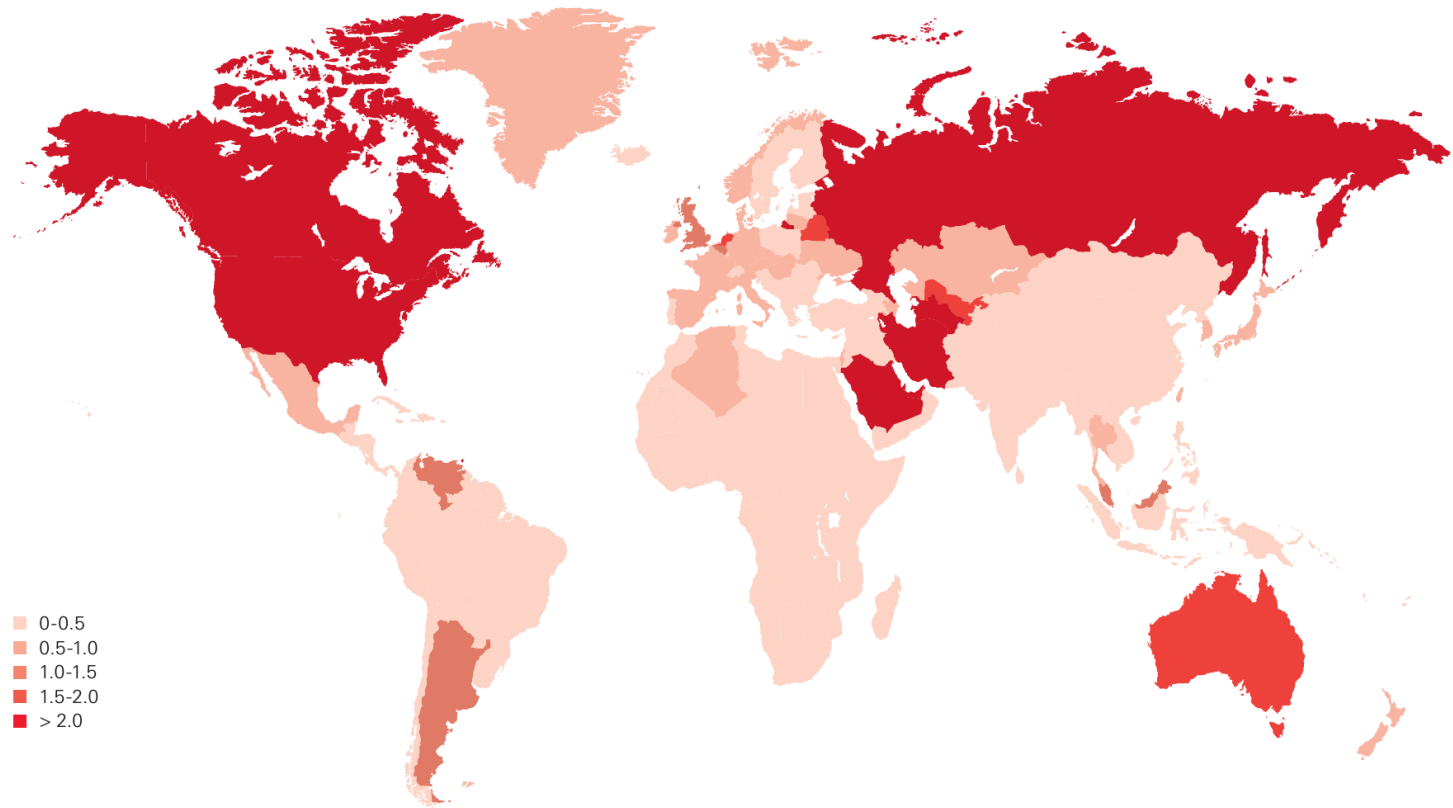
History



Source: BP Statistical Review of World Energy 2017, p. 27

World market for natural gas

Natural gas: Consumption per capita 2016
Tonnes oil equivalent

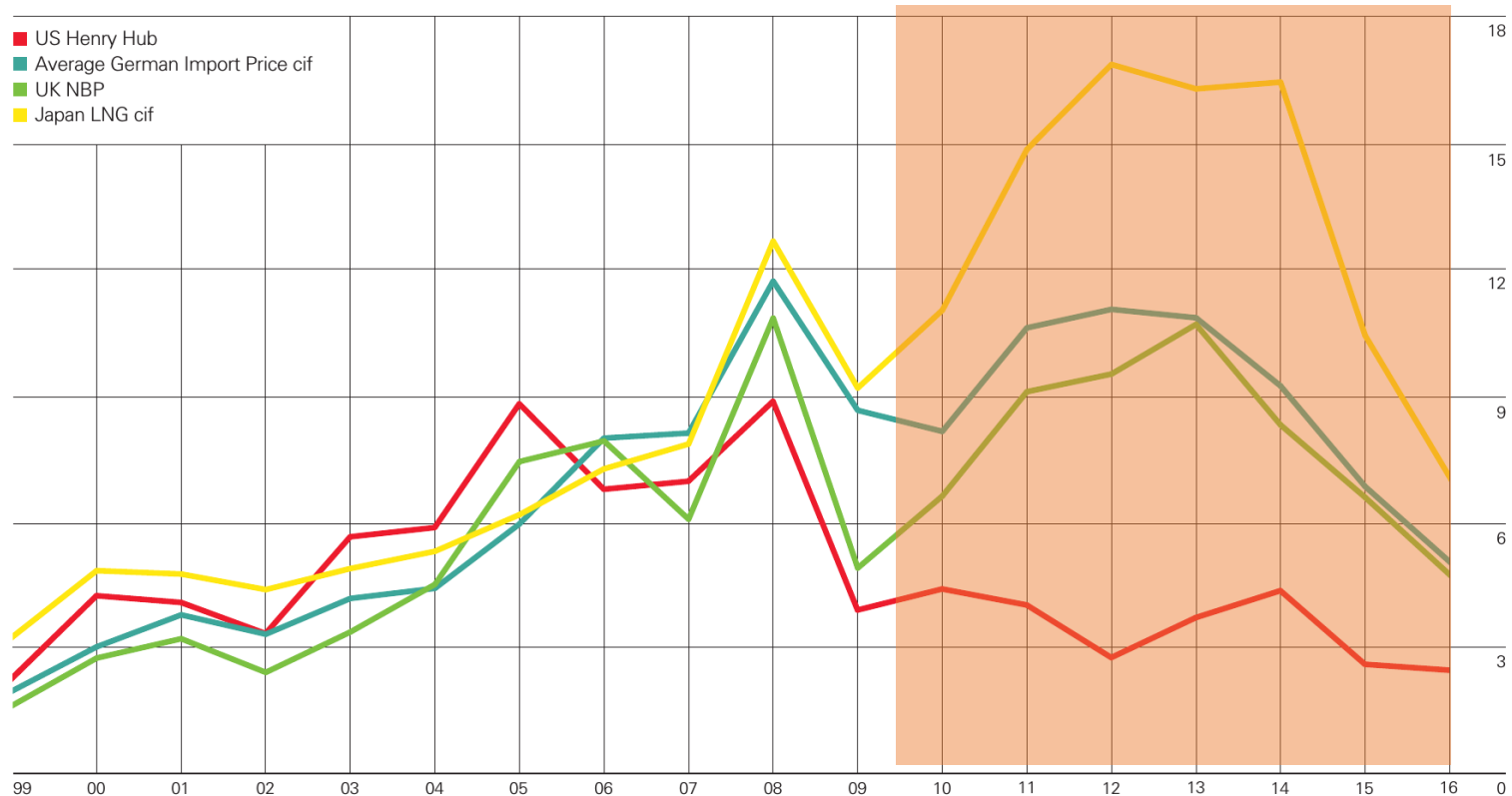


Source: BP Statistical Review of World Energy 2017, p. 32

World market for natural gas

Different development of gas prices (\$/mmbtu)

Prices
\$/mmbtu



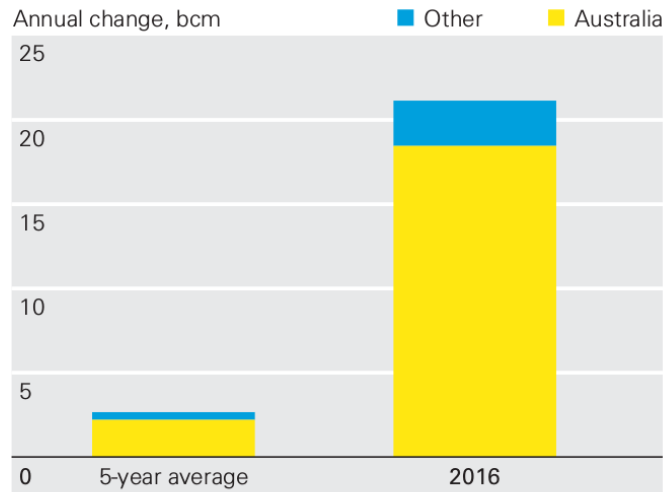
Source: BP Statistical Review of World Energy 2017, p. 33

Recent Market Drivers for Global Gas Market

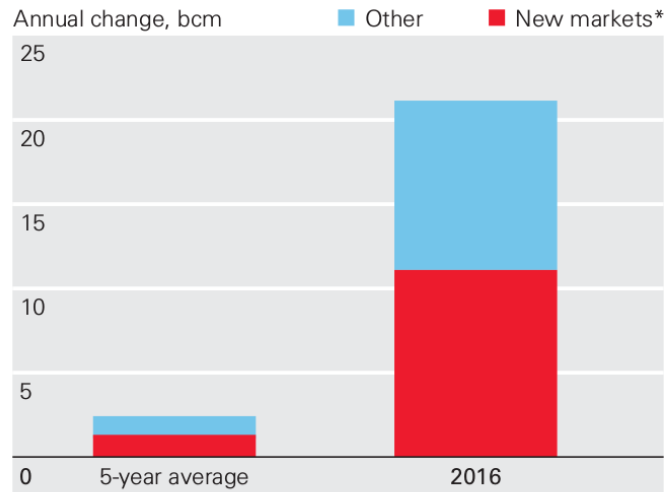
- Slight gas consumption increase of 1.5% compared to 2015
- Heavily increasing growth of LNG hub's
 - Increasing competition and integration in gas markets
 - Political independency from single supplier situations

LNG supply and demand

Supply



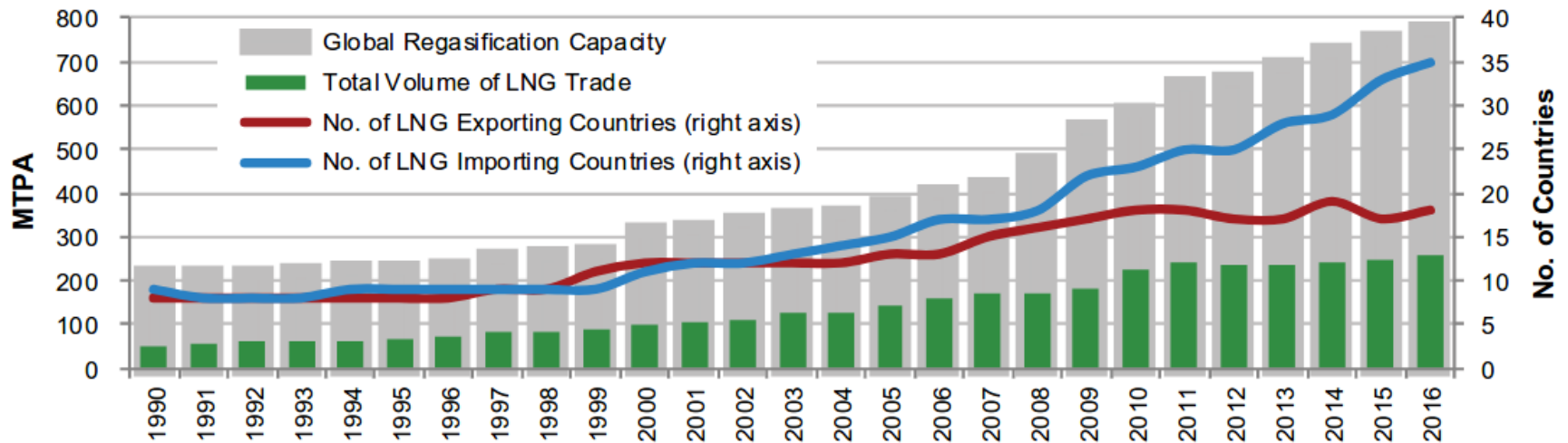
Demand



Source: BP Statistical Review of World Energy 2017, p. 6

*Includes Egypt, Pakistan, Poland, Jamaica, Colombia and Lithuania

LNG Growth



Source: IGU 2017, World LNG Report, p. 7

Liquified Natural Gas (LNG)

- Increases energy density ~*600 (more than CNG or Diesel)
 - High attractiveness for marine transport due to energy density and safety (low pressure)
 - Cooling to ~ -160°C
- Growing Importance for the transport sector
 - E.g. LNG road trains in China
 - Marine shipping

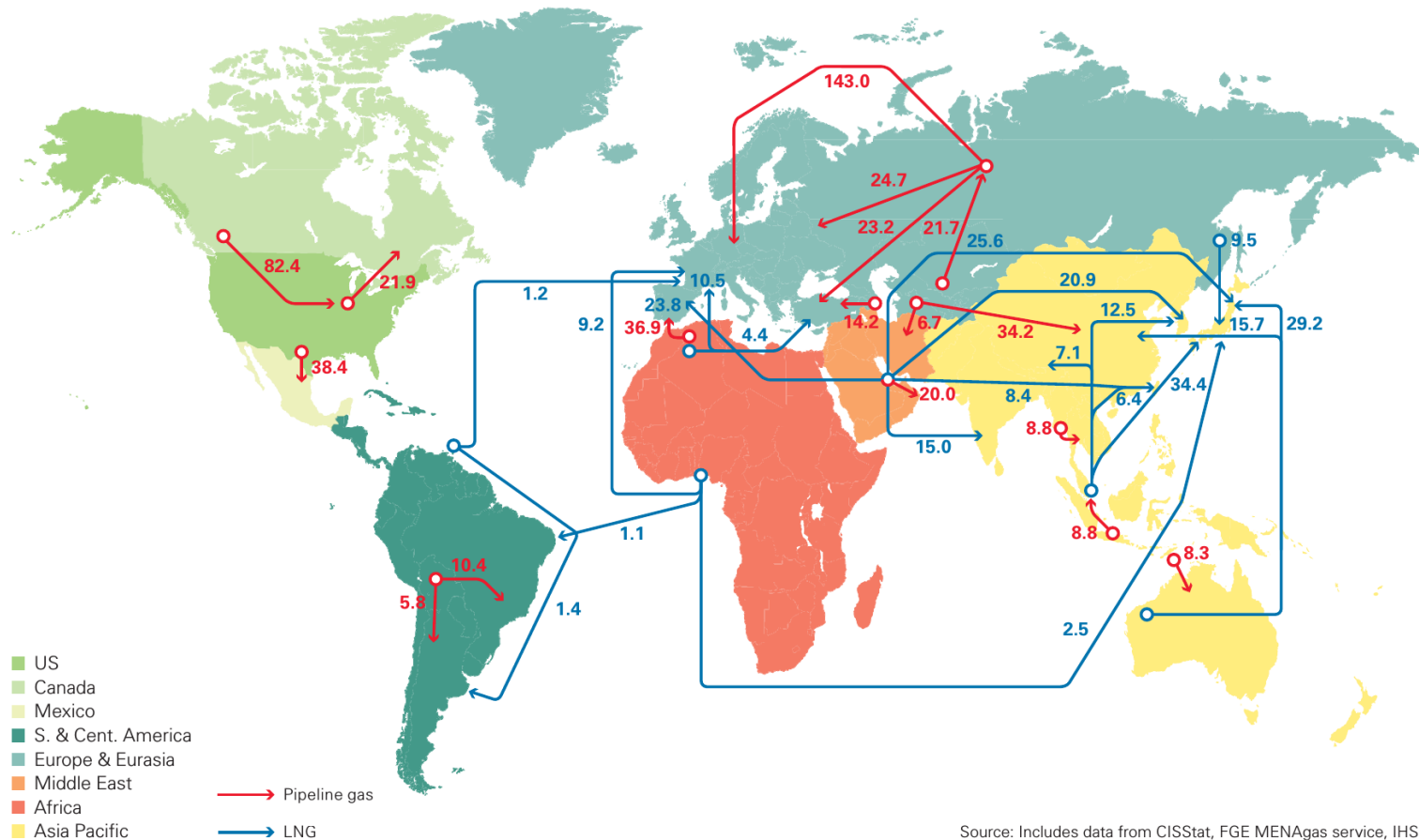


Source: IGU 2017, World LNG Report, p. 13

World market for natural gas

Major trade movements 2016

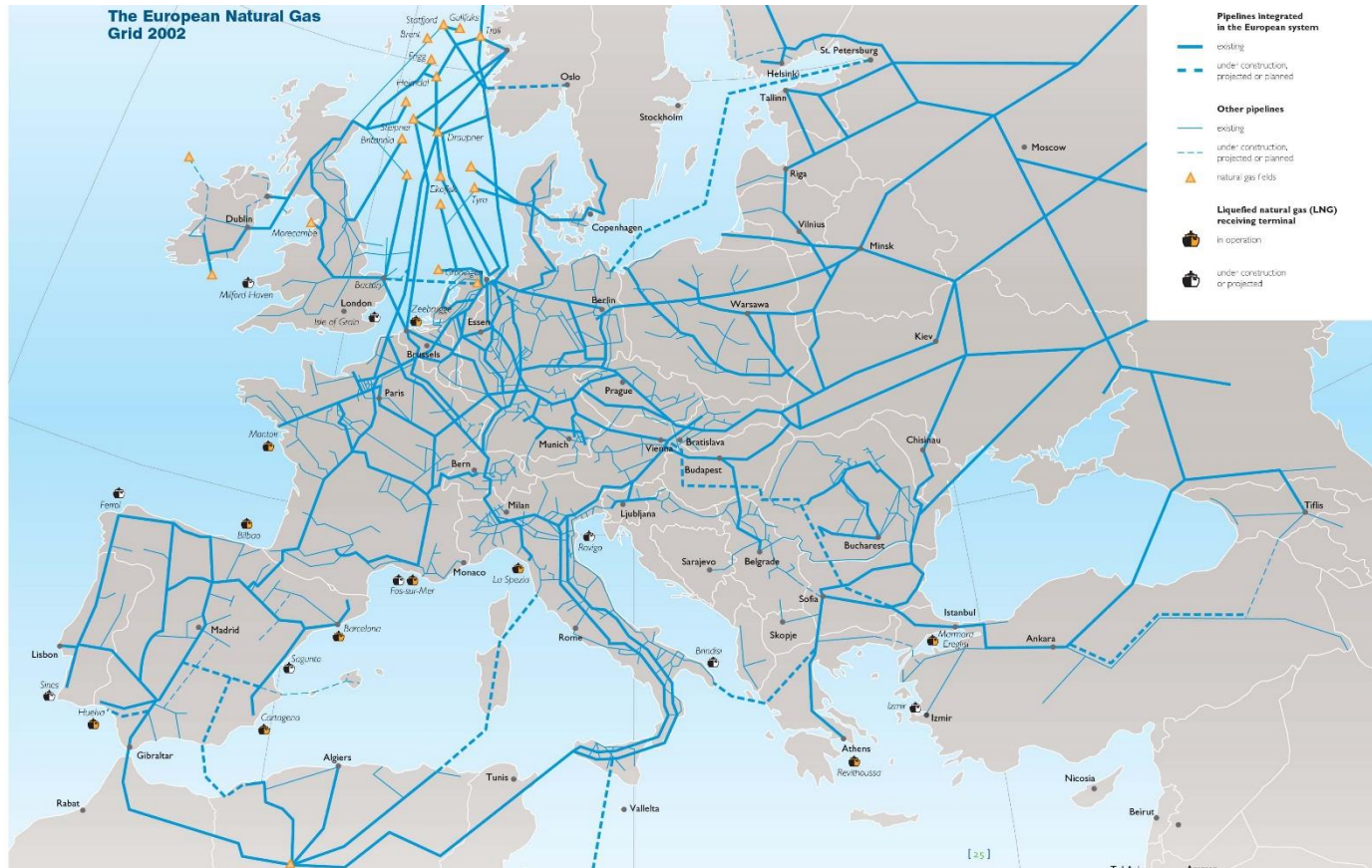
Trade flows worldwide (billion cubic metres)



Source: Includes data from CISStat, FGE MENAgas service, IHS.

Source: BP Statistical Review of World Energy 2017, p. 35

The European Gas Grid



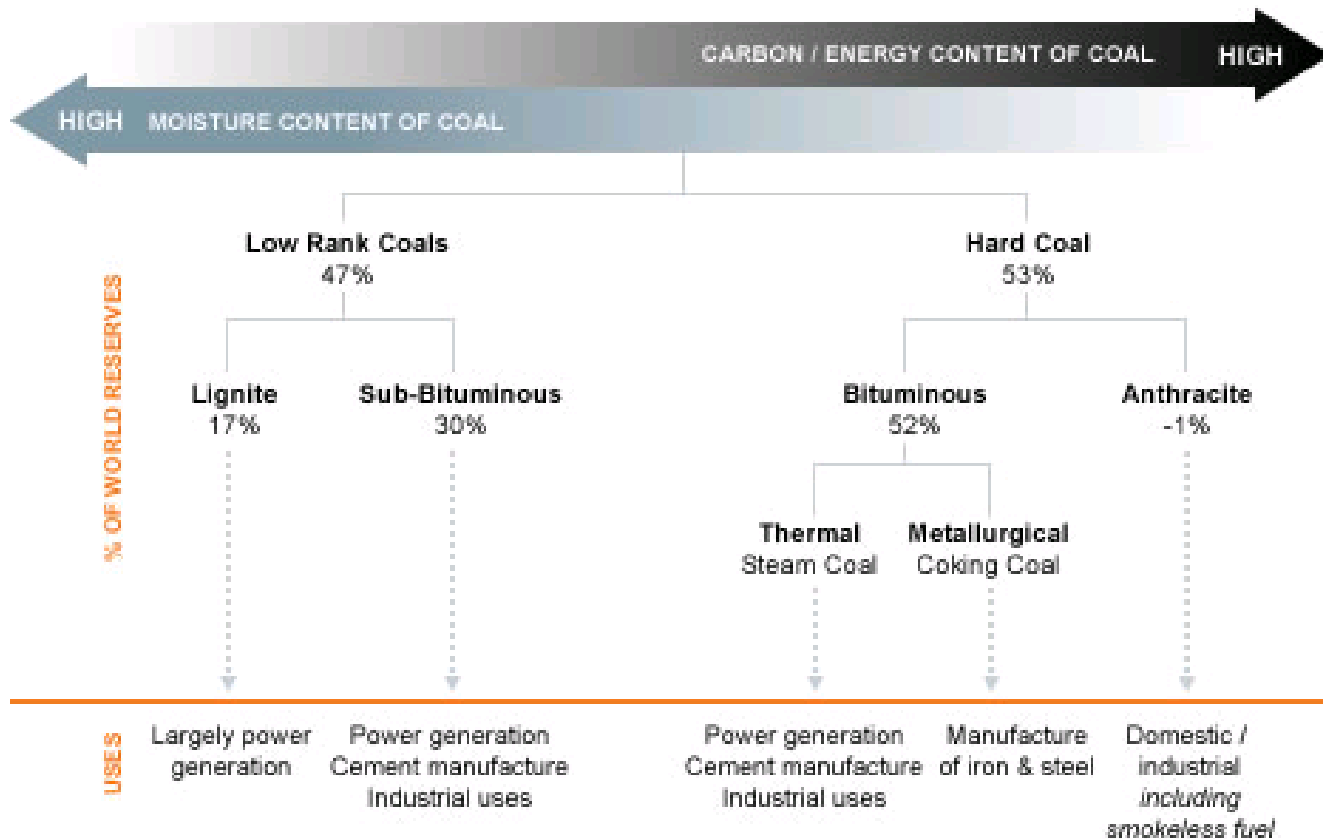
Source: Eurogas 2002

World Market for Coal



Differnet Types of Coal

Types of Coal

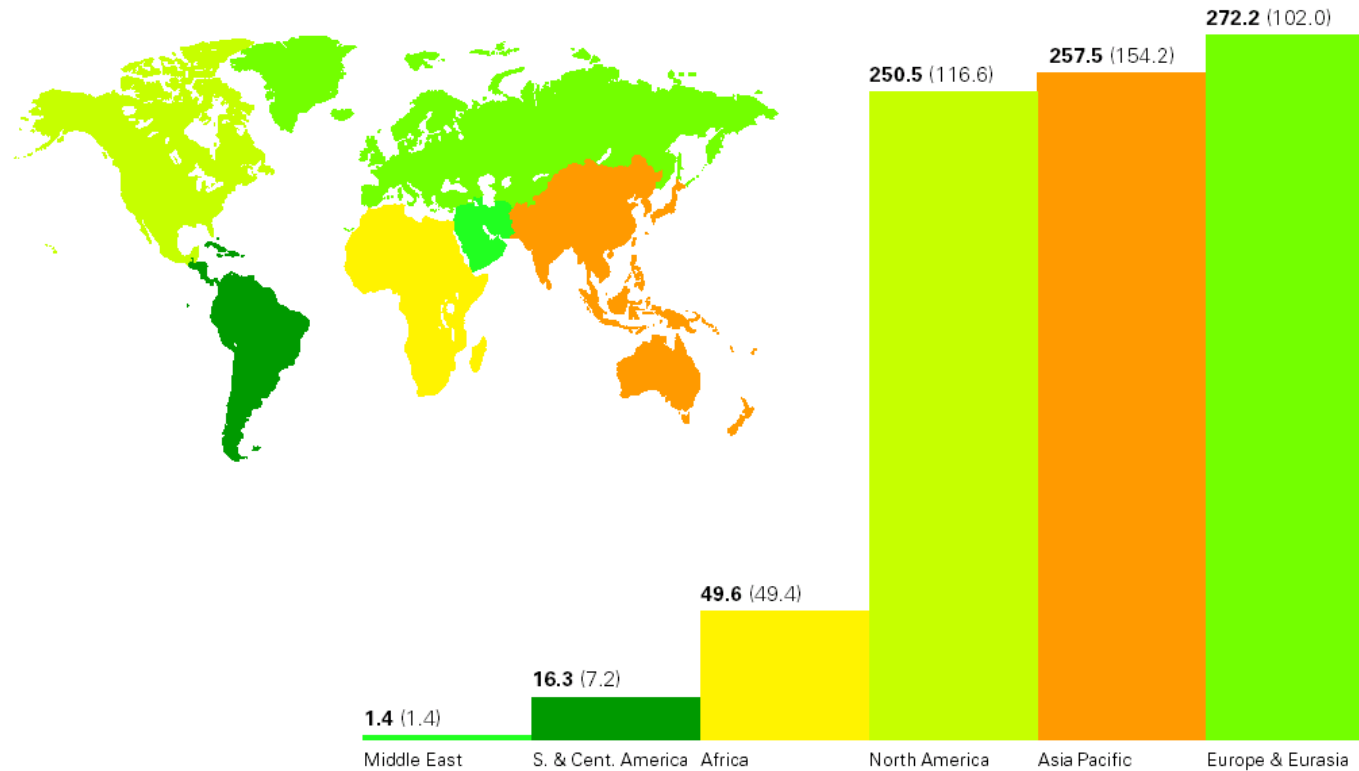


Source: World Coal Institute, no year, p. 4

Proved coal reserves

Proved reserves at end 2007

Thousand million tonnes (anthracite and bituminous coal shown in brackets)



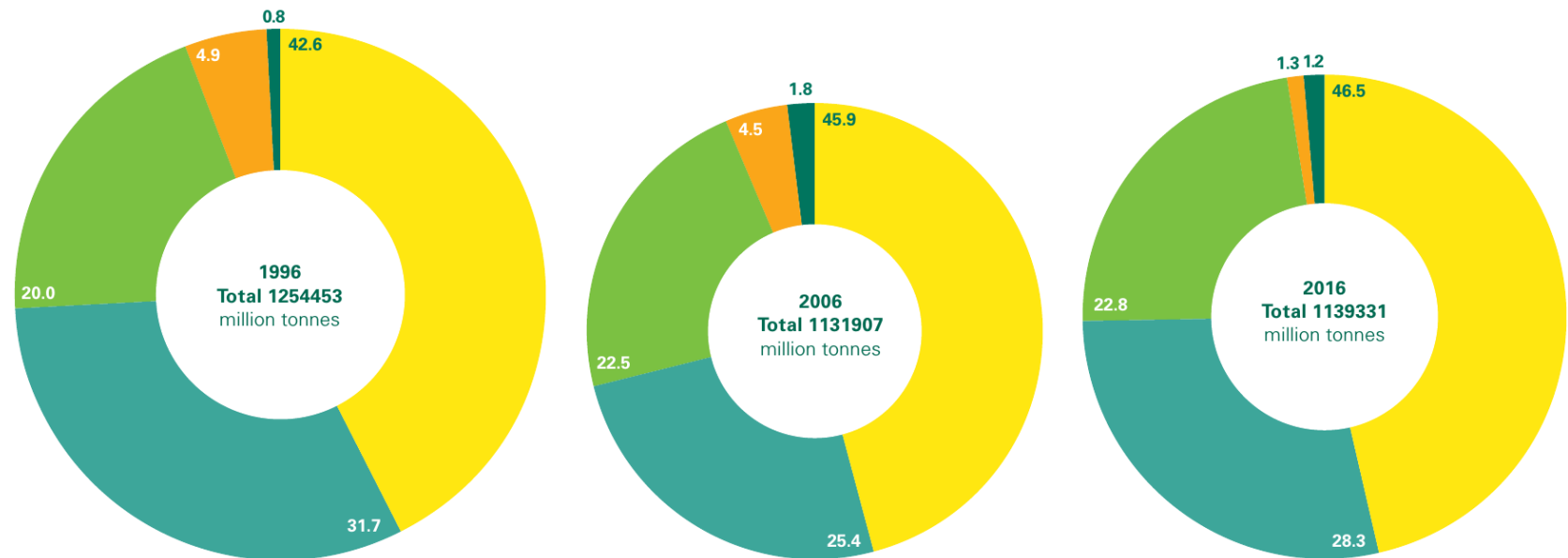
Source: BP Statistical Review of World Energy 2008, p. 33

Proved coal reserves

Distribution of proved reserves in 1996, 2006 and 2016

Percentage

- Asia Pacific
- Europe & Eurasia
- North America
- Middle East & Africa
- S. & Cent. America



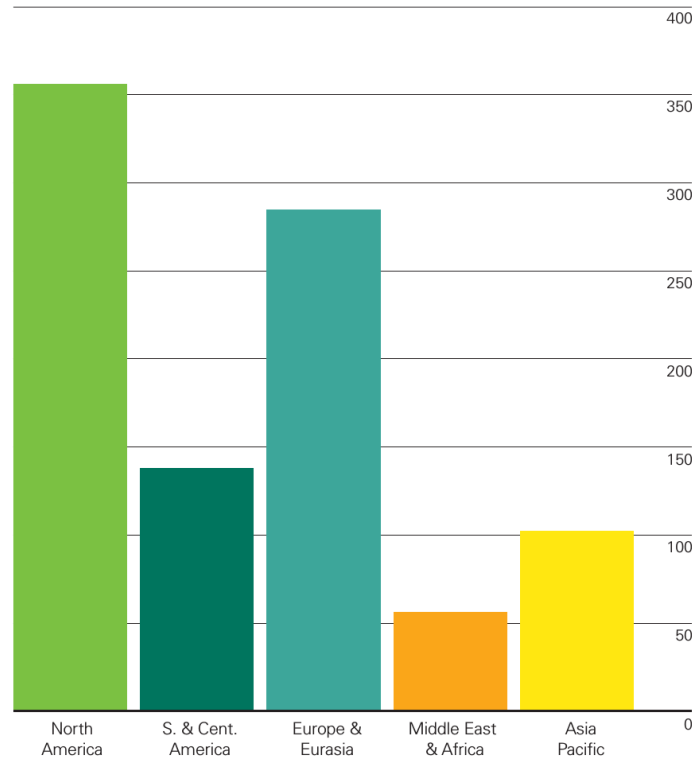
Source: BP Statistical Review of World Energy 20017, p. 37

Proved coal reserves

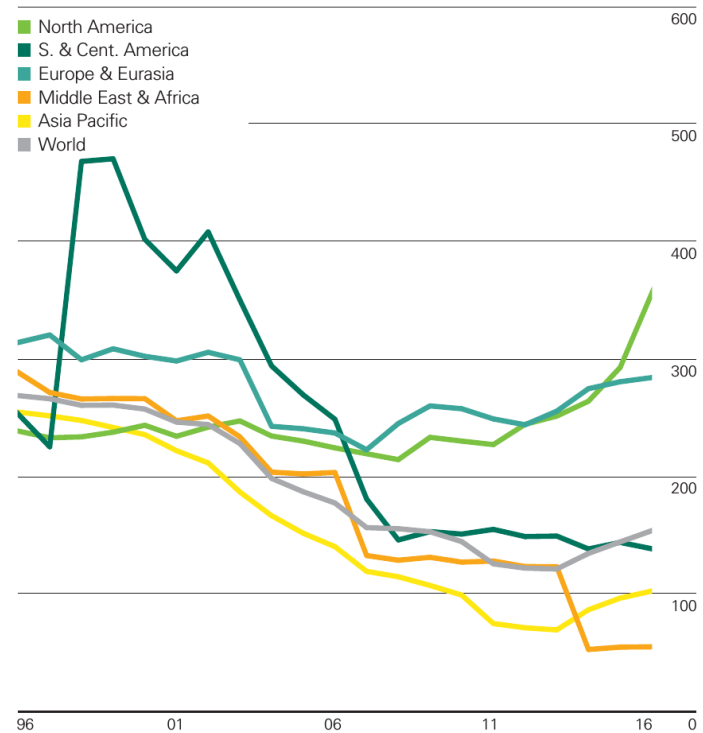
Reserves-to-production (R/P) ratios

Years

2016 by region



History

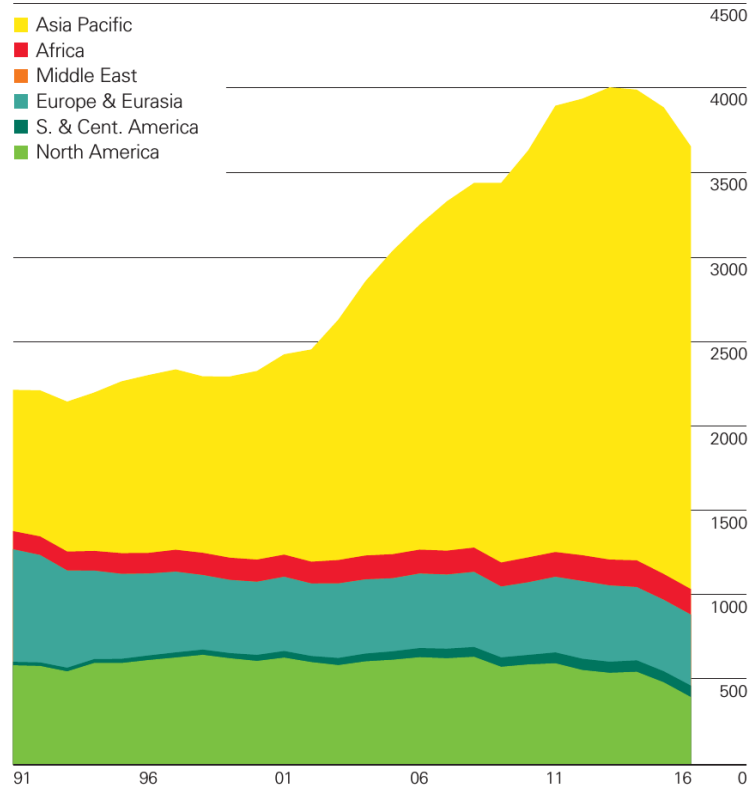


Source: BP Statistical Review of World Energy 20017, p. 37

World Market for Coal

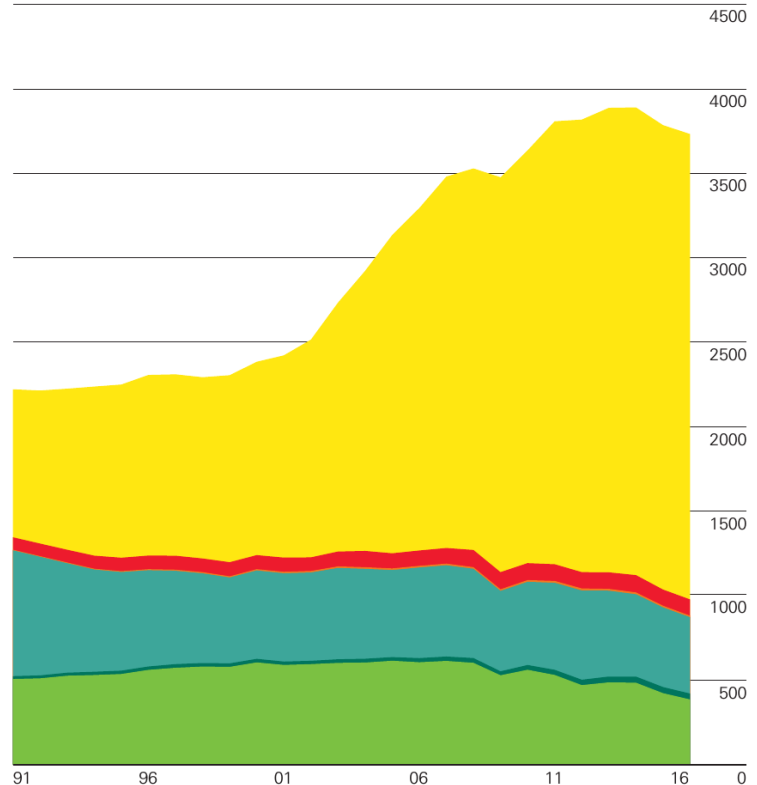
Coal: Production by region

Million tonnes oil equivalent



Coal: Consumption by region

Million tonnes oil equivalent

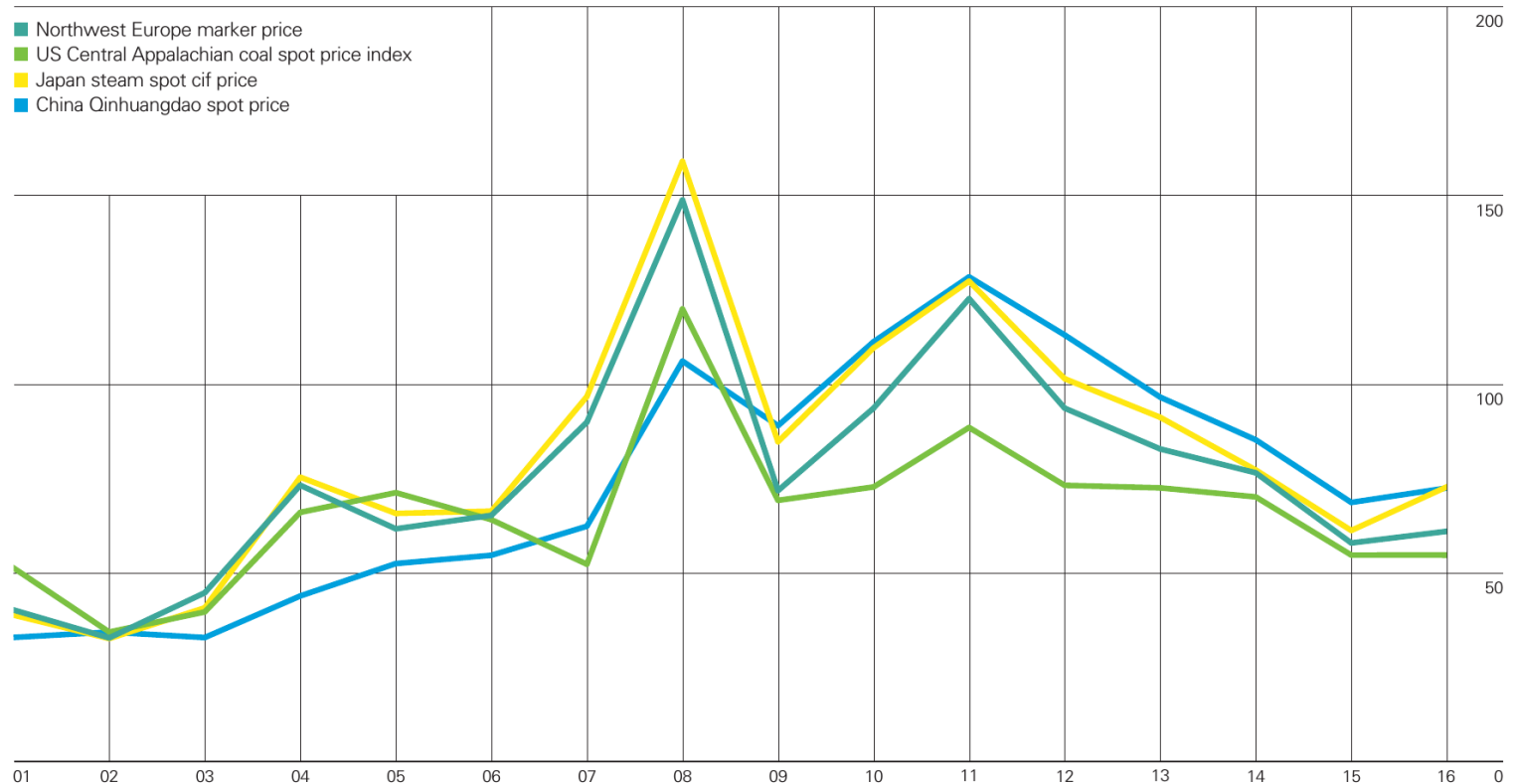


Source: BP Statistical Review of World Energy 2017, p. 39

World Market for Coal

Coal prices

US dollars per tonne



Source: BP Statistical Review of World Energy 20017, p. 40

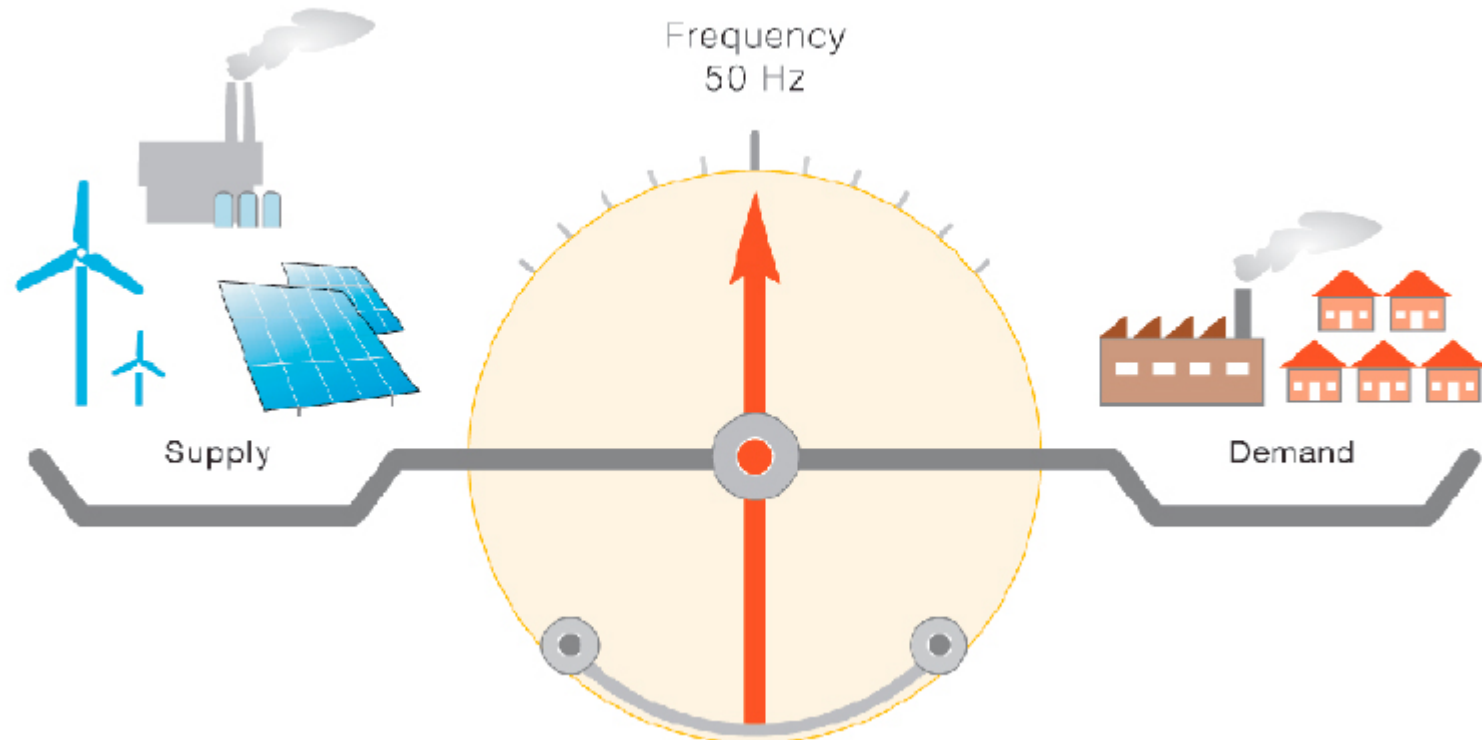
Electricity Market



Electricity as a Secondary Energy Source

- Secondary energy sources are in most cases derived from primary energy source like e.g.:
 - Fossil: Coal, Oil, Gas, etc.
 - Nuclear
 - Renewables: solar, (wind), (biomass), geothermal, etc.

Key challenge: Balance of supply and demand

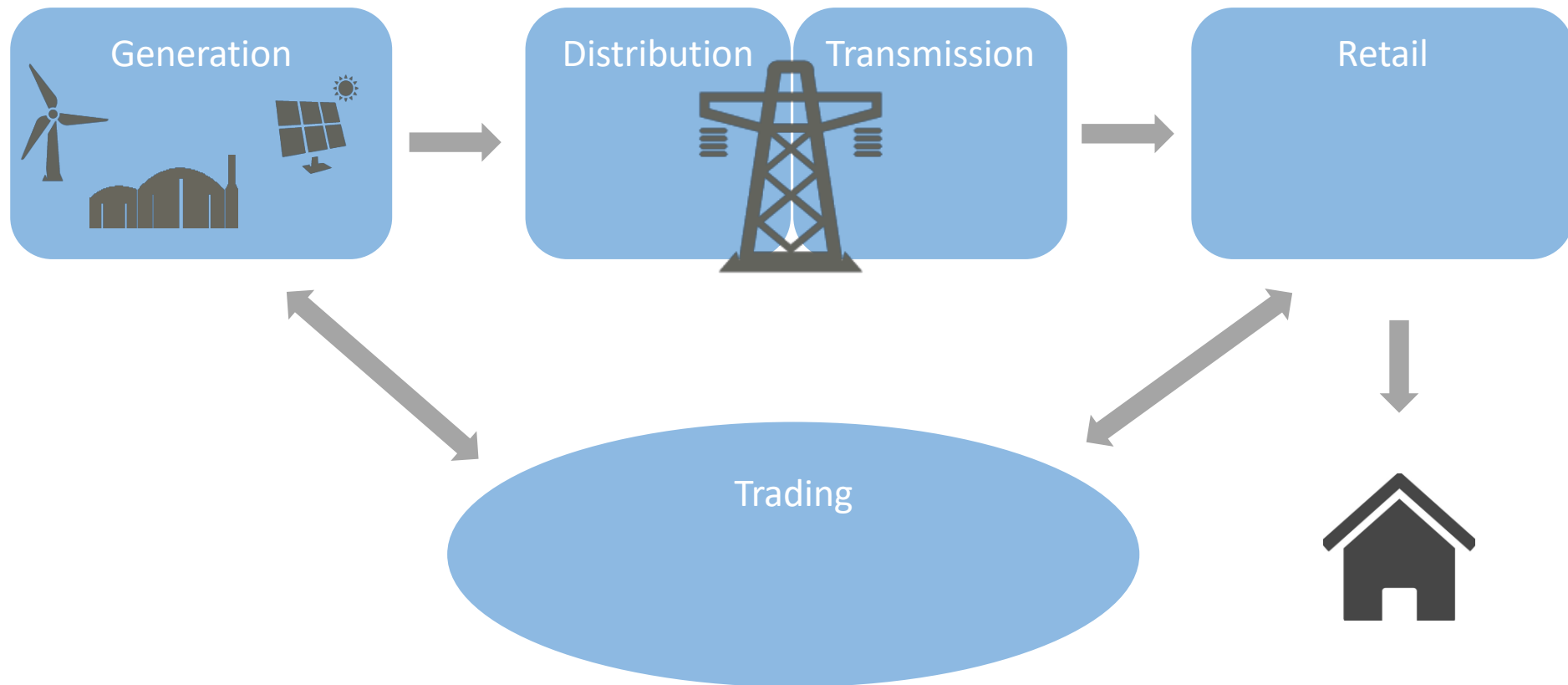


Electricity Market

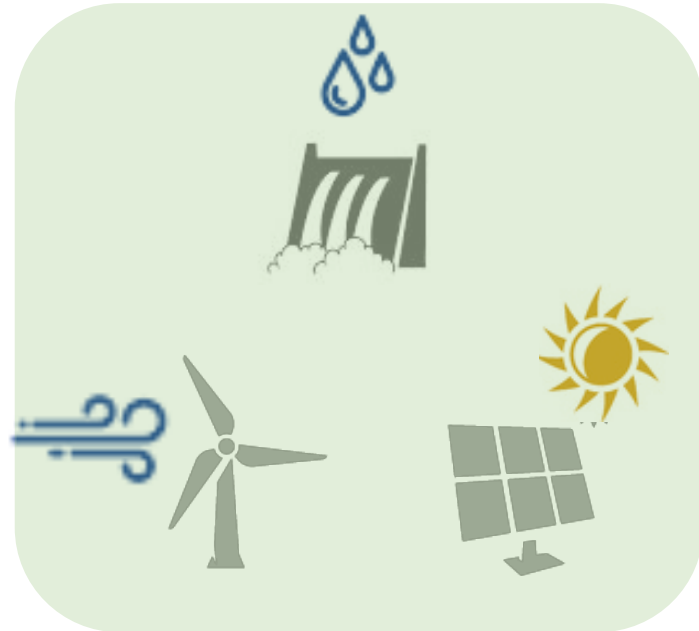
Background

- An electricity market is a system for effecting the purchase and sale of electricity
- Unlike coal, oil and gas, electricity can hardly be stored directly and has to be produced on demand
- Electricity market is based on a transmission grid or network that is available to the wholesalers, retailers and the consumers
- The market can be organized as a regional monopoly, OTC or spot market

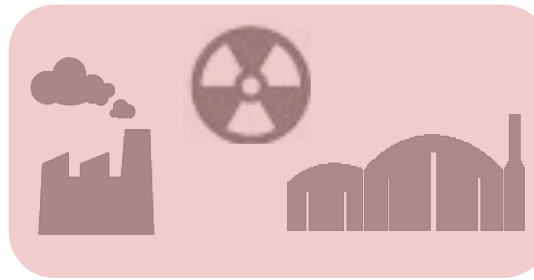
Basic Organisation of Electricity Markets



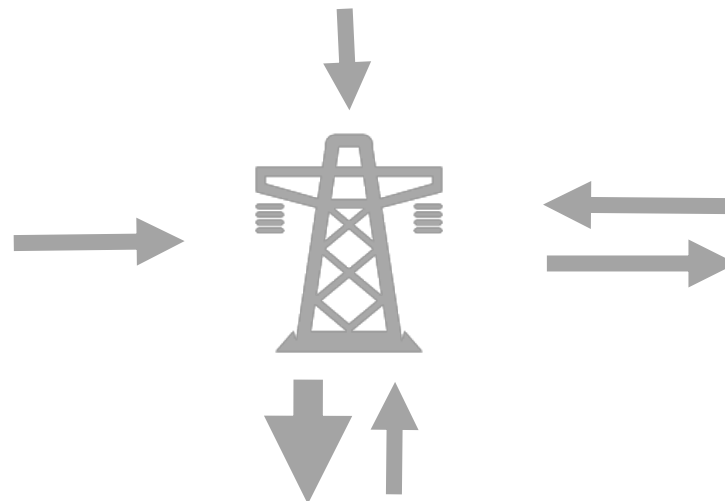
Renewables



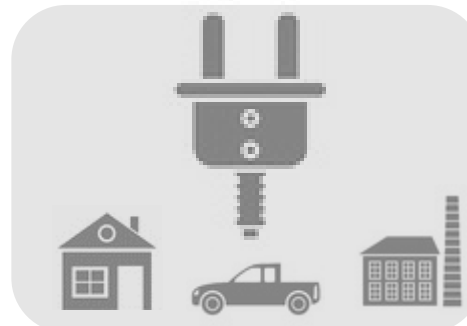
Conventionals



Storage



Consumption



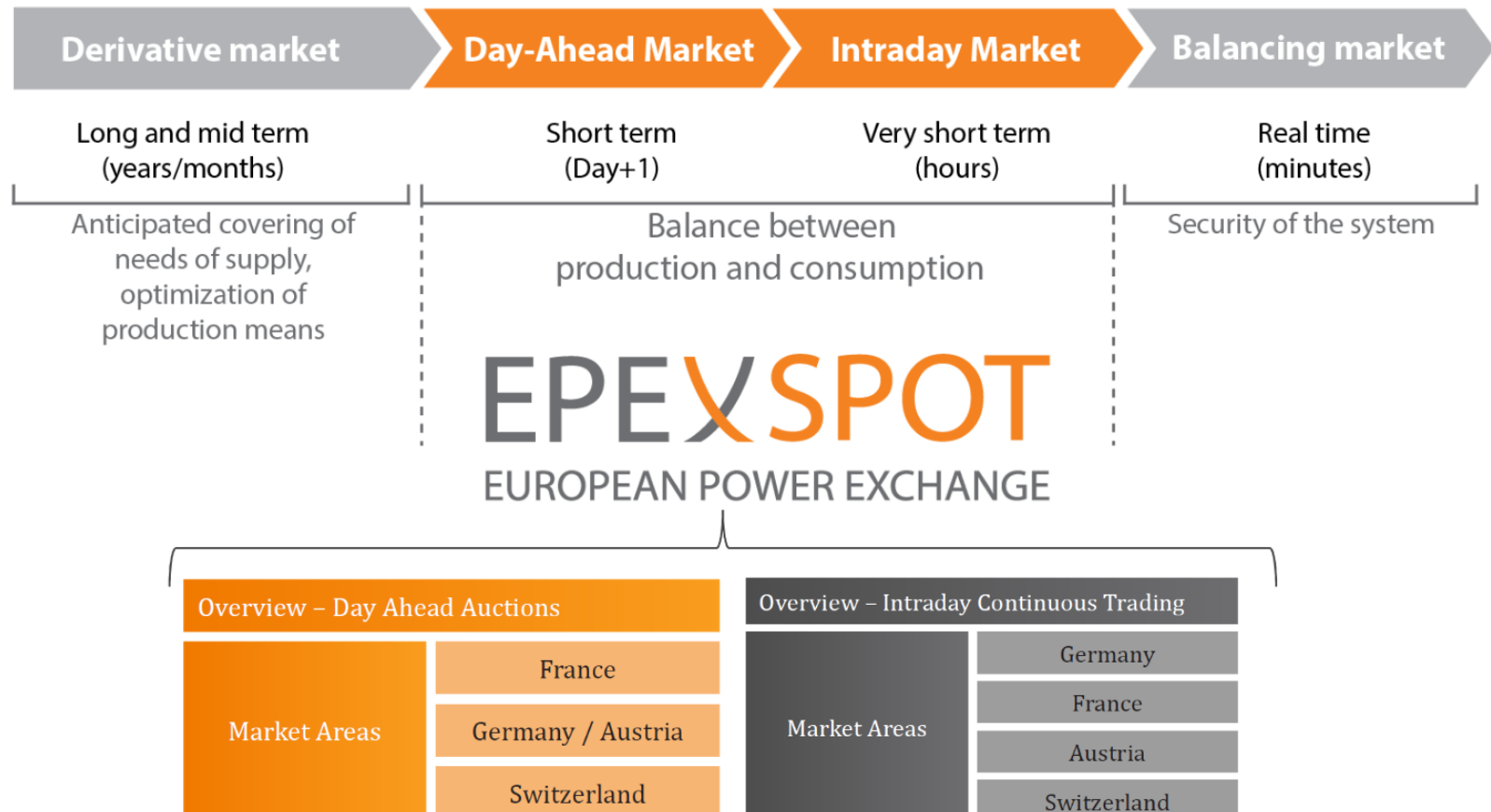
Different Parts of the Electricity Market



Wholesale Market – OTC Trading

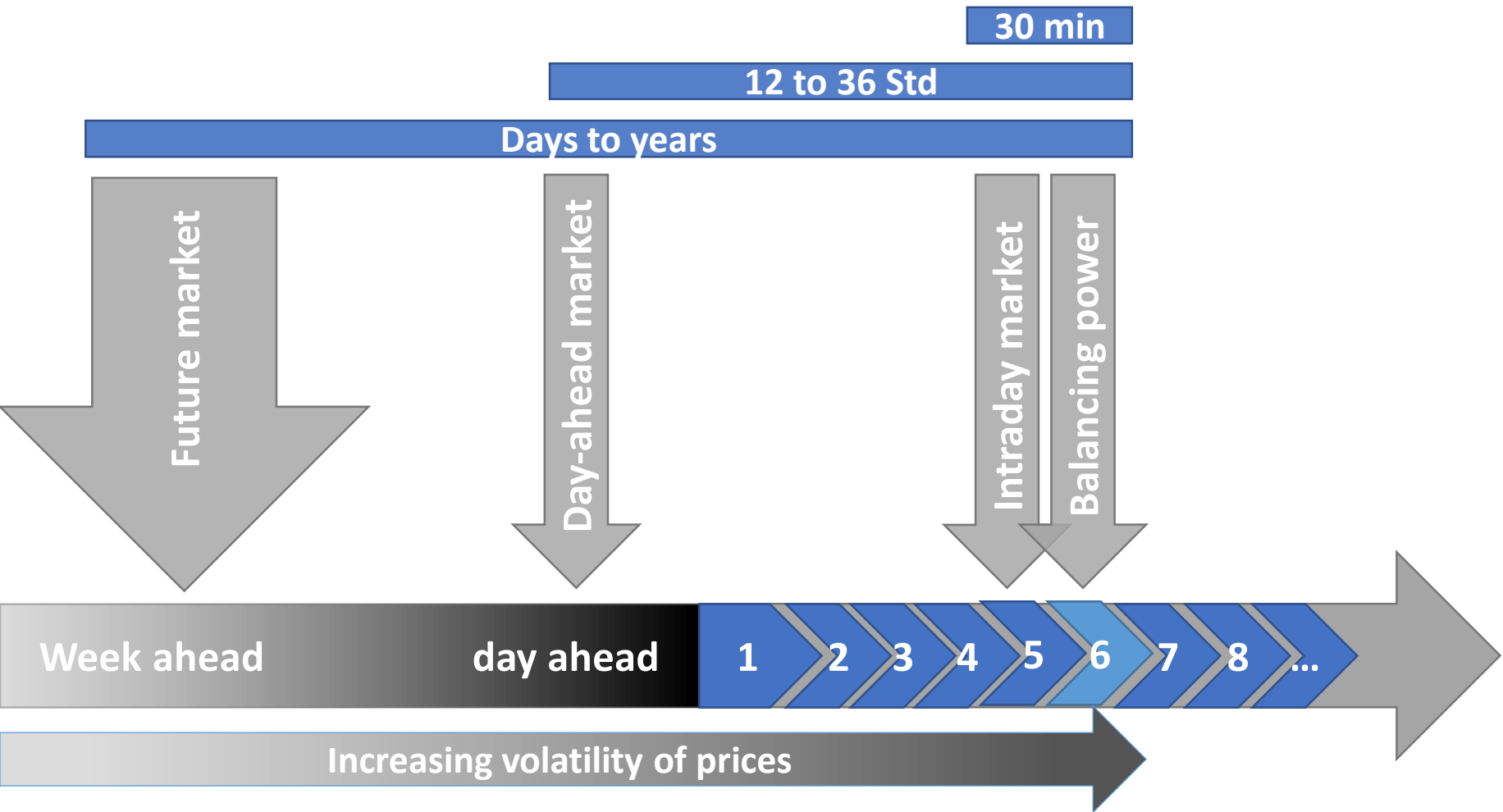
- OTC (Over the Counter) Trading
 - Counterparties know each other
 - Dealing outside the organized stock exchange
 - Trading of mostly individual, non-standardized products
 - Mostly long-term bilateral direct contracts between supplier and consumer
 - No disclosure of prices
 - Risk of non delivery lies by the consumer

Wholesale Market – Spot Market Trading



Source: EPEX SPOT n.d., URL: <https://www.epexspot.com/document/25343/EPEX%20SPOT%27s%20presentation>

Different markets for different purposes



Spot Market

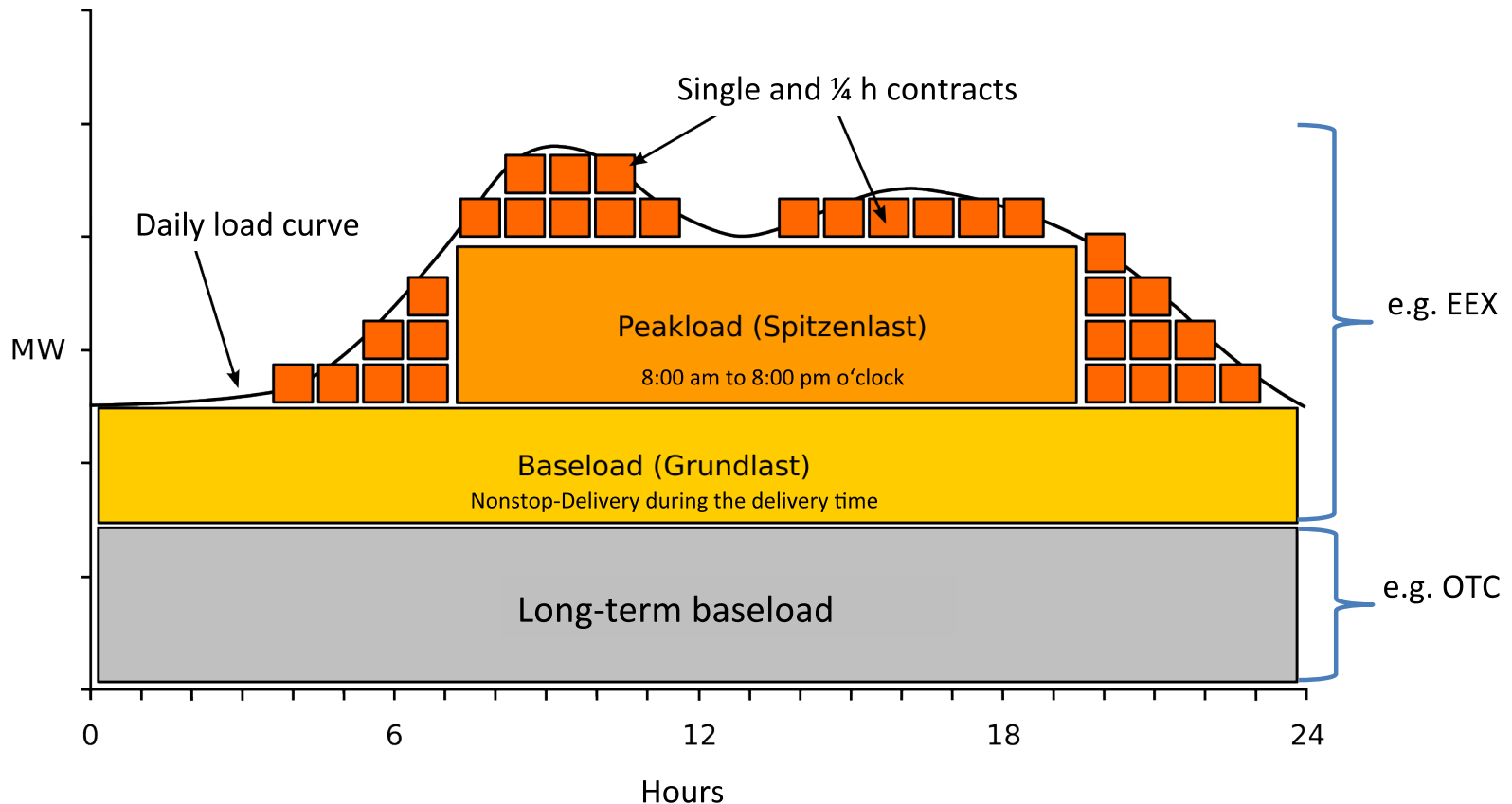
- Day Ahead Market

- Daily auction
- Pay as cleared
- Day ahead auction at 12:00 day ahead

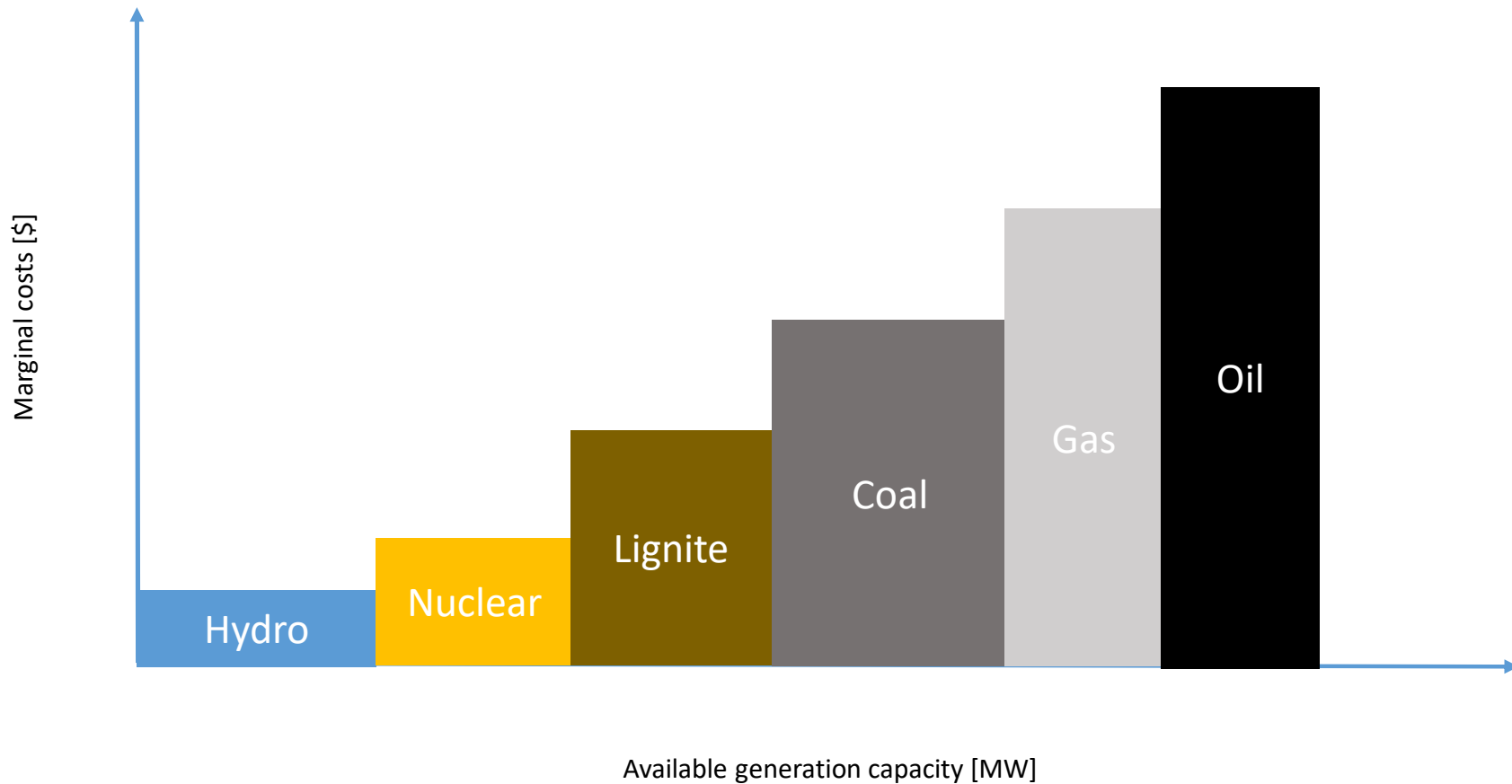
- Intraday Market

- Continuous trading from 15:00 day ahead
- Pay as bid
- Trading until 30 min ahead of each hour

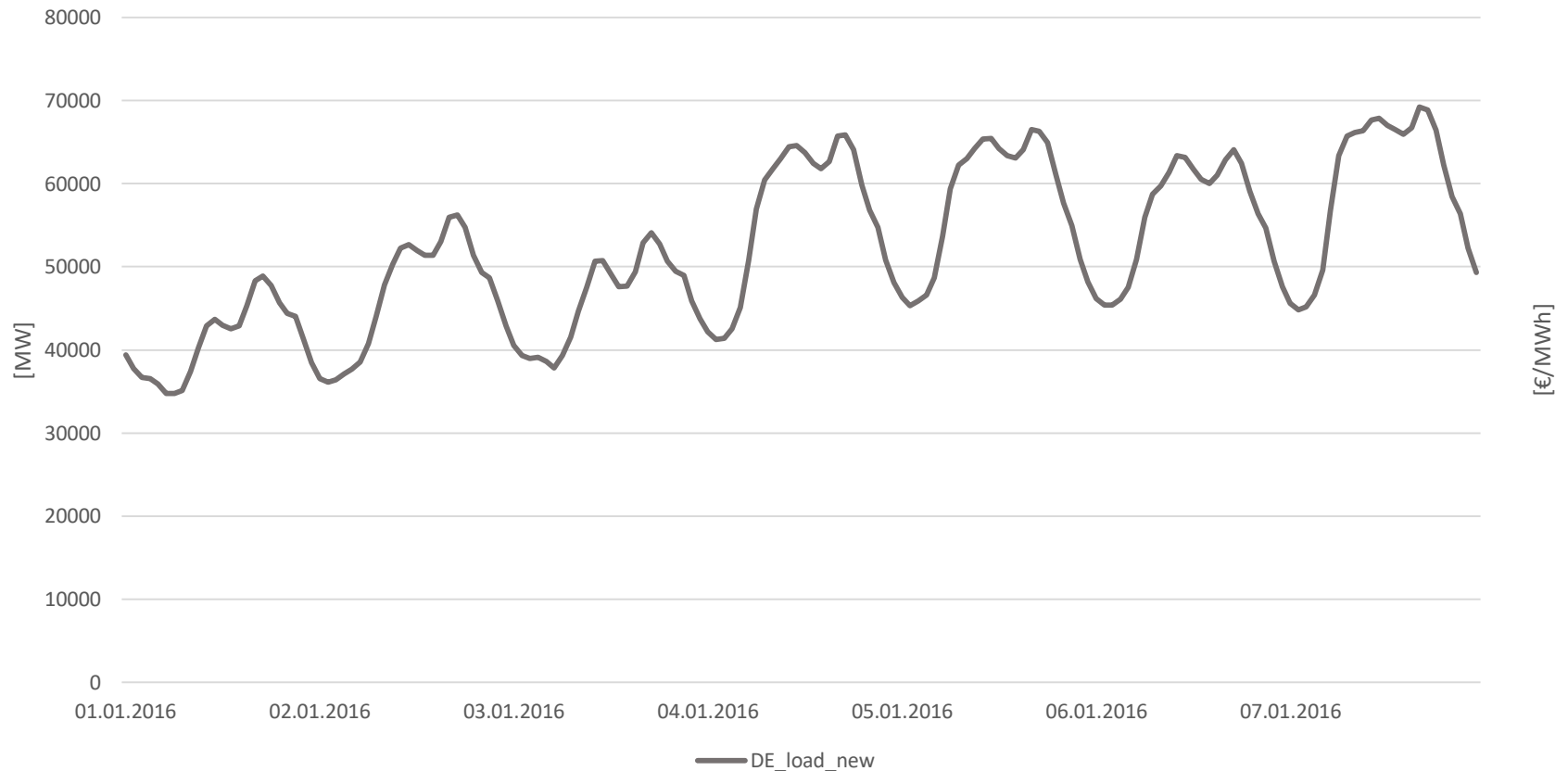
Electricity Products – Liquidity vs. Level of Detail



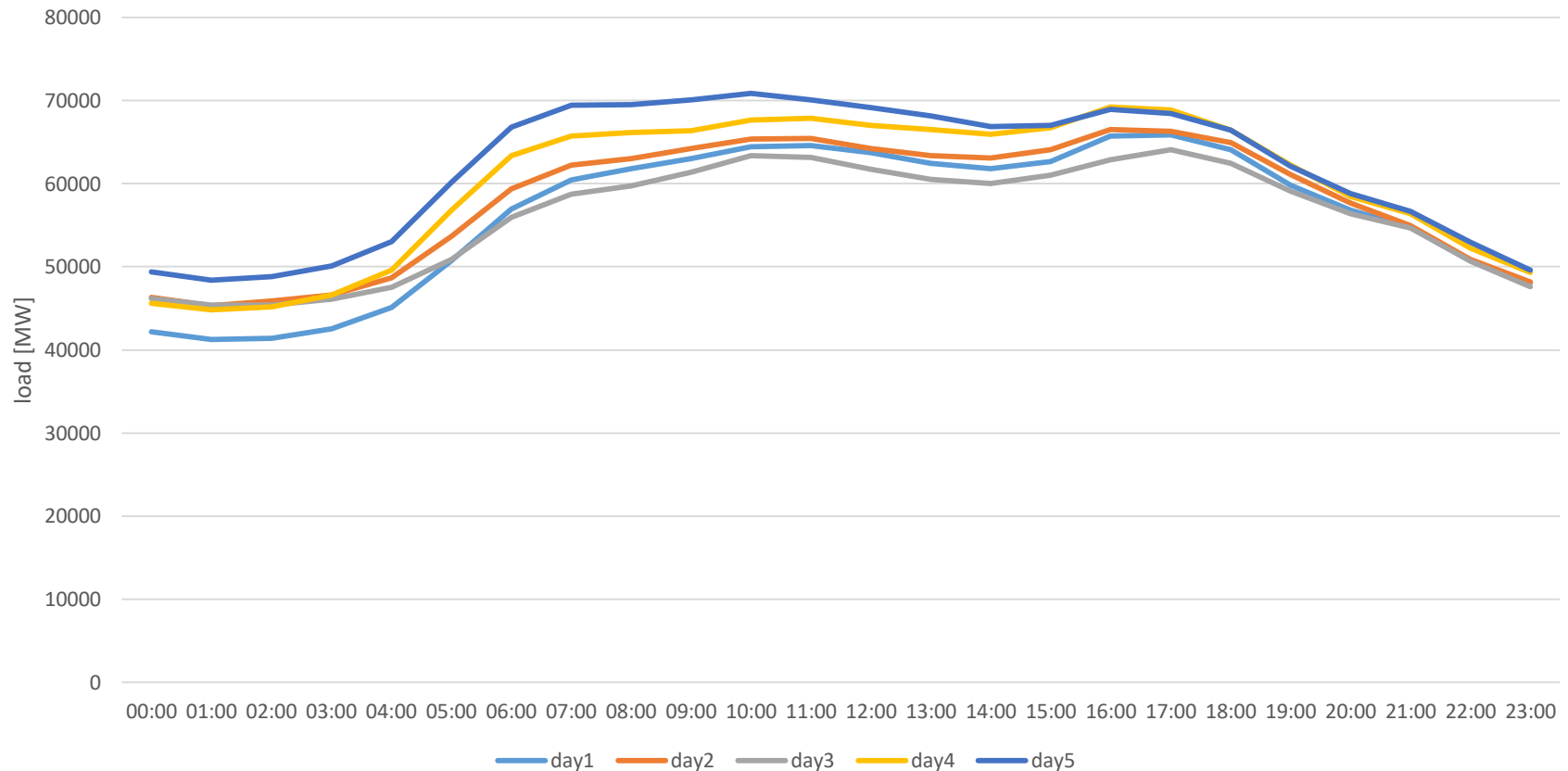
Merit Order - Fundamentals



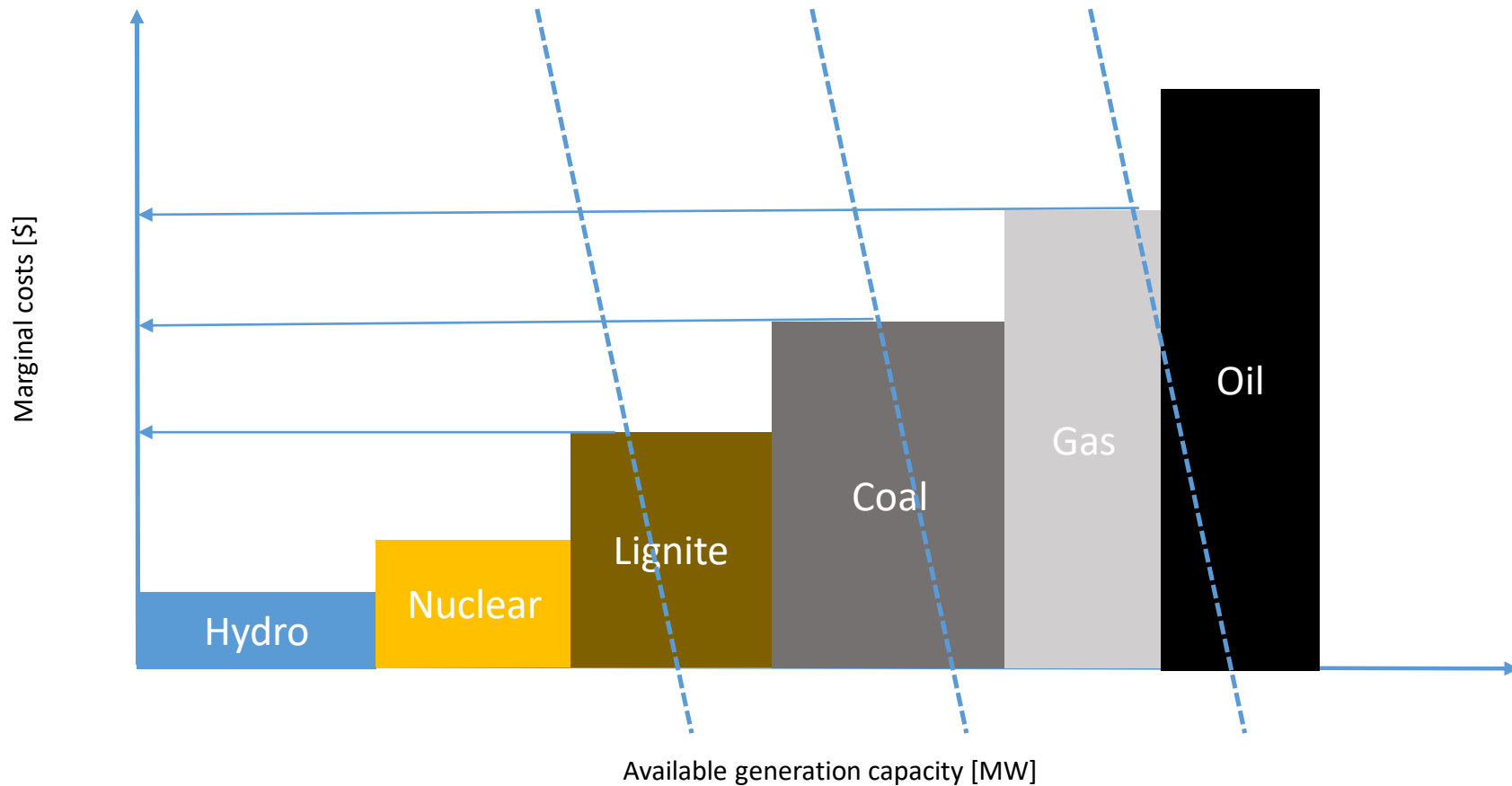
Electricity Price – Fundamental Drivers



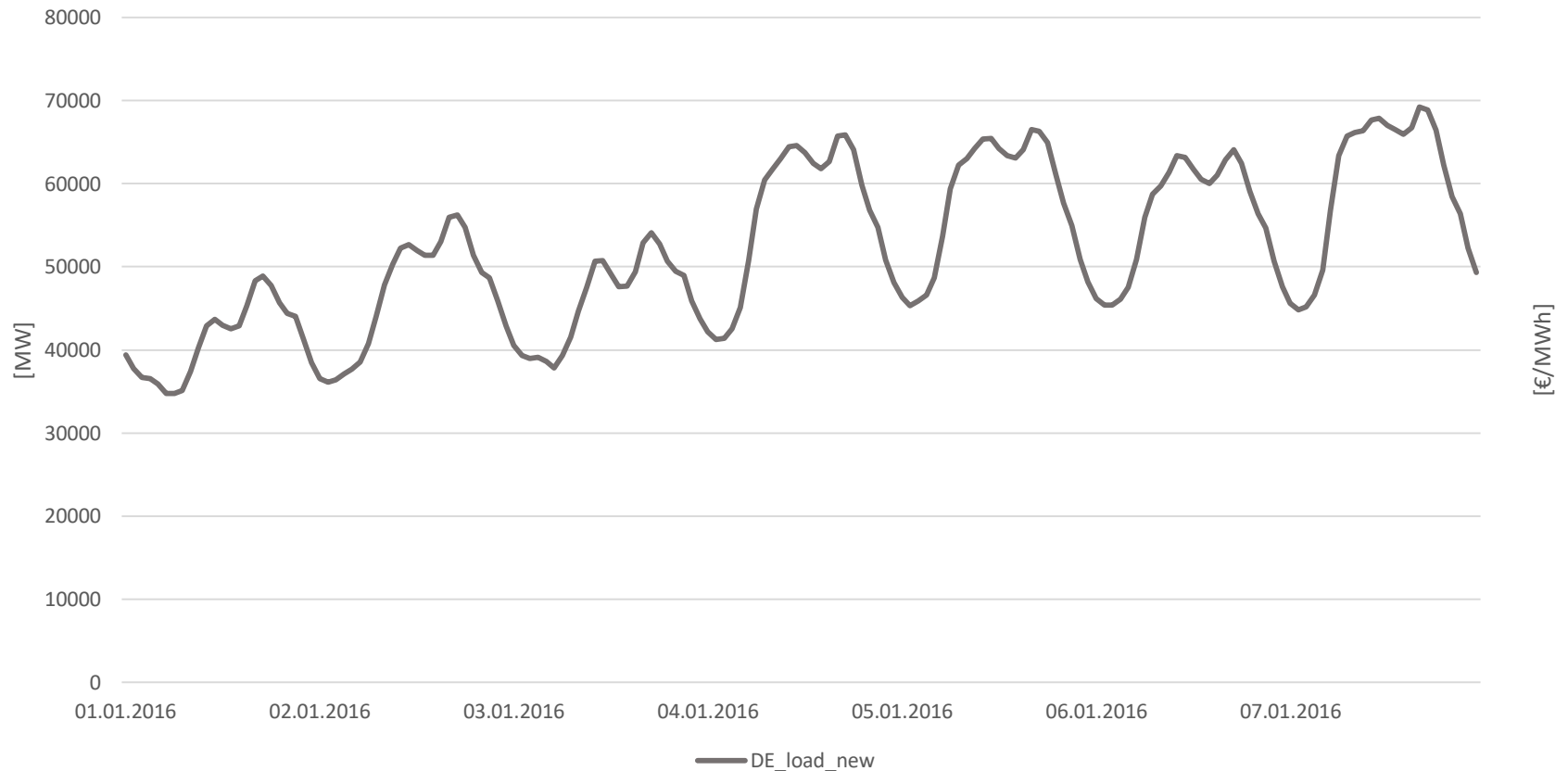
Typical Electrical Consumption Behaviour



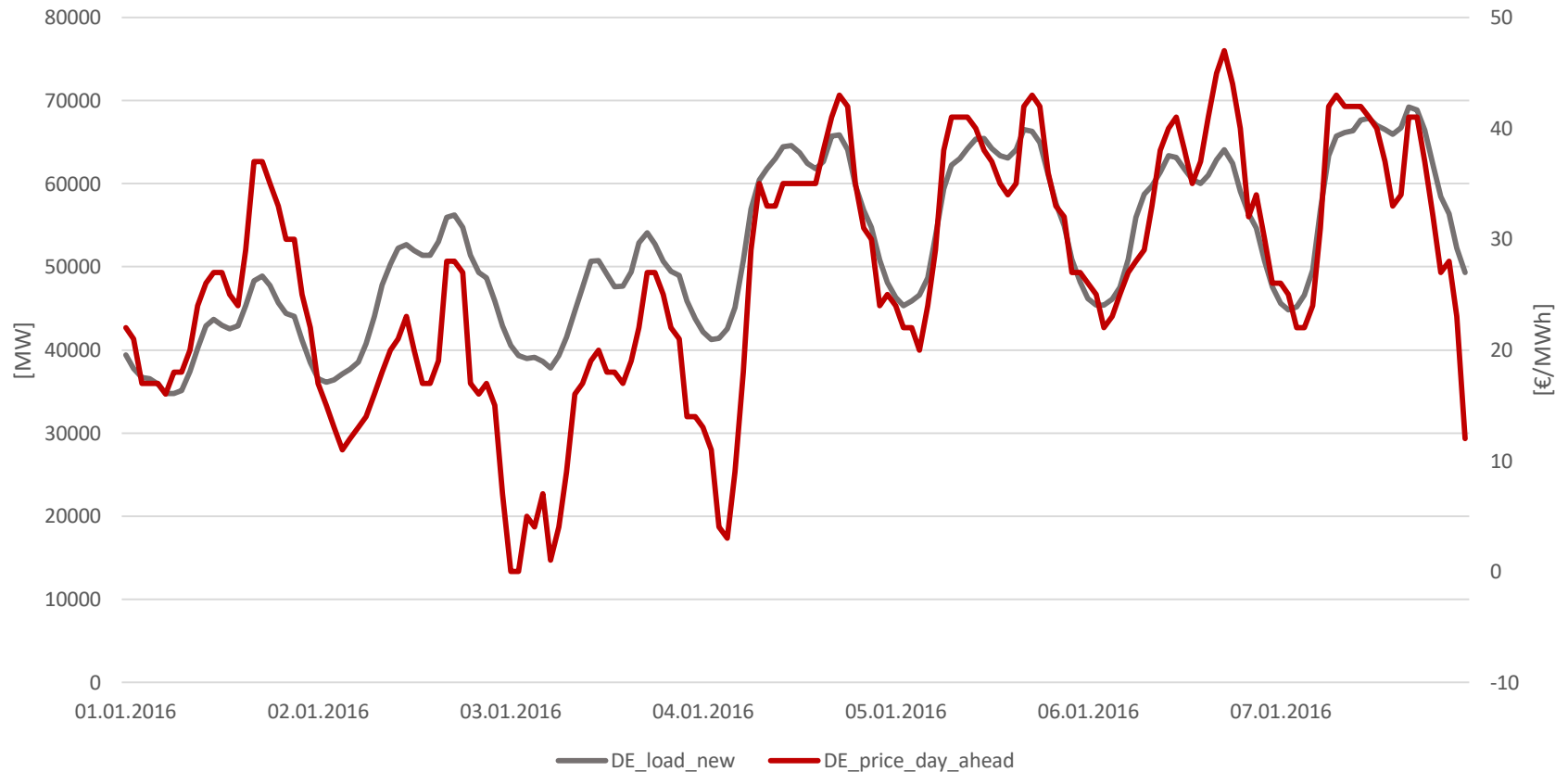
Merit Order - Fundamentals



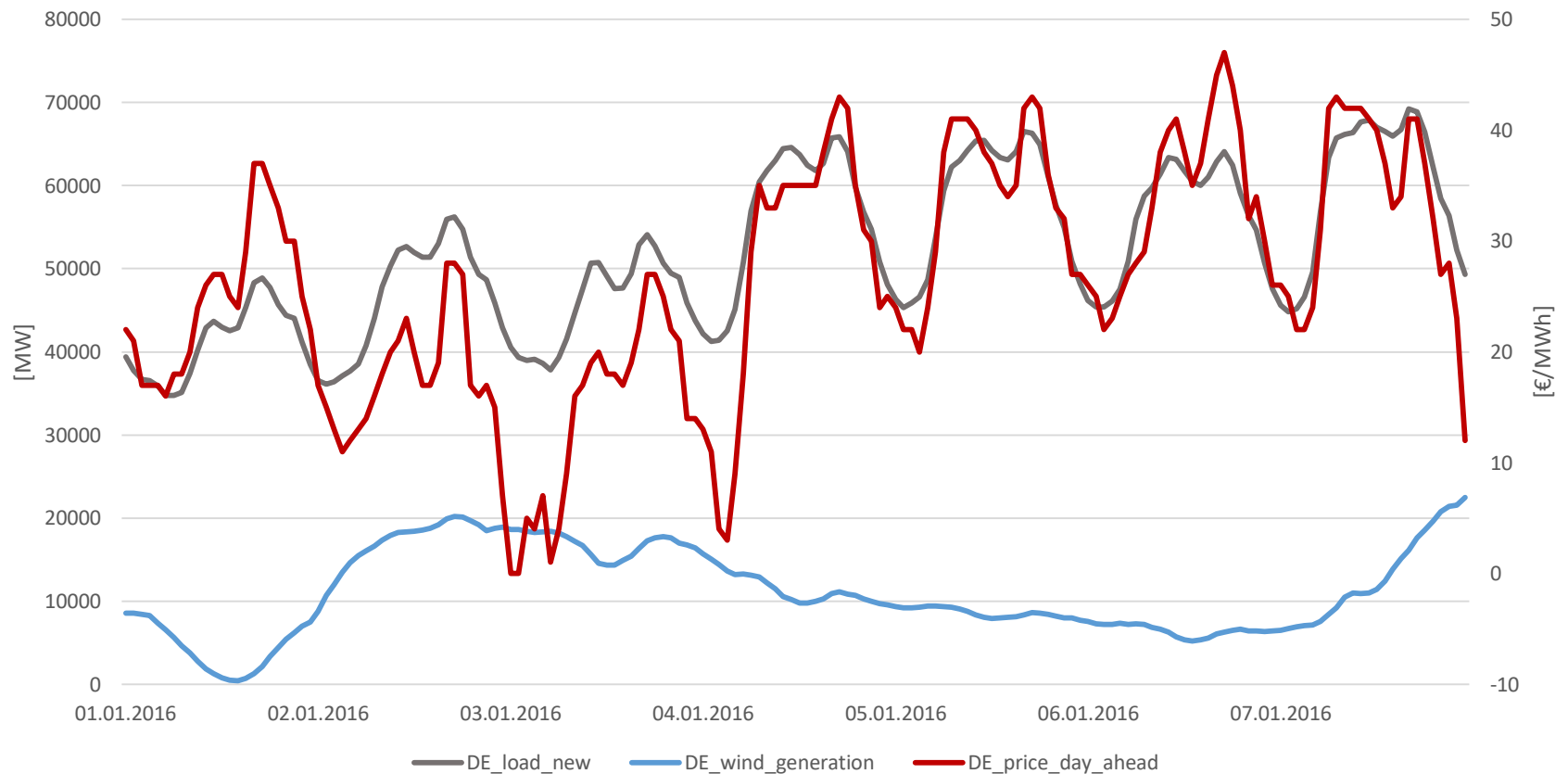
Electricity Price – Fundamental Drivers



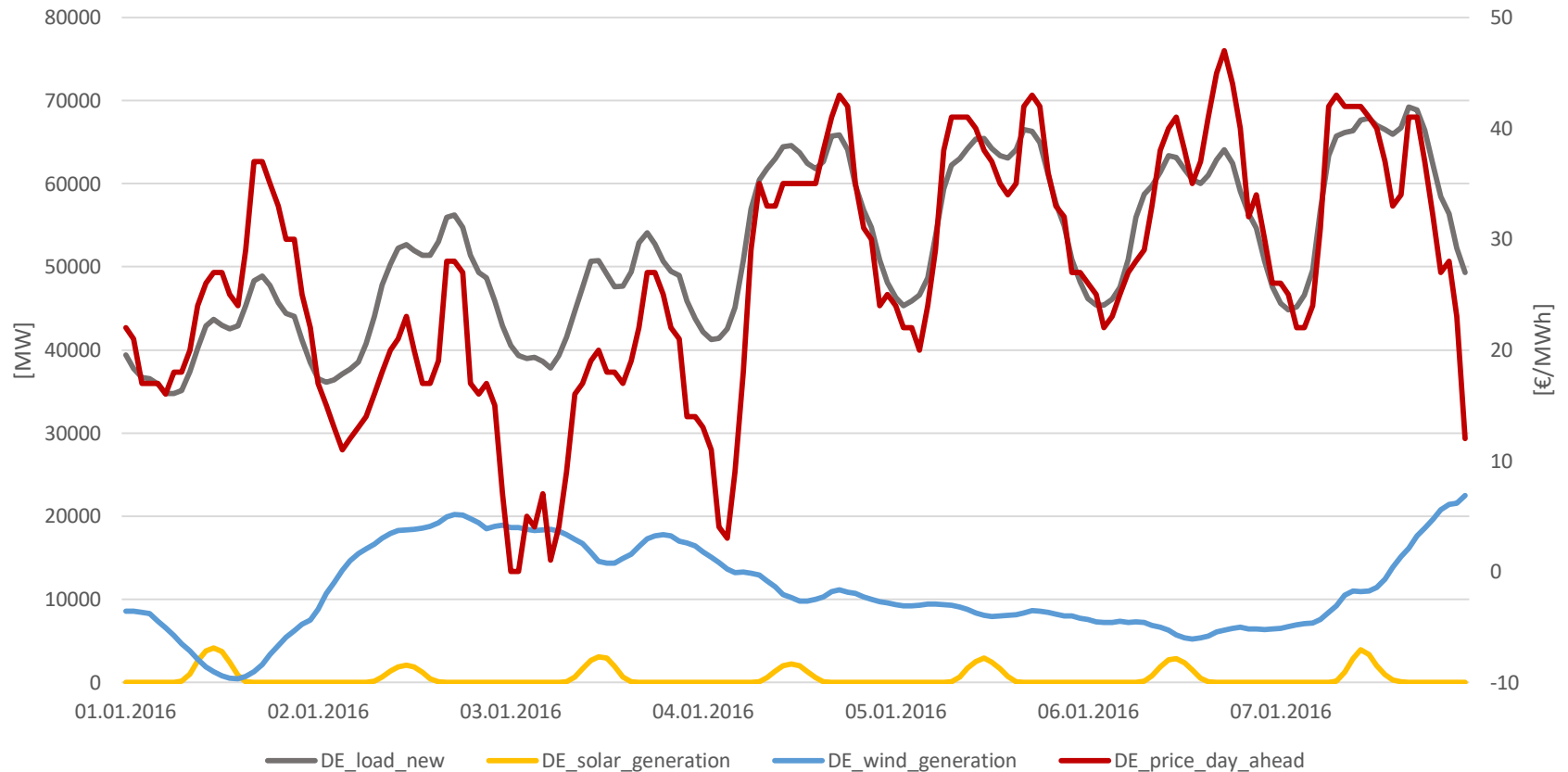
Electricity Price – Fundamental Drivers



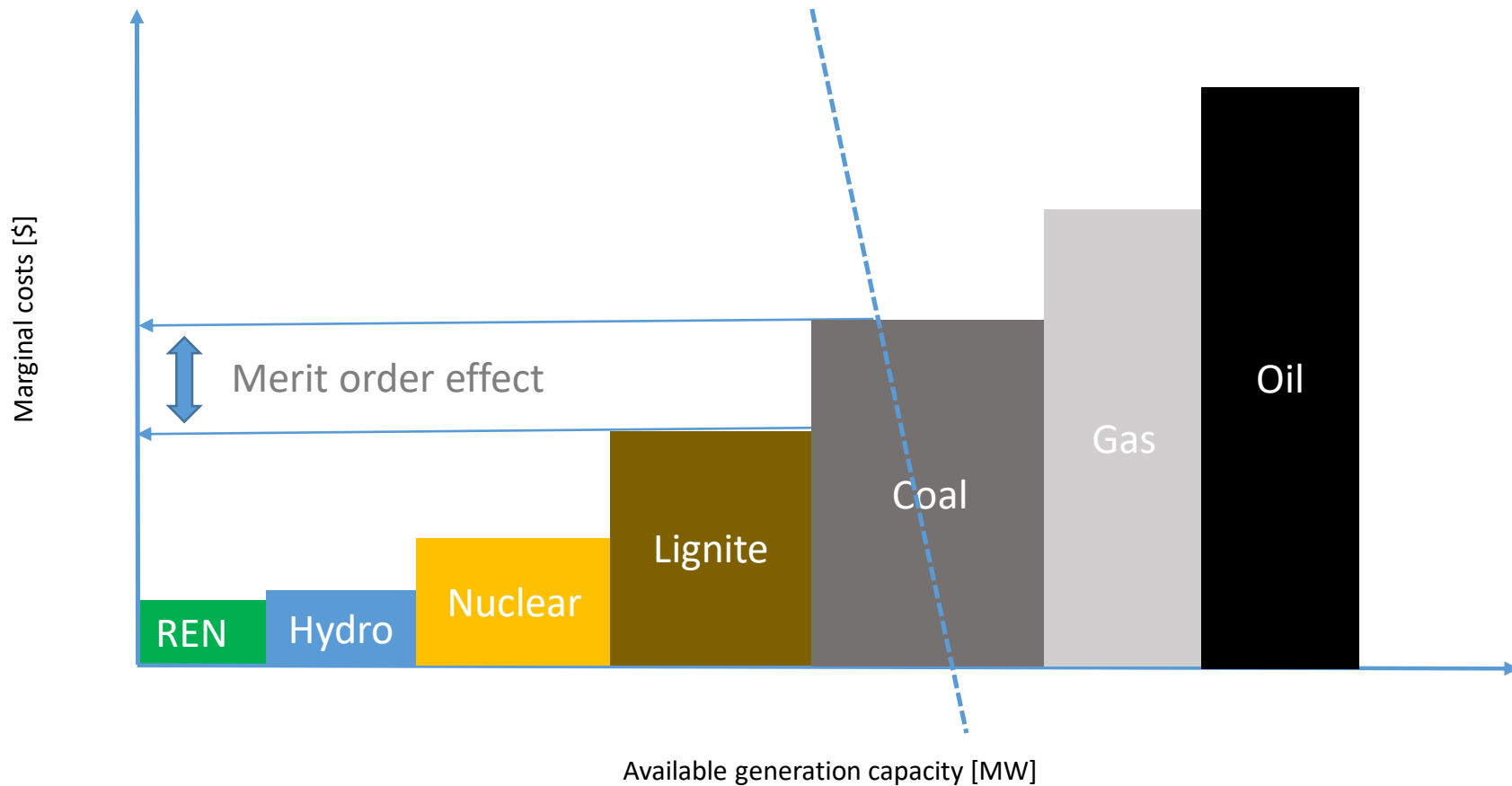
Electricity Price – Fundamental Drivers



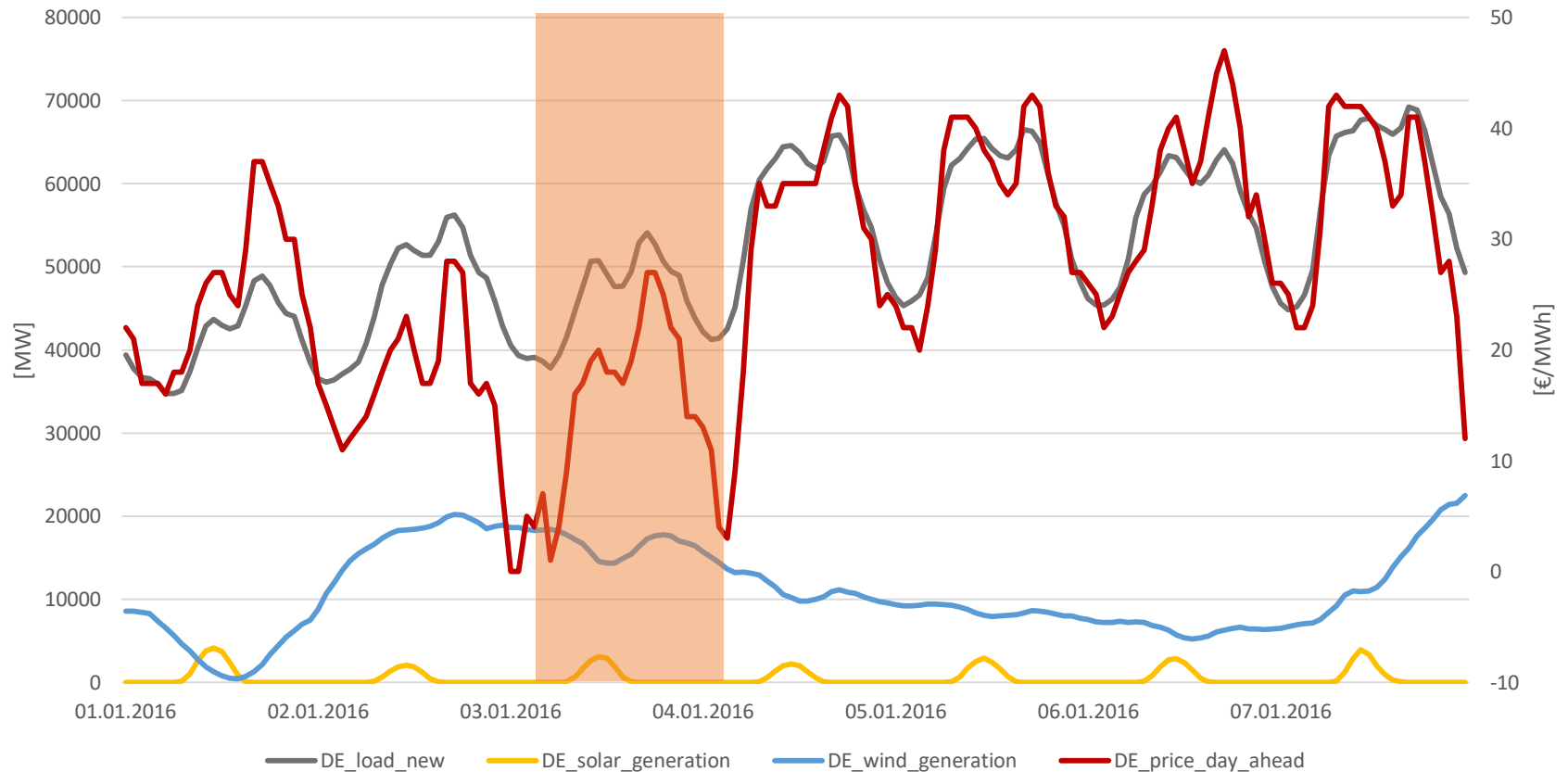
Electricity Price – Fundamental Drivers



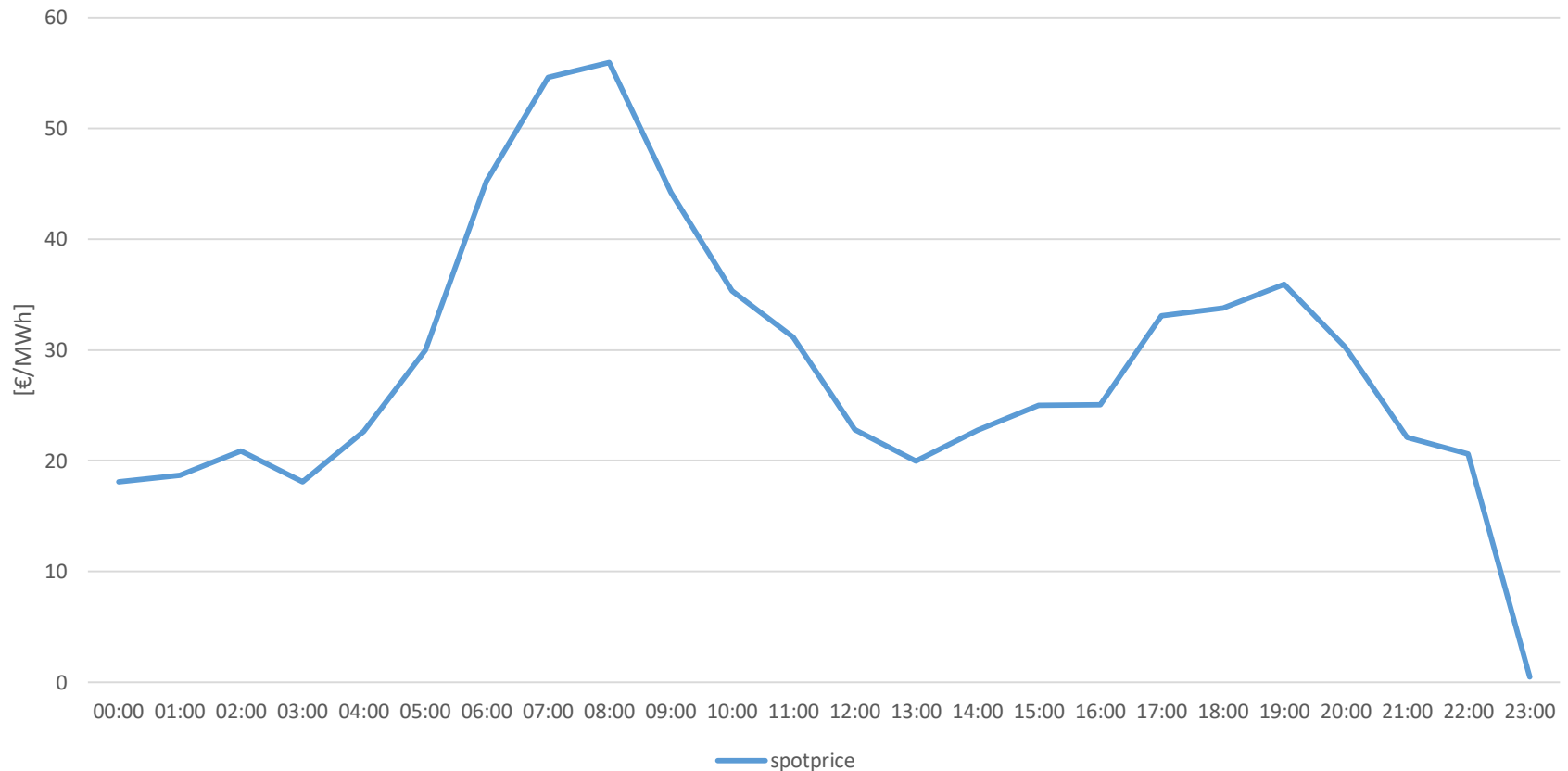
Merit Order - Fundamentals



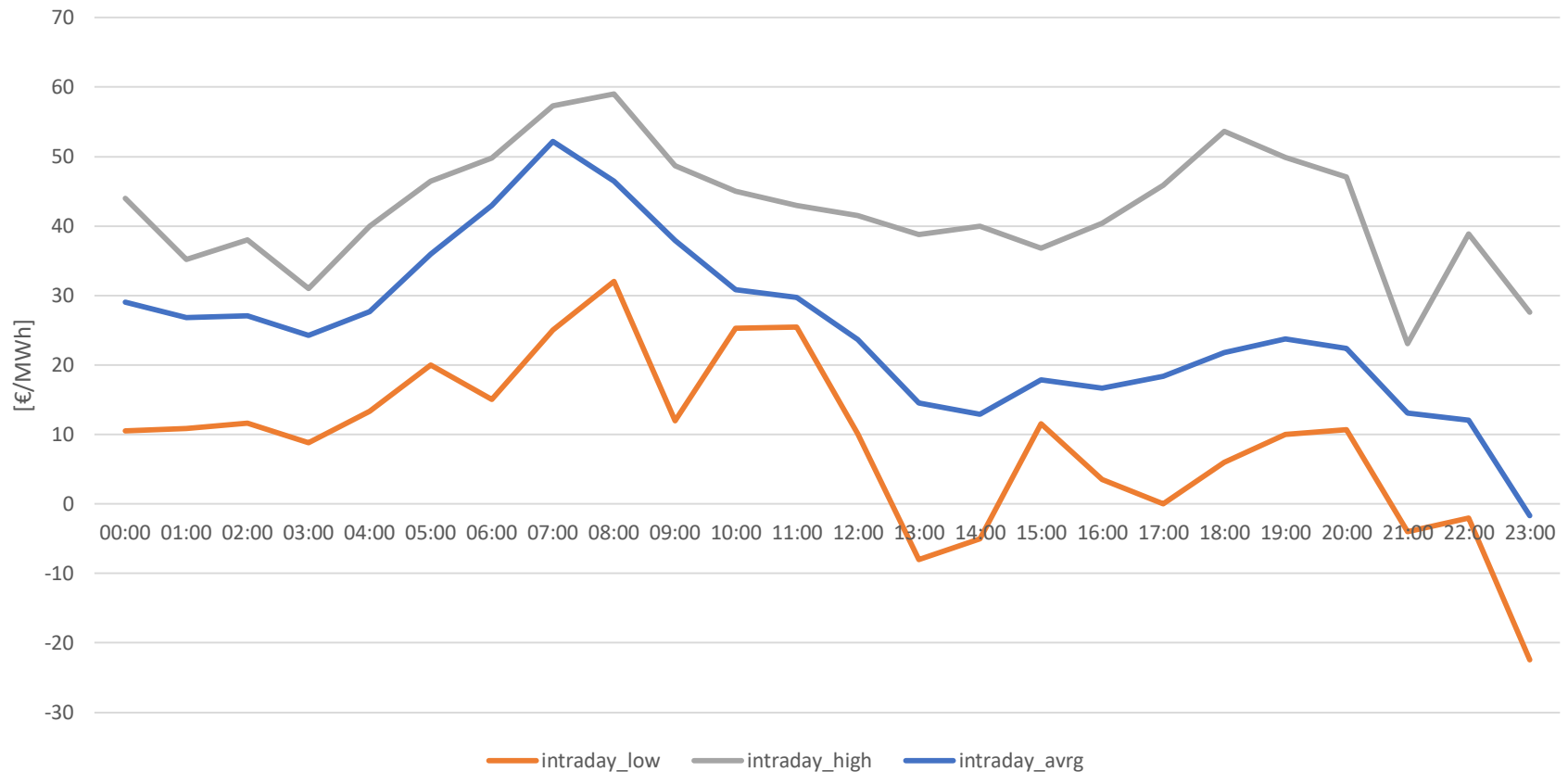
Electricity Price – Fundamental Drivers



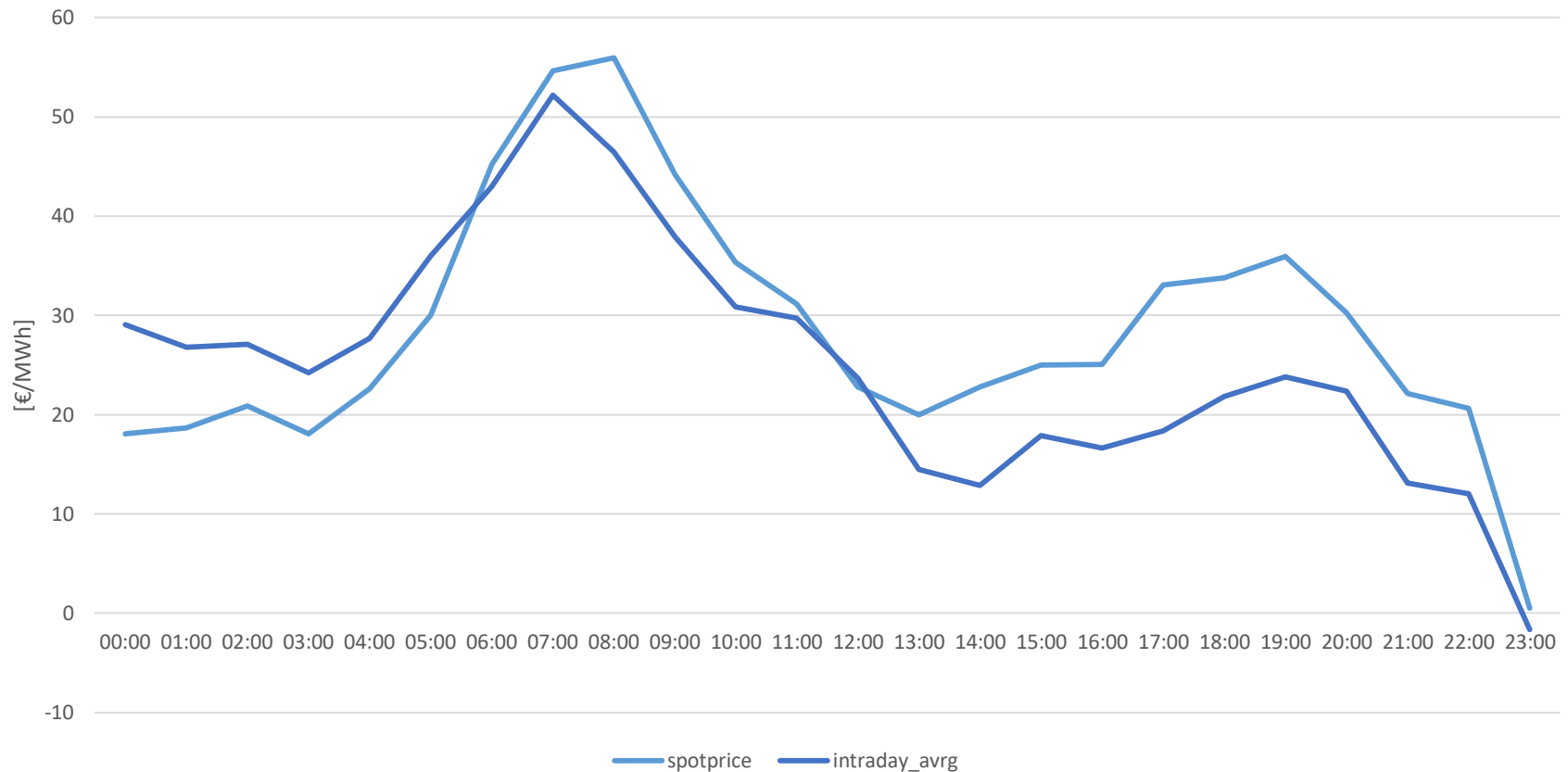
Intraday and Spot Prices 4th of January 2016



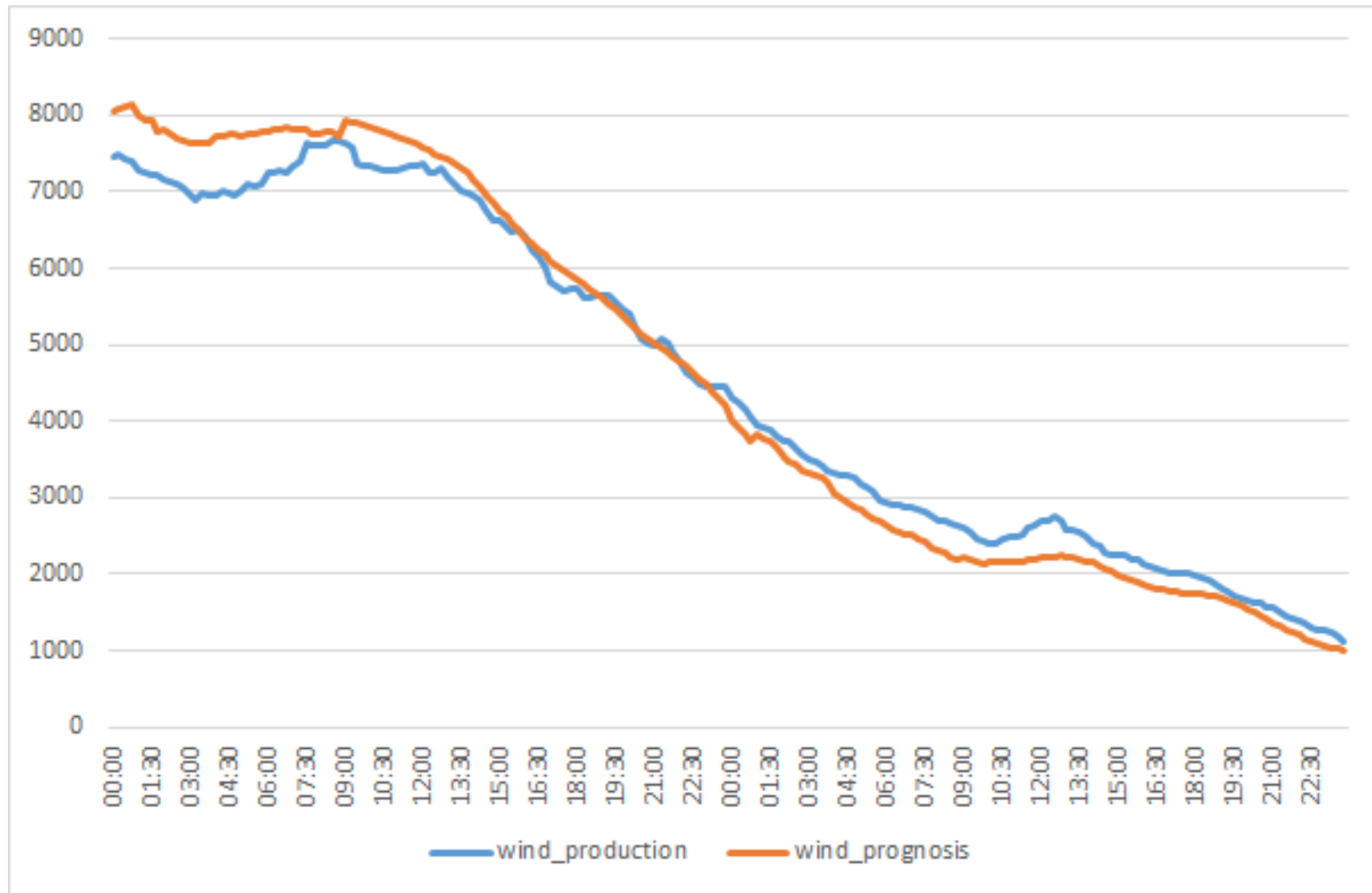
Intraday and Spot Prices 4th of January 2016



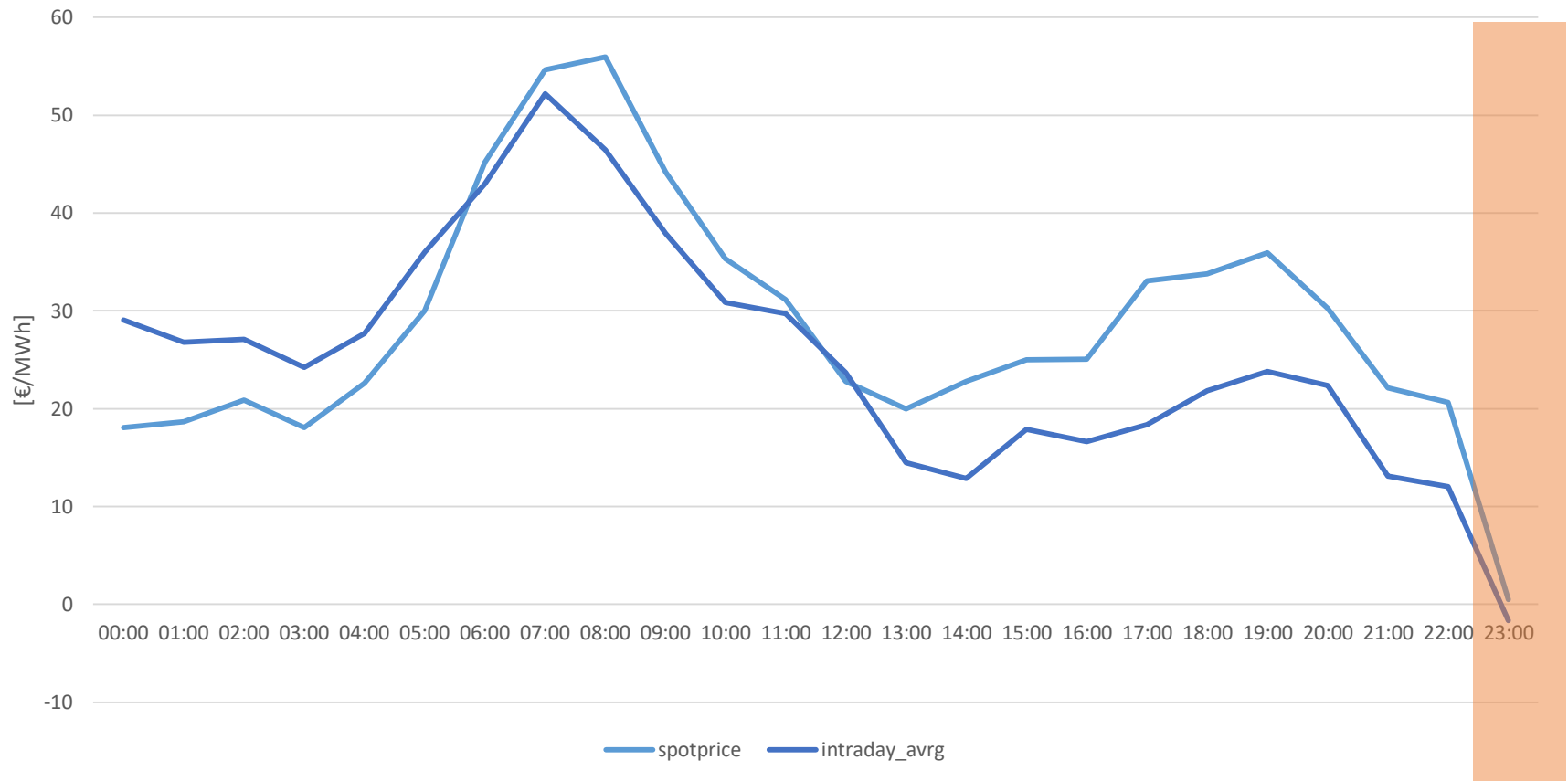
Intraday and Spot Prices 4th of January 2016



Intraday and Spot Prices 4th January 2016



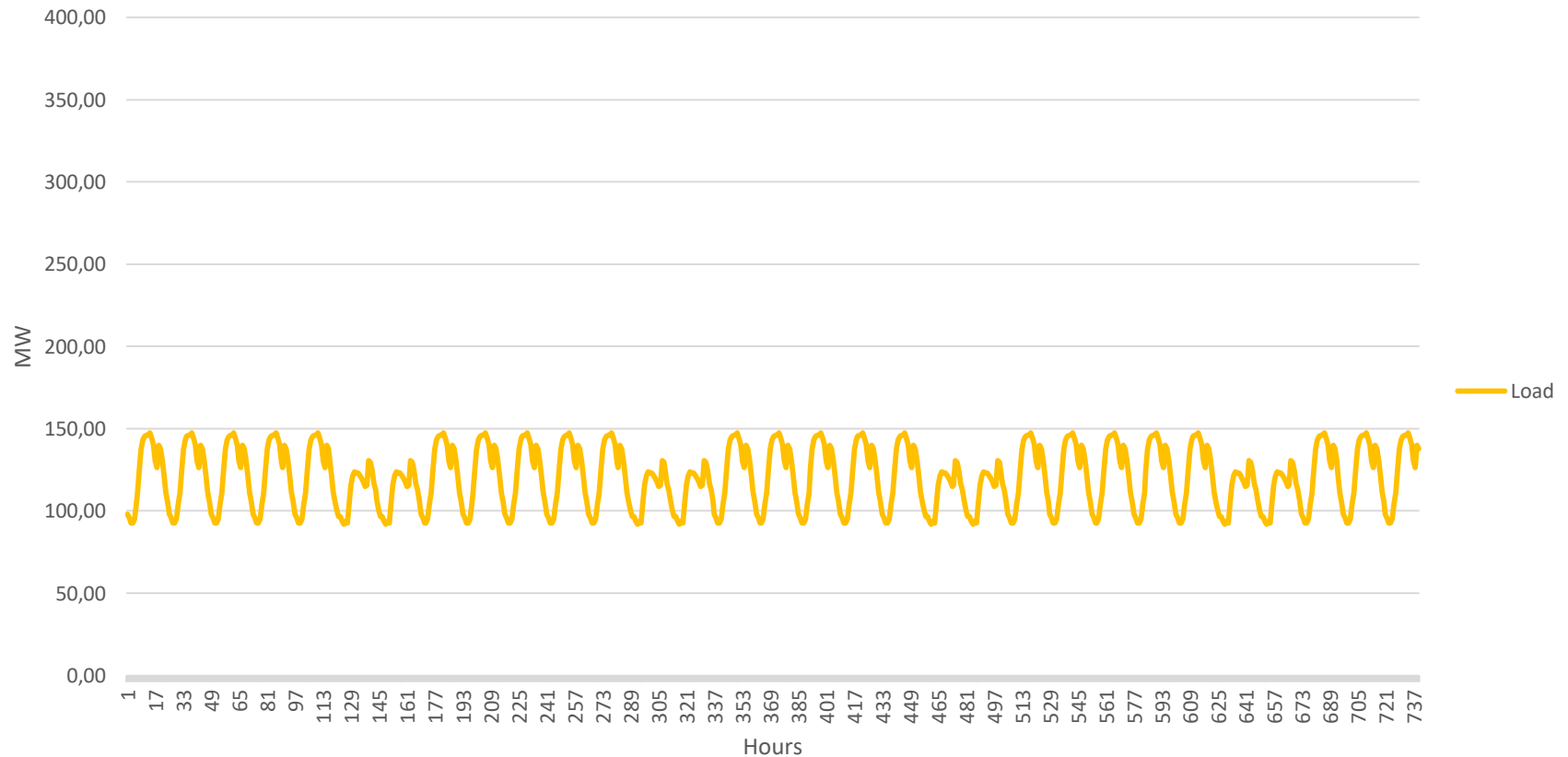
Intraday and Spot Prices 4th of January 2016



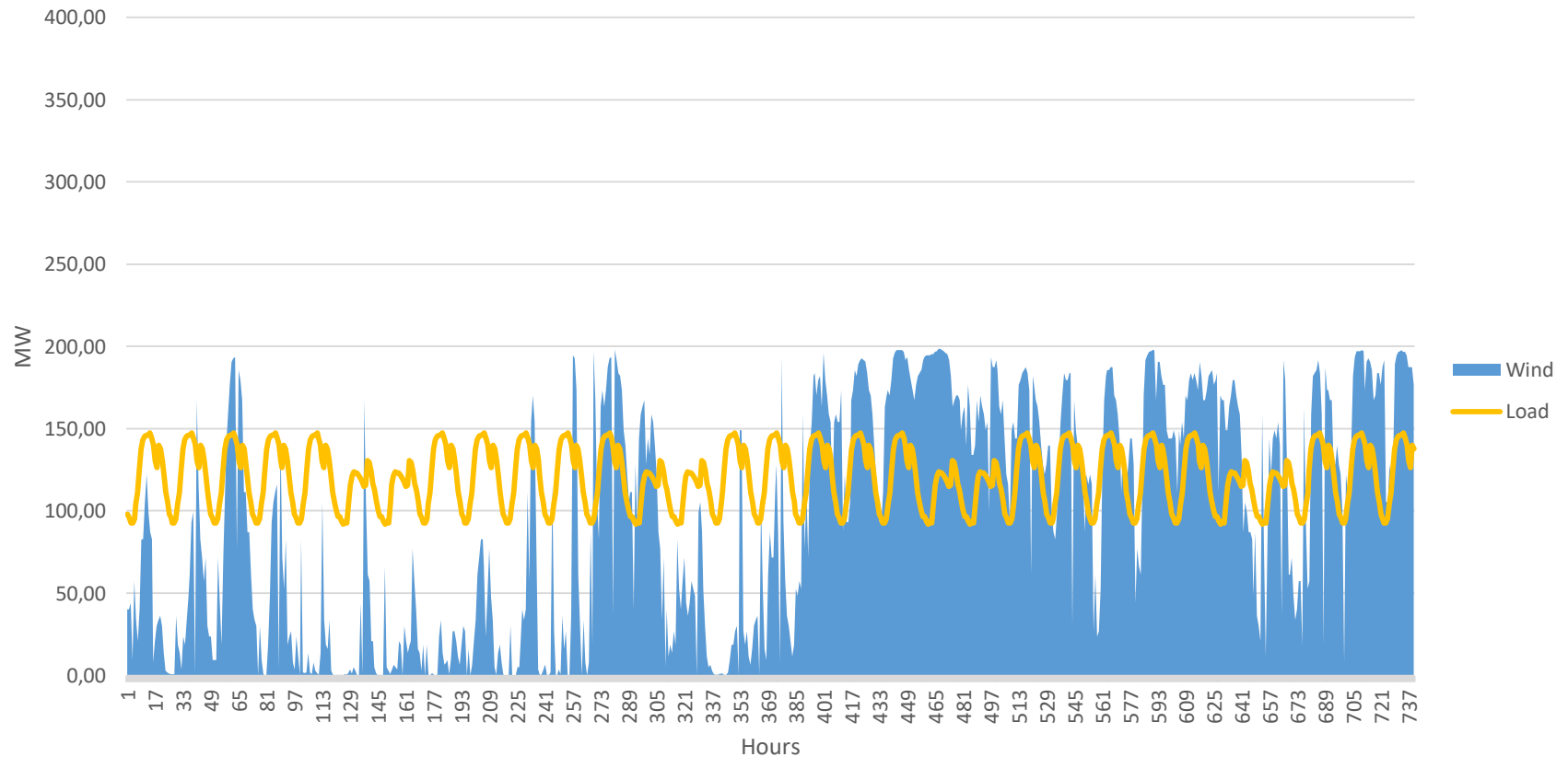
Negative Electricity Prices

- Day ahead market
 - High share of renewables production
 - Low consumption
 - Must run capacity
 - Thermal/flexibility restrictions
 - Bound to physical delivery on other markets
- Intra day market
 - High deviation between day ahead plan and actual generation/consumption
 - E.g. breakdowns, poor forecasting of consumption or generation

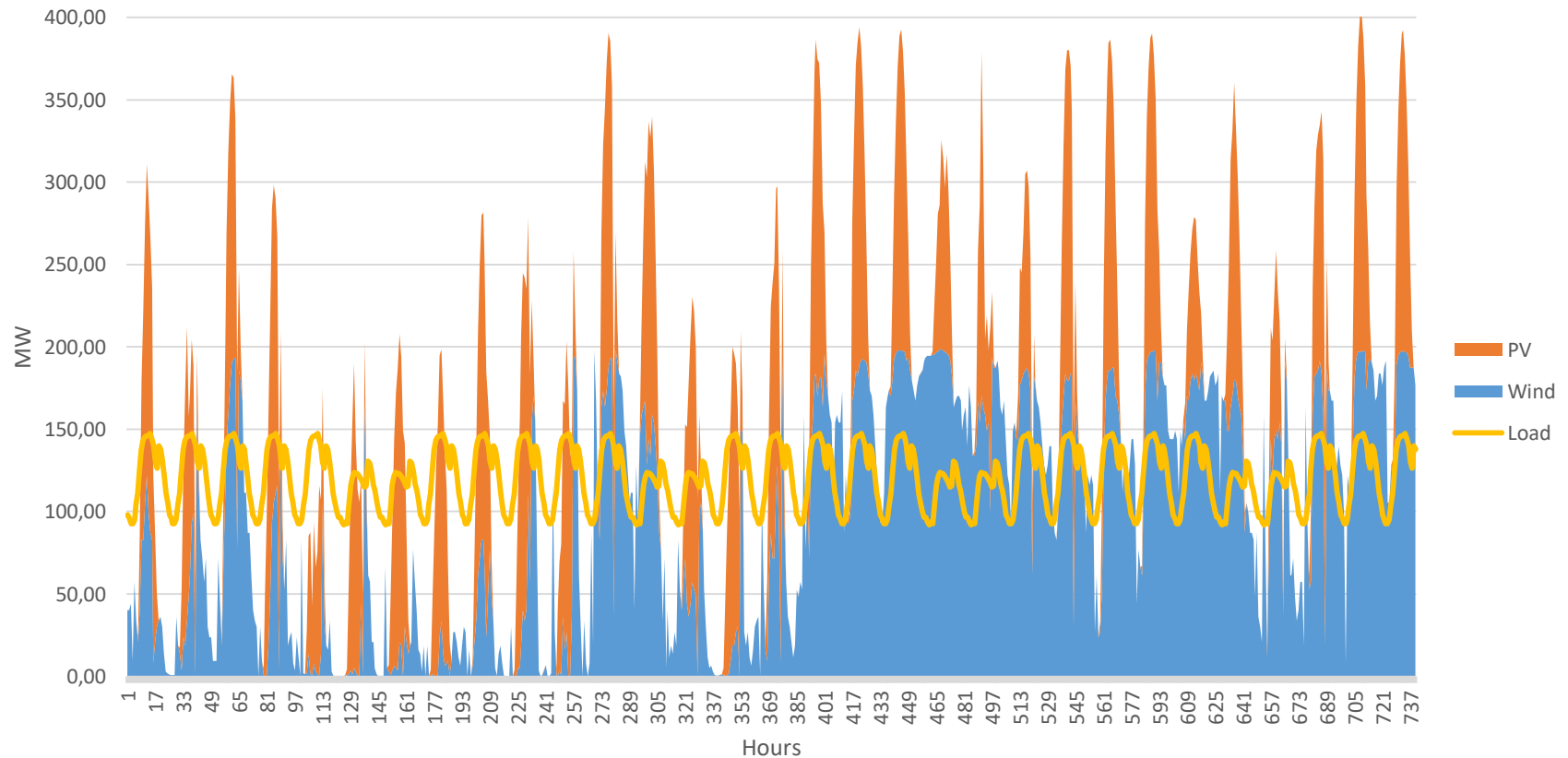
Island Example of 100% Renewables Scenario



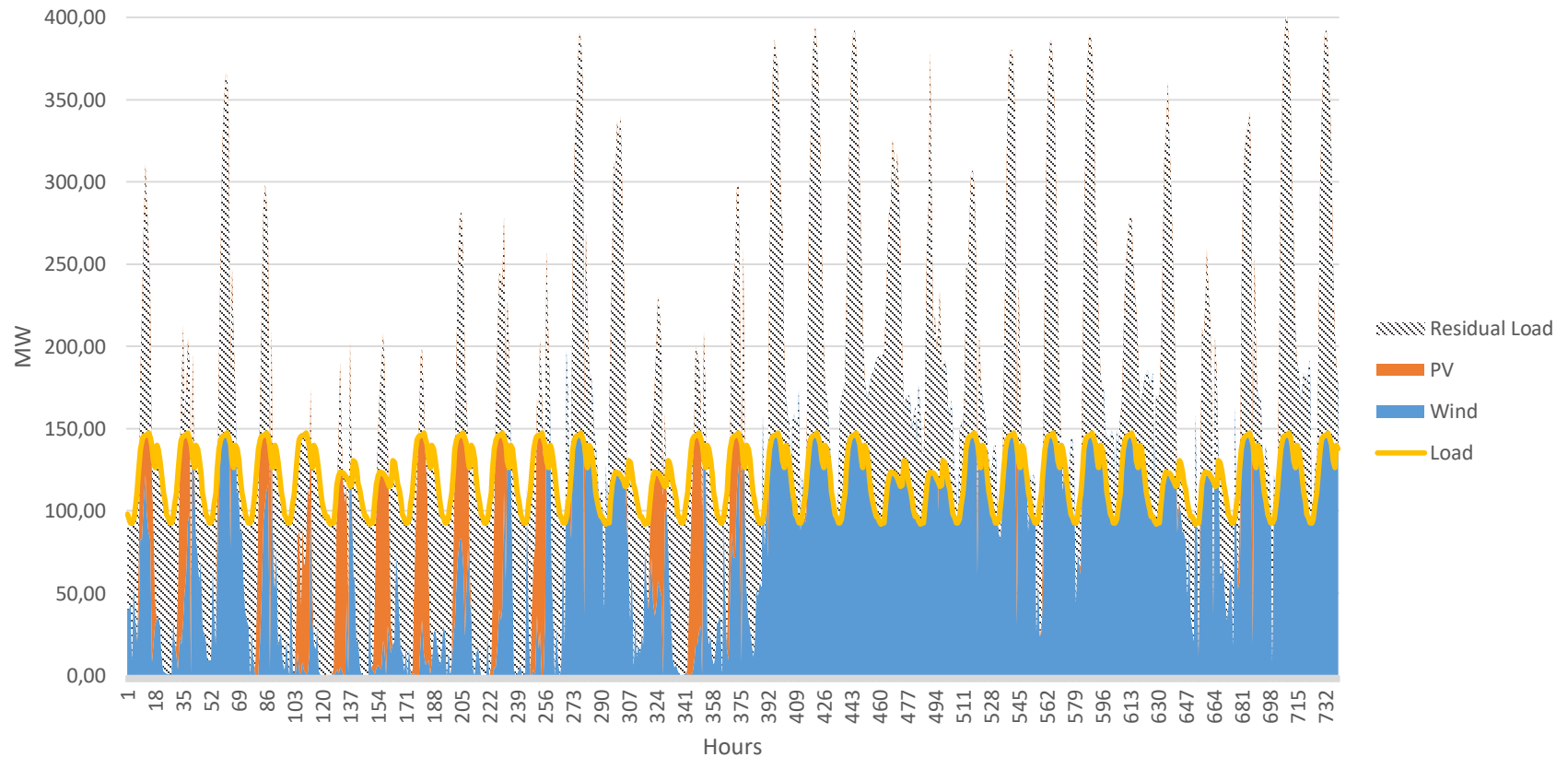
Island Example of 100% Renewables Scenario



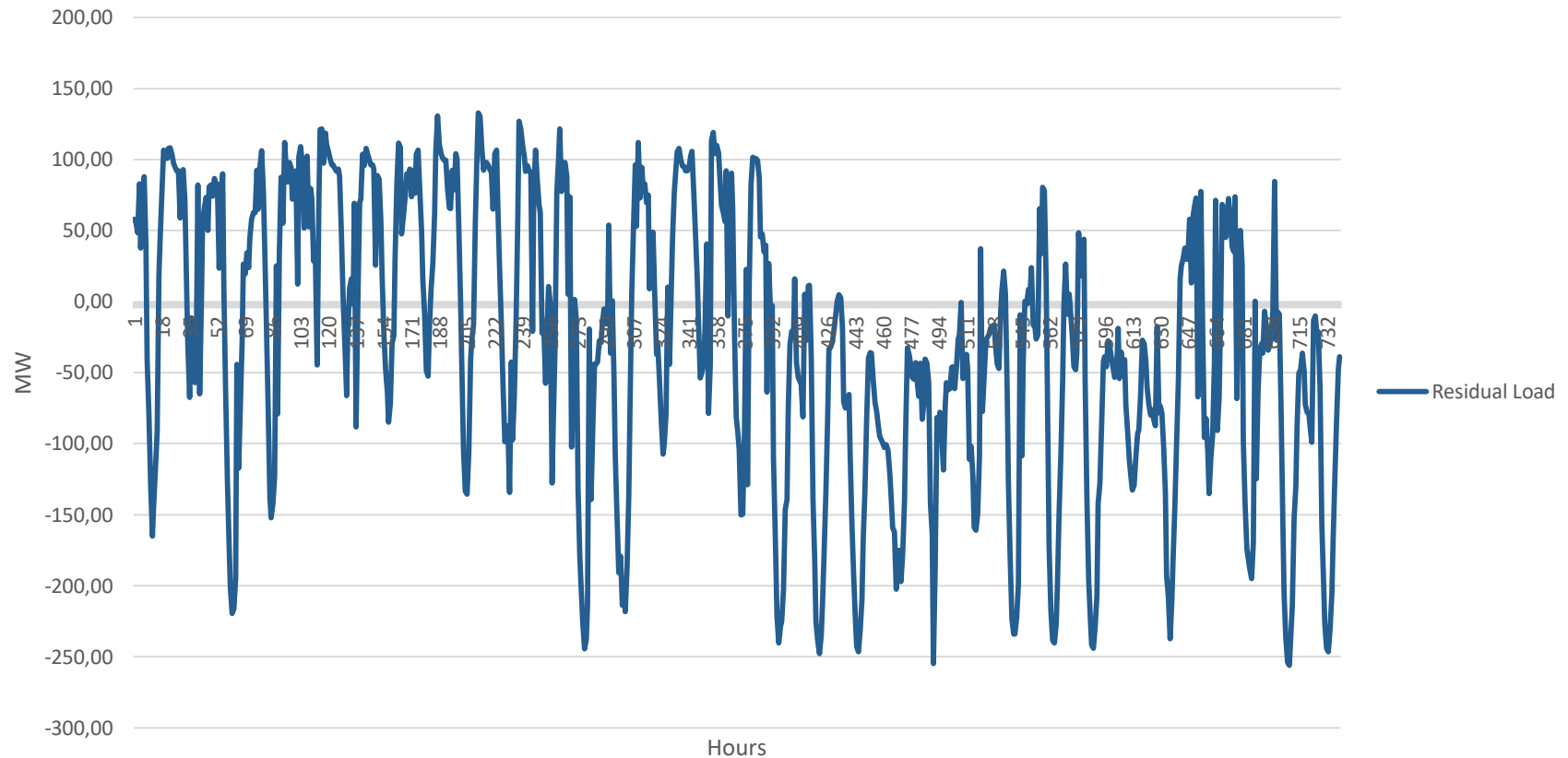
Island Example of 100% Renewables Scenario



Island Example of 100% Renewables Scenario



Island Example of 100% Renewables Scenario

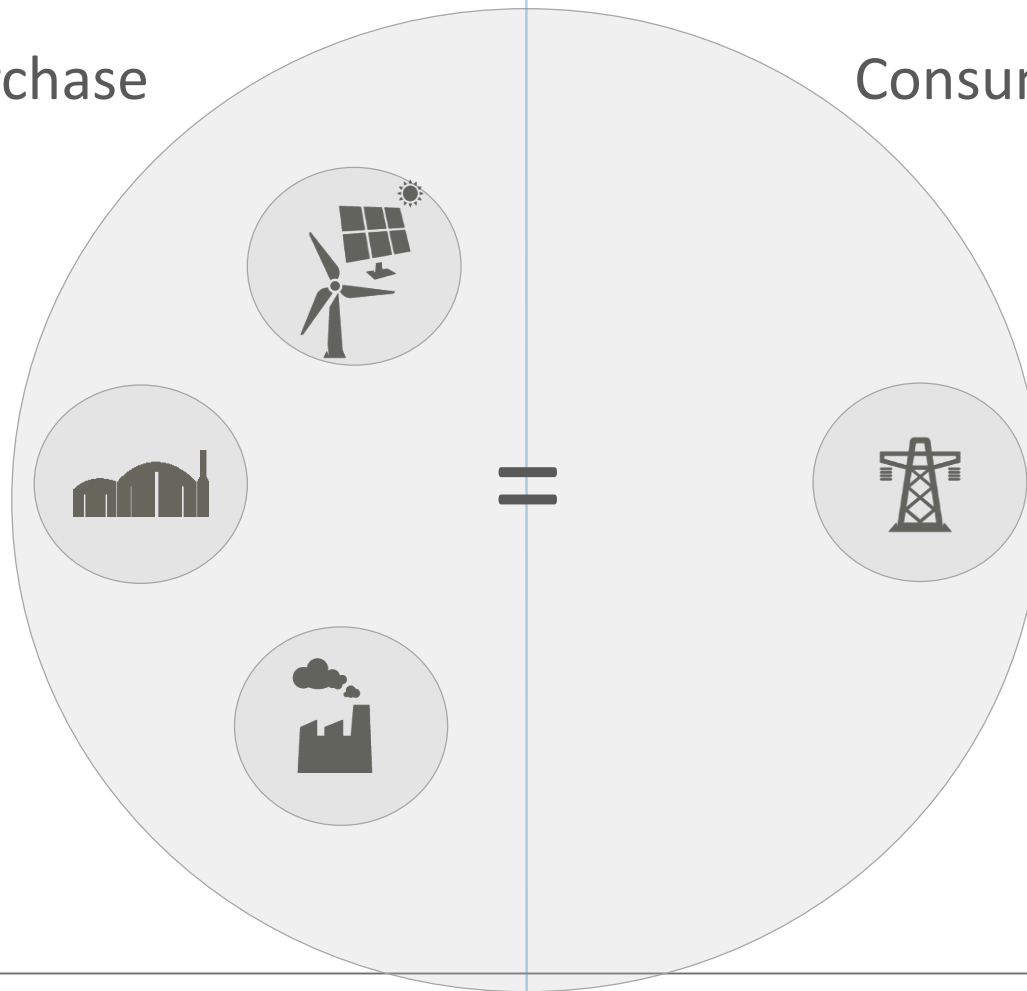


The Principle of Balance Groups

Productio/Purchase

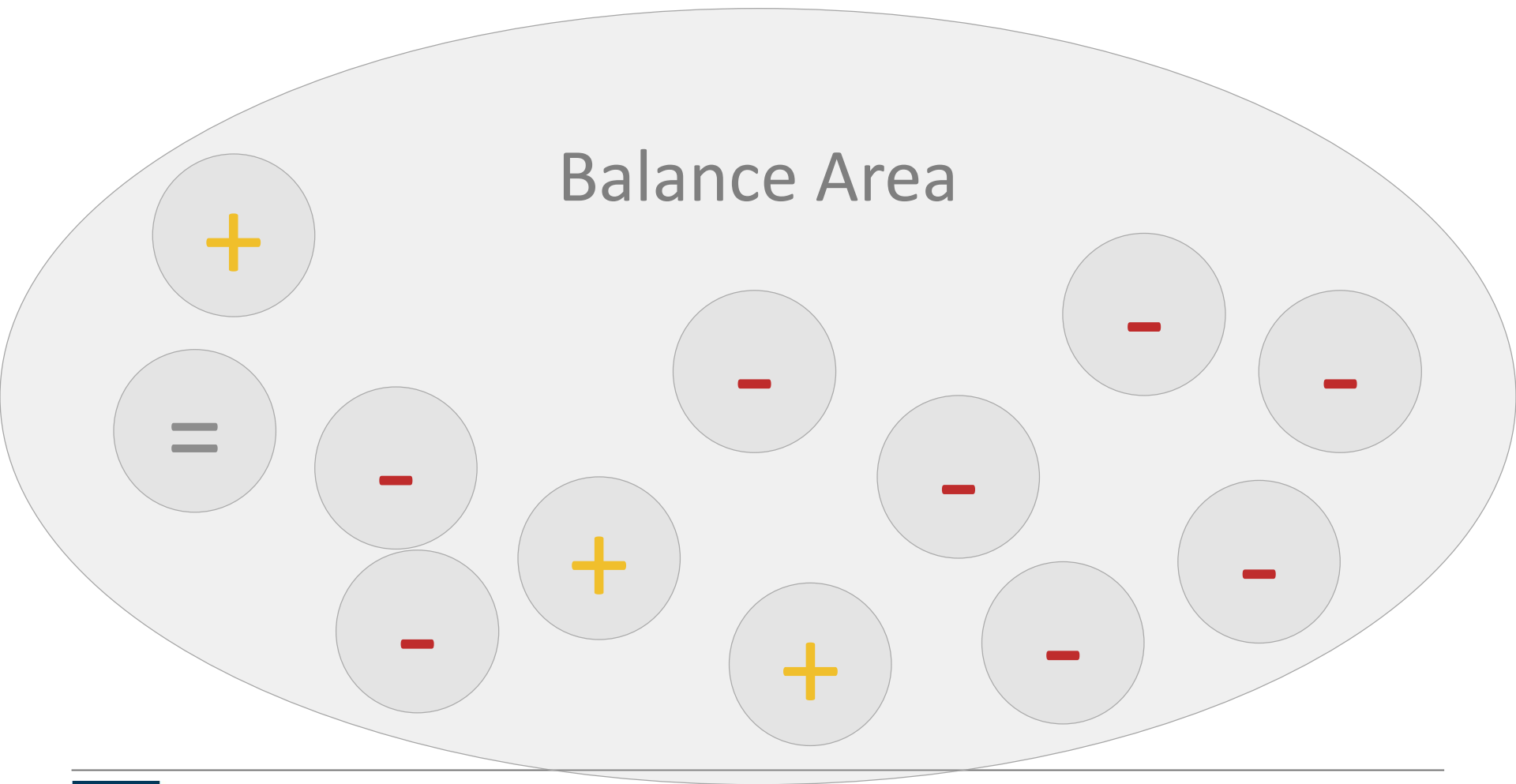
Consumption/Sales

IN

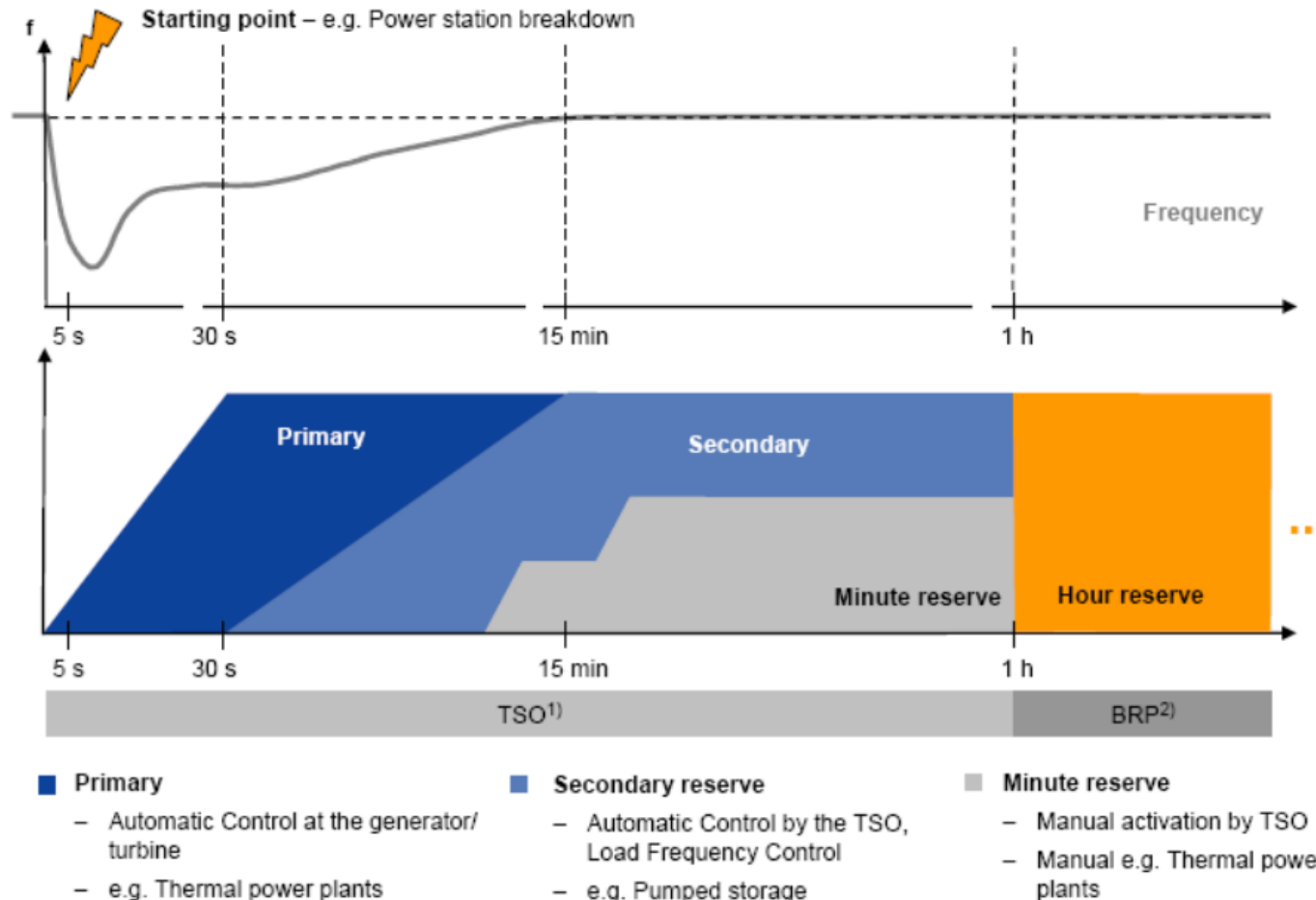


OUT

The Principle of Balance Areas and Groups



Balancing Power Market's

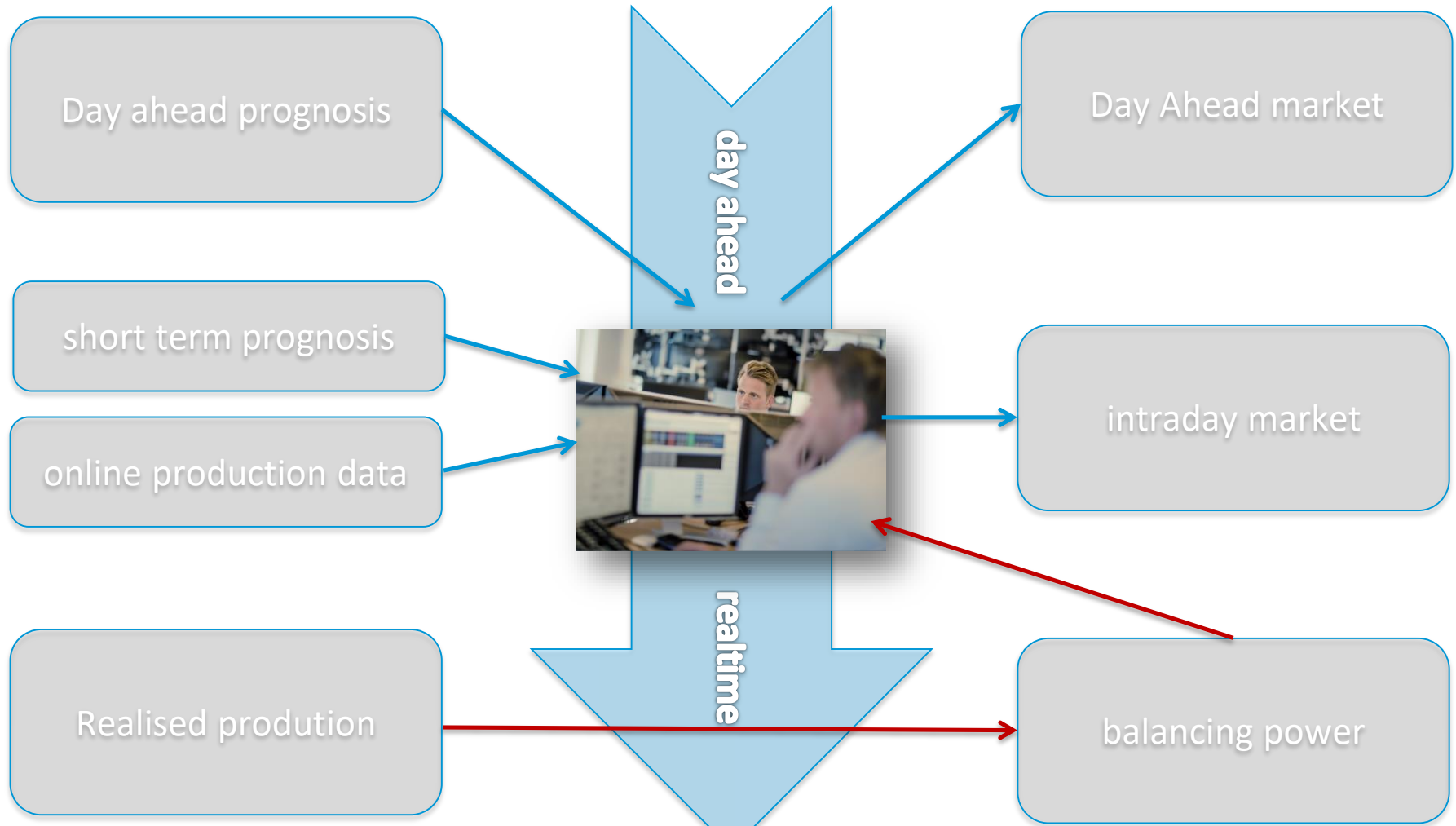


1) TSO: Transmission System Operator

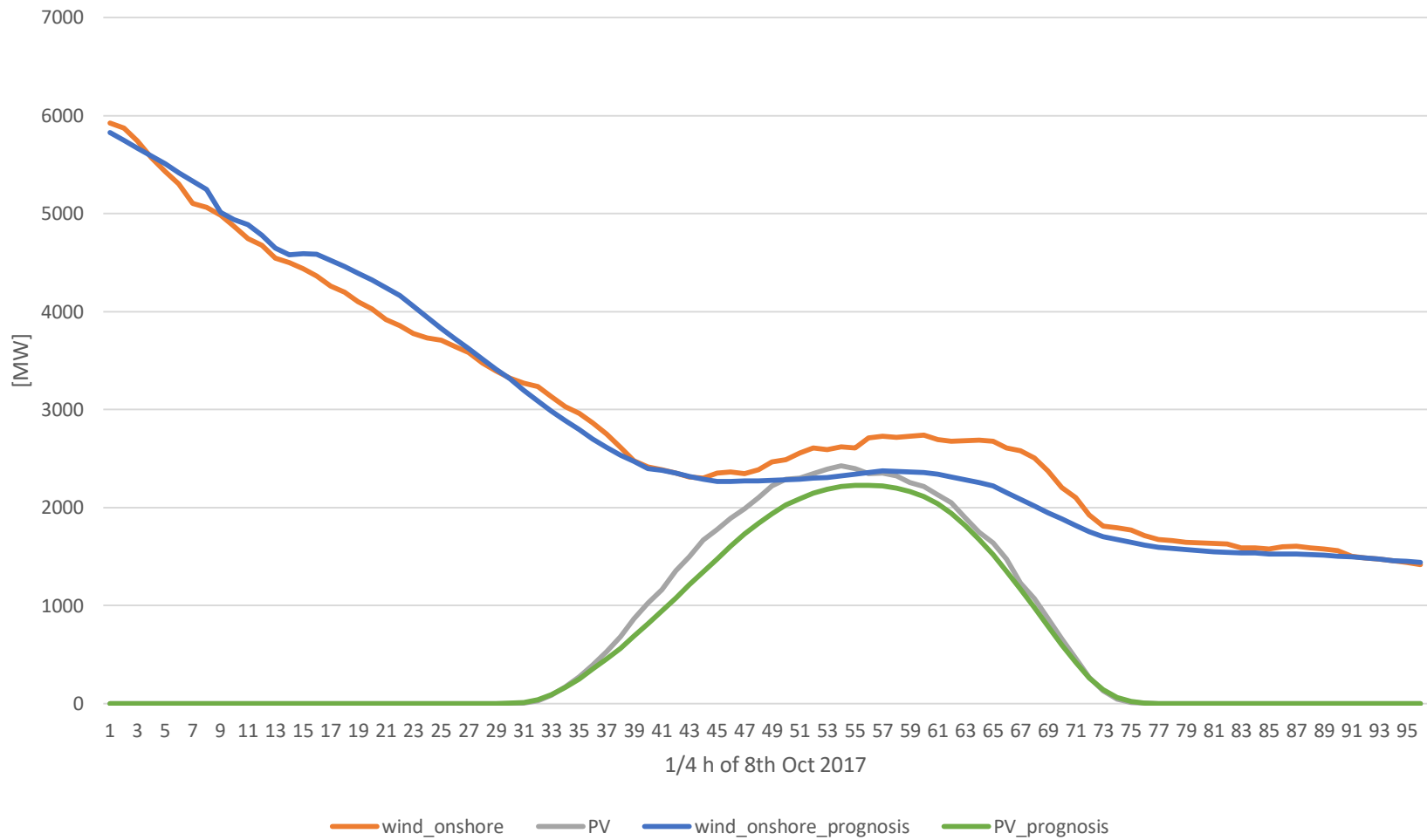
2) BRP: Balance Responsible Party

Source: RWE, URL: <http://rwecom.online-report.eu/factbook/en/marketdata/electricity/generation/balancingpower.html>

Trading Renewable Energies



Prognosis vs. Real Time Production



Electricity Market's

- You are BRP for a small gas power plant which just broke down due to a technical error. What can you do?

Electricity Market's

- You are BRP for several wind parks. It's 12 am and you got a reduction of your 2-3pm forecast of 25 MW. What to do? How will the markets react?

Market Mechanisms

Categorisation of Energy Markets

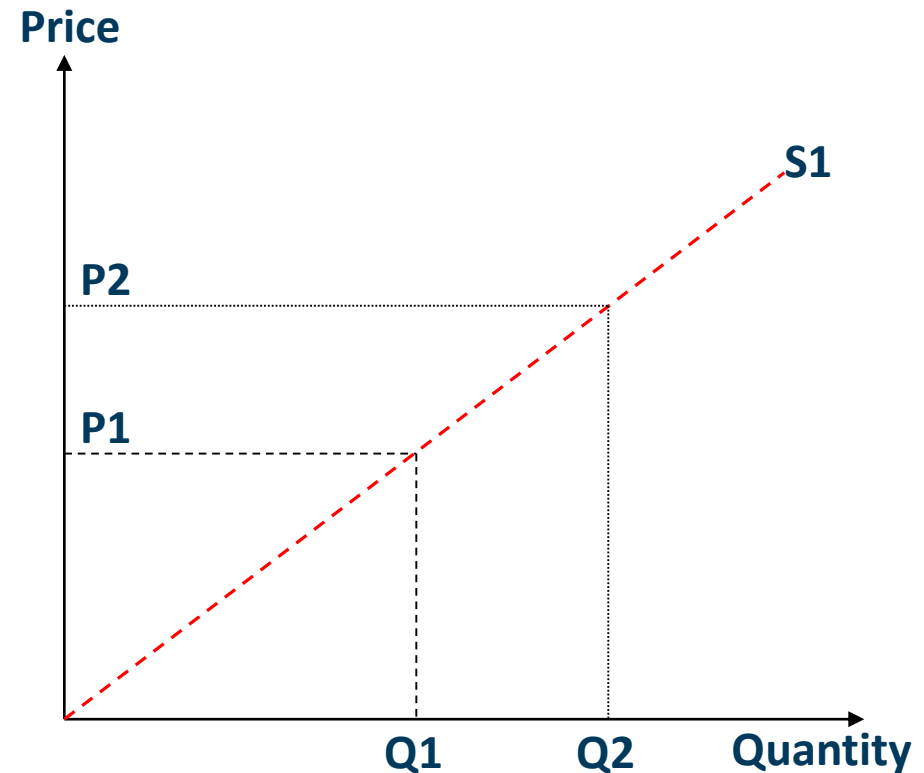
- E.g. Markets by fuel or type of energy
 - coal market
 - electricity market
 - gas market
 - oil market
 - crude oil market
 - wholesale petrol market
 - retail petrol market

Categorisation of Energy Markets

- Markets by type of energy service (customers may not care about the fuel, if the same energy service is supplied)
 - market for mechanical power
 - market for motive power
 - market for light and communication power
 - heat market
 - low temperature heat
 - high temperature heat

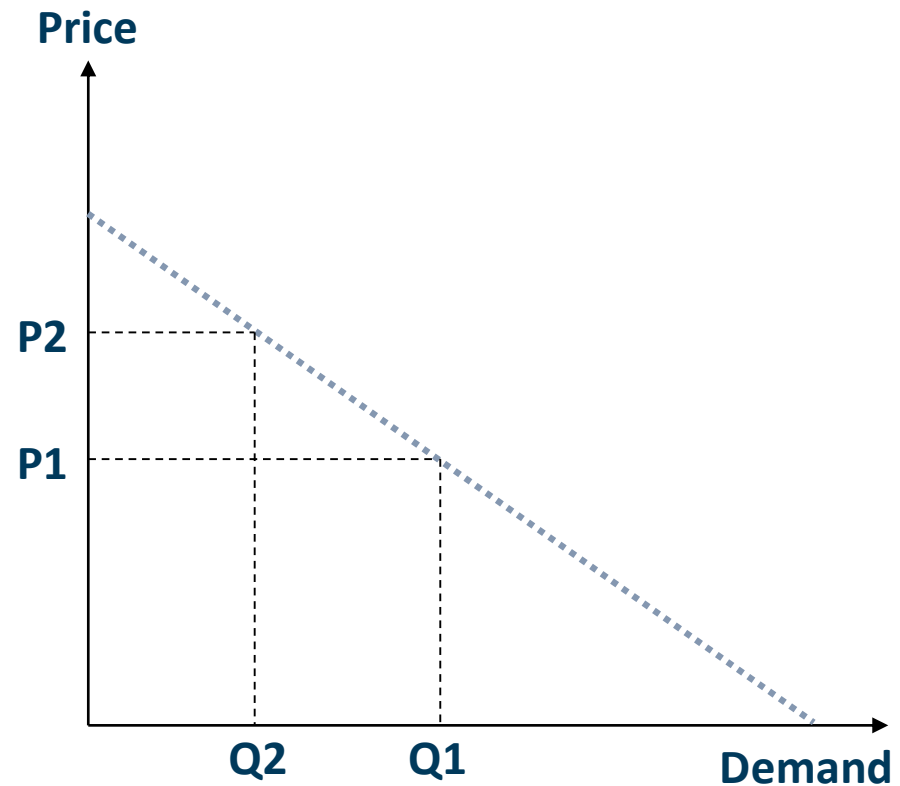
Supply Model

- Relationship between market price and amount of goods produced
- Supply curve is a graphical depiction of a supply schedule plotting price on the vertical axis and quantity supplied on the horizontal axis



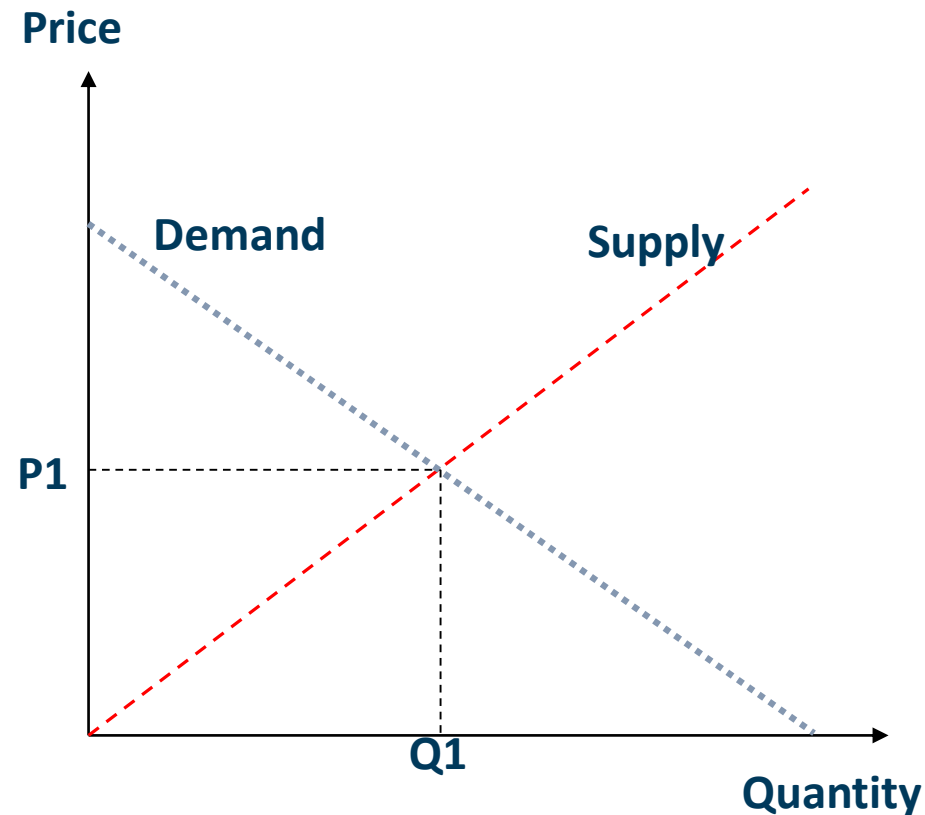
Demand Model

- Demand is the amount of goods and services buyers are willing and able to purchase at a given price over a given period of time
- A demand curve is the graphical representation of a demand schedule, in which quantity demanded is plotted on the X axis and price on the Y axis



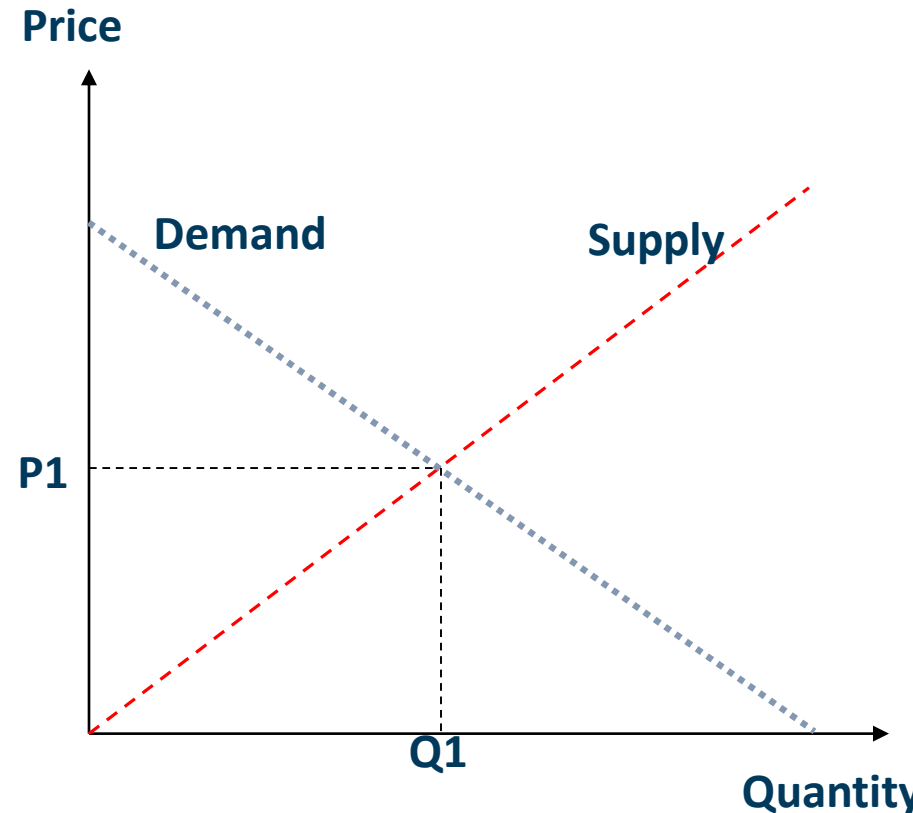
Basic Market Forces

- Supply and demand describes market relations between sellers and buyers for goods and services
- The supply and demand model determines price and quantity sold in a market

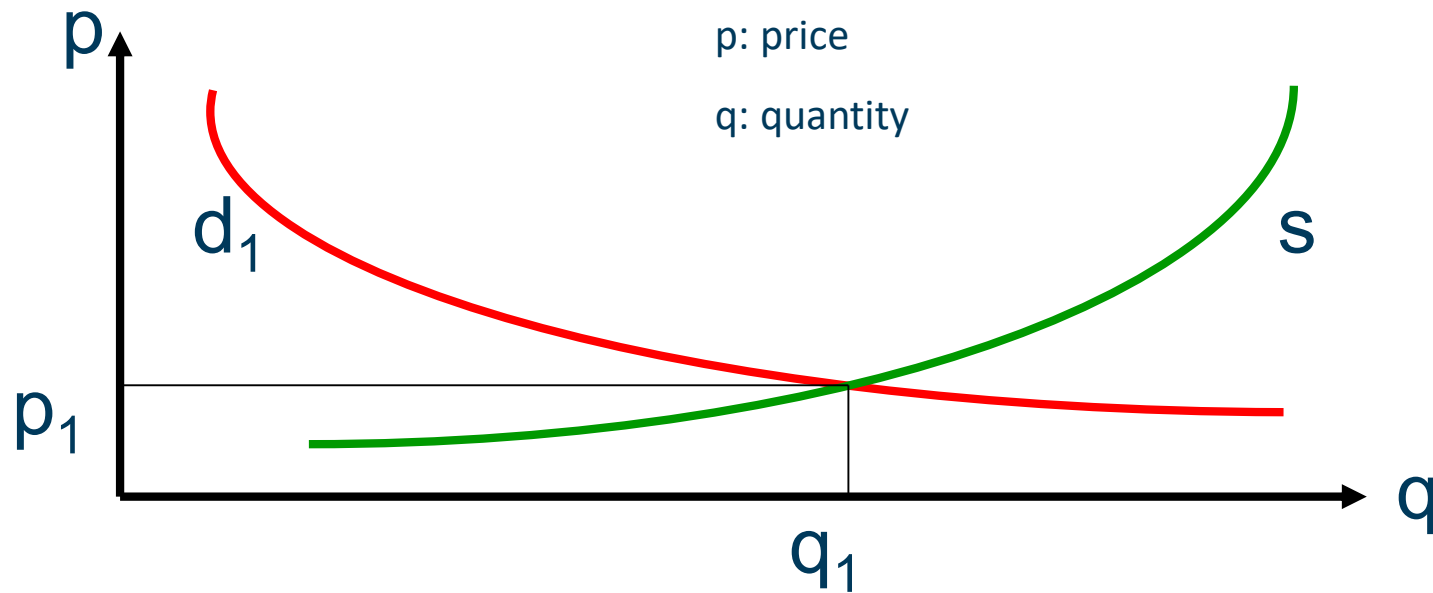


The Price Mechanism

- The price of a product is formed on the basis of supply and demand
- The price is a signal of the relative scarcity of a product
- with a constant structure of supply an increase in demand increases the price
- The market mechanism reconciles supply and demand by price adjustment
- The relative prices of competing goods (coal, oil, gas) guide the demand according to the quantities supplied
- Optimal control by the price mechanism needs perfect competition on the supply and demand side
- Every actor in the market needs to be a price taker (no influence on the price)

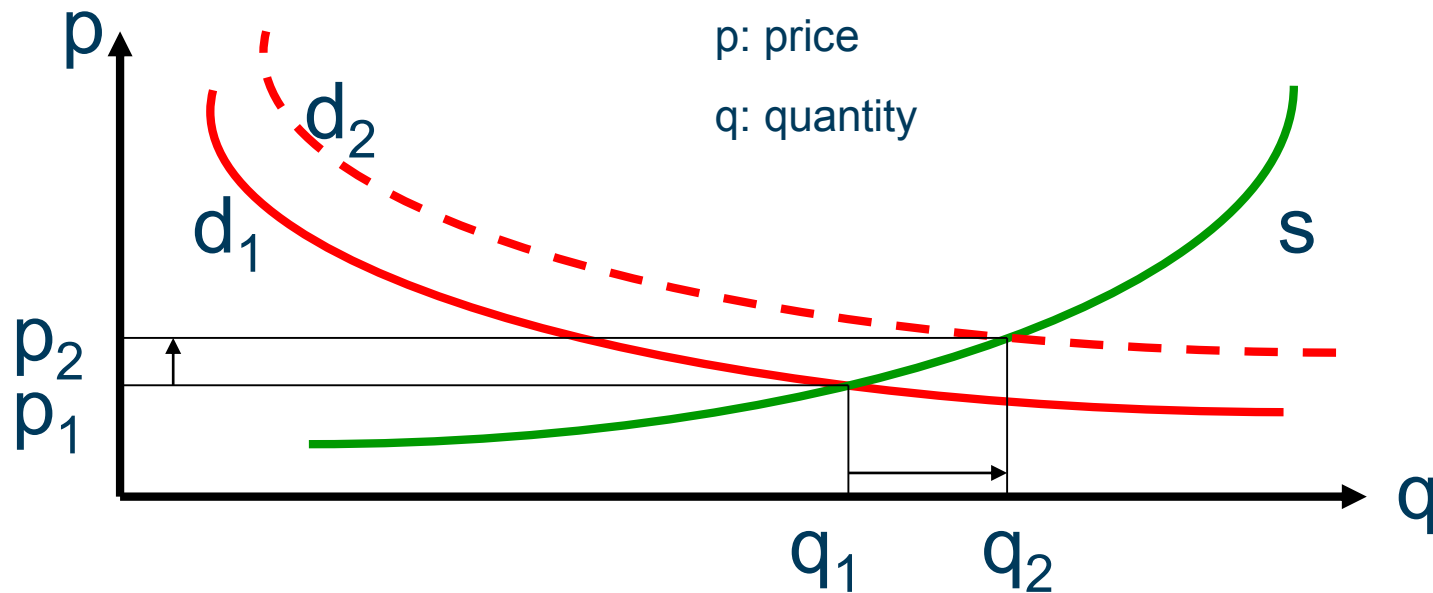


Supply and Demand under Perfect Competition



The price p_1 results from a given supply and demand structure

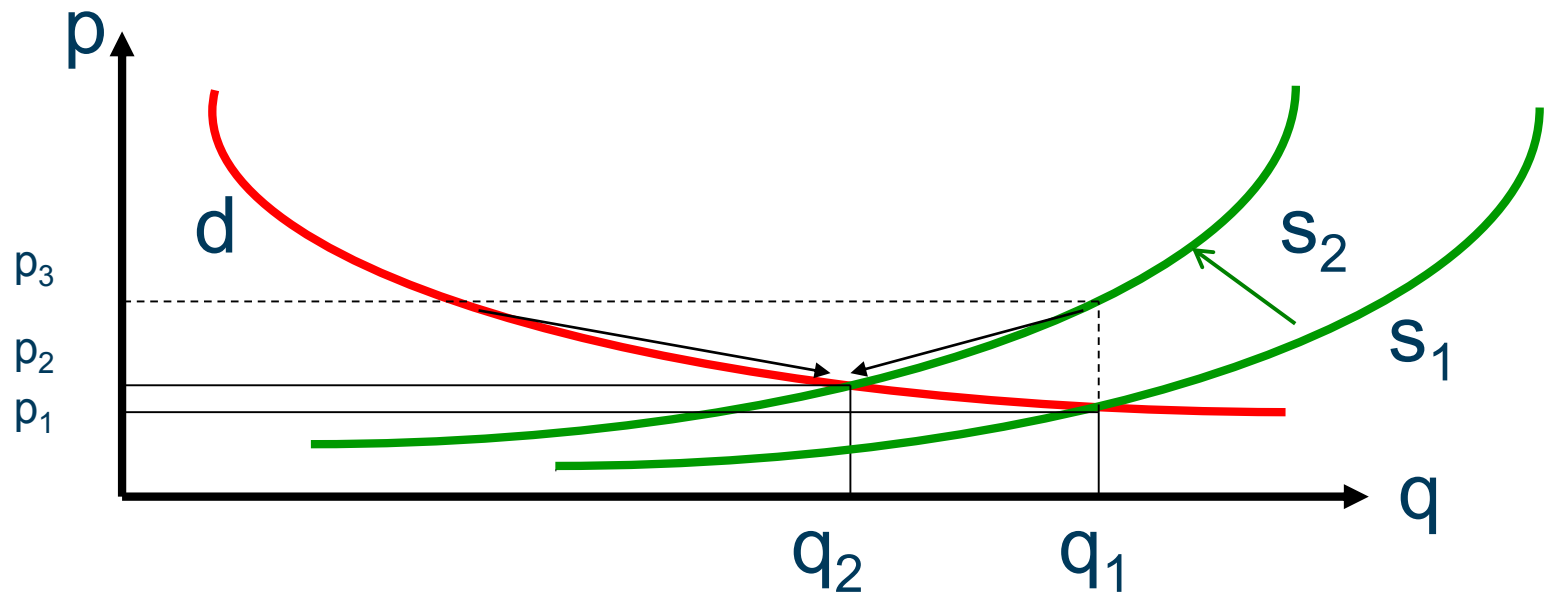
Supply and demand under perfect competition / increasing demand



If the demand rises from q_1 to q_2 the market price rises from p_1 to p_2

Reaction of price and quantity with different elasticities 1.

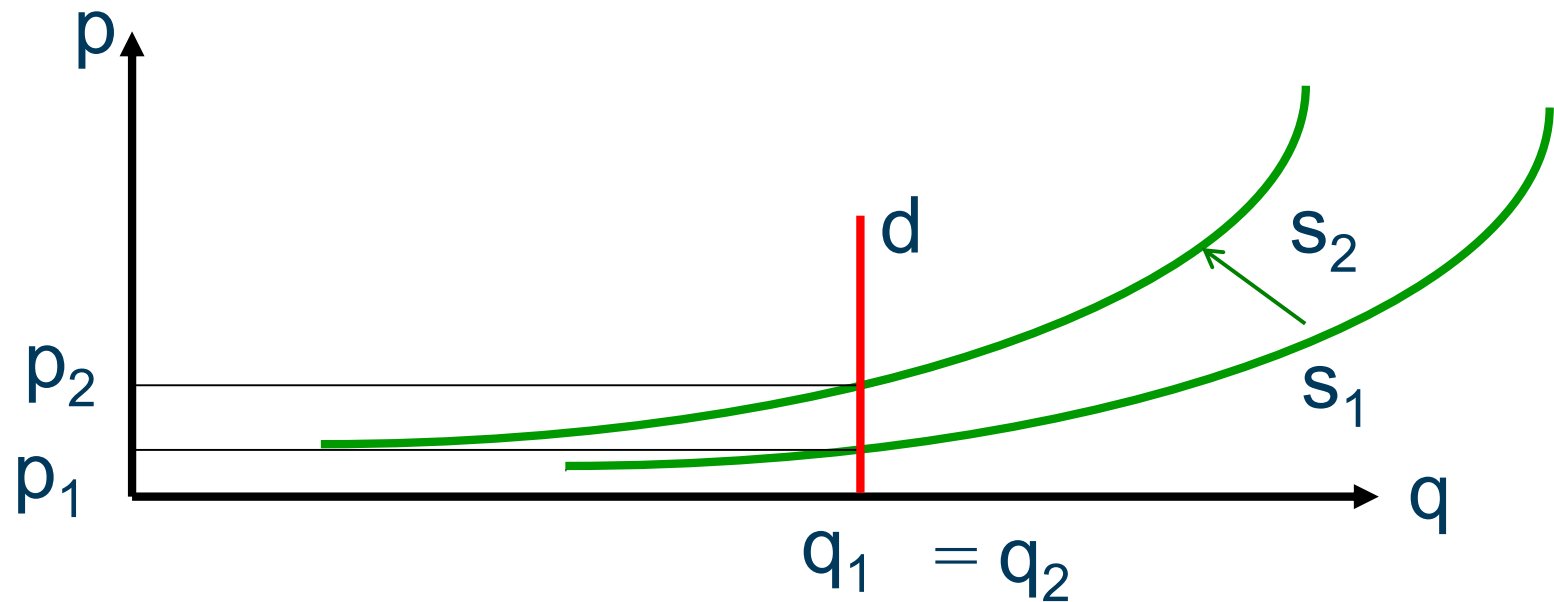
Elastic demand (decreasing supply)



If the supply decrease from s_1 to s_2 demanded quantity drops from q_1 to q_2 and the market prices increases from p_1 to p_2

Reaction of price and quantity with different elasticities

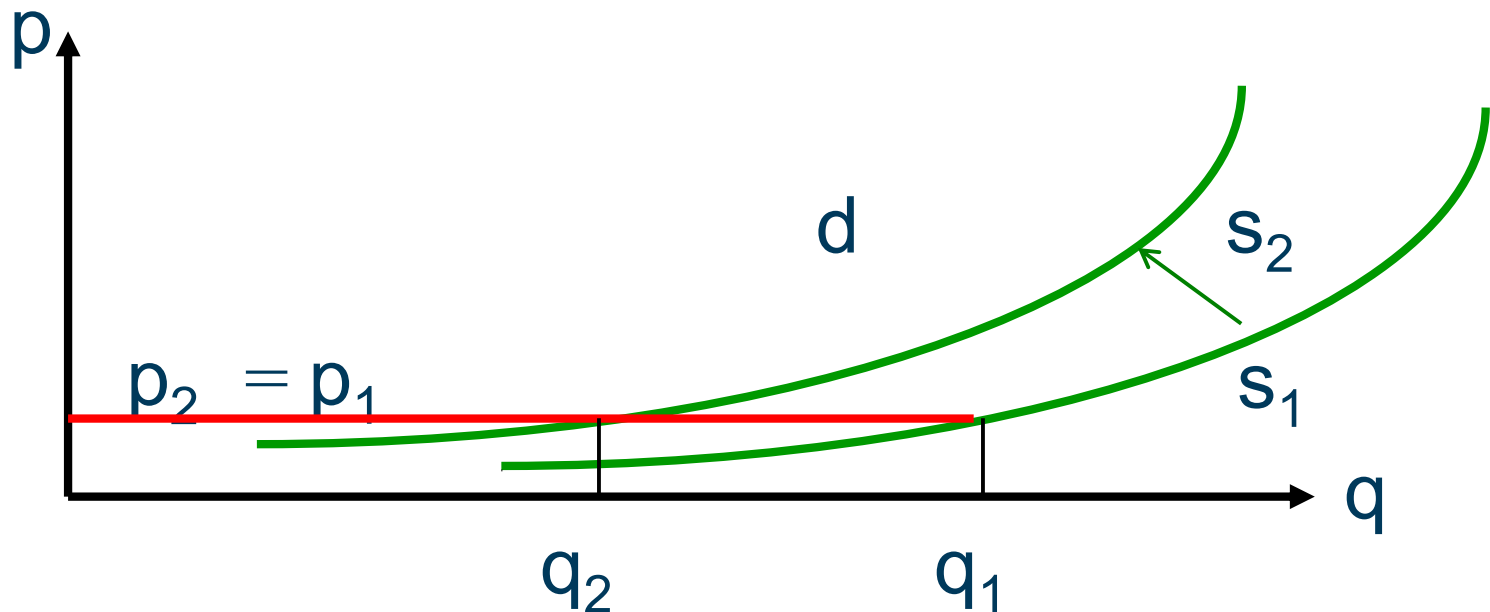
2. Totally inelastic demand (decreasing supply)



If the supply decreases, quantity stays constant (q_1 equal q_2) while the market prices increases from p_1 to p_2

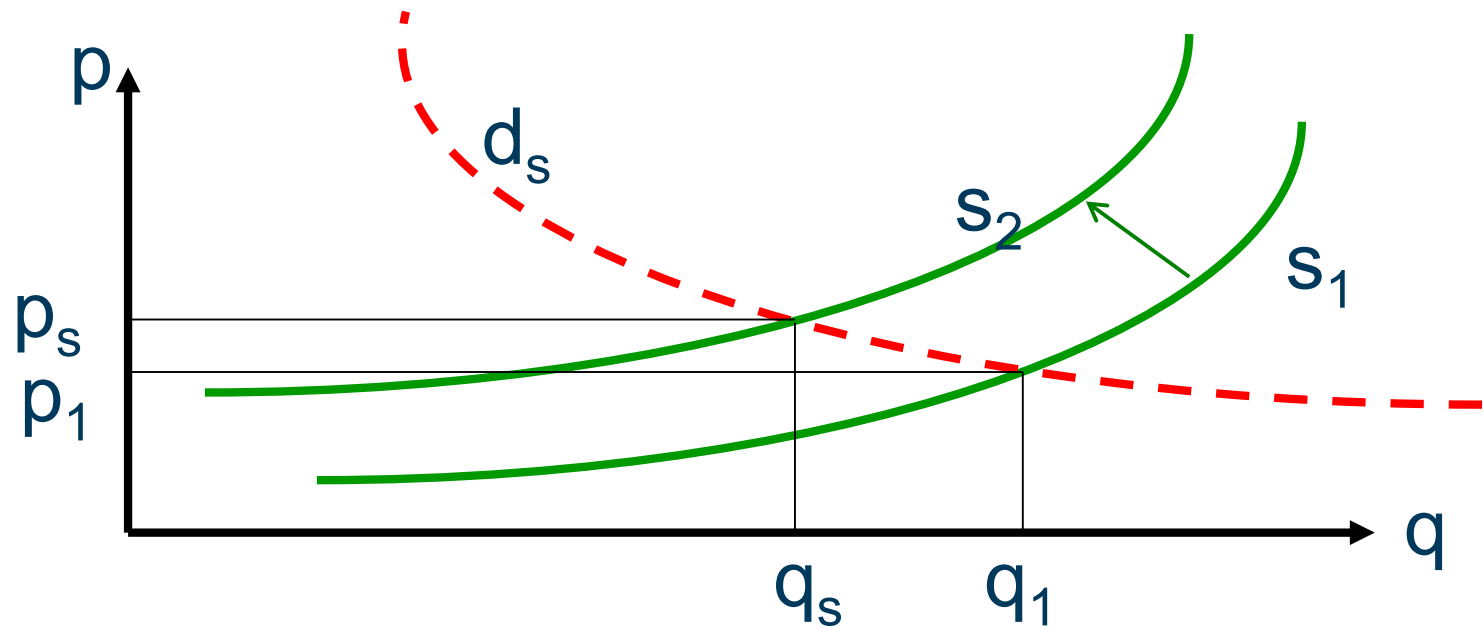
Reaction of price and quantity with different elasticities

3. Totally elastic demand (decreasing supply)



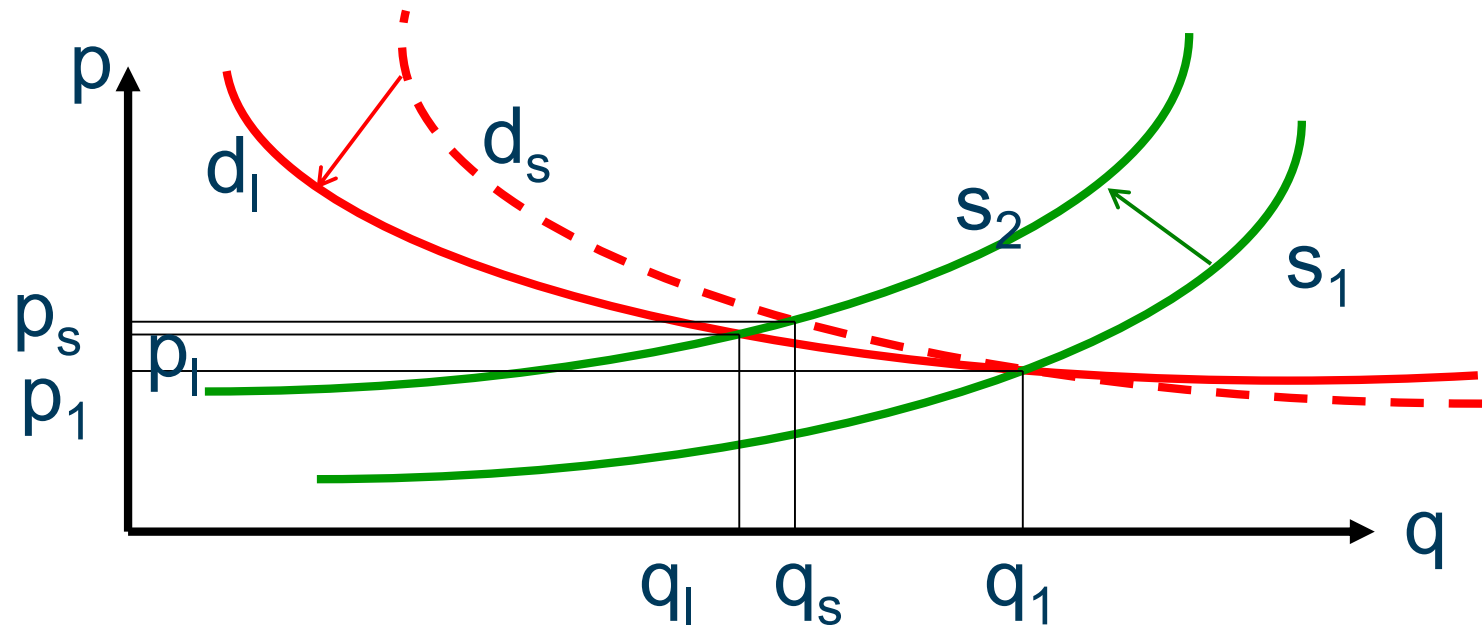
If the supply decreases, quantity drops from q_1 to q_2 while the market price remains unchanged ($p_1 = p_2$)

Short term elasticity of demand (decreasing supply)



A reduction in supply leads to a limited reduction of demand and to a relatively high price increase.

Difference between short and long term elasticity (decreasing supply)



Long term demand is more elastic. Thus, a price increase due to a shift in supply leads to greater reductions in quantity demanded q_l and to a lower price p_l increase as due to short term elasticity (q_s and p_s).

Types of Markets

Three basic types of markets:

- perfect competition (many suppliers or buyers)
 - no control over prices
- oligopoly (few supplier or buyers)
 - strong impact on market prices
- monopoly (one supplier or buyer)
 - able to set market price according to internal cost structure to maximise profits

Reasons for few suppliers:

- ownership of resources
- barriers to market entry (high capital costs for smallest production plant, economies of scale)
- natural monopolies or political monopolies (concession areas)



Monopoly

Monopoly - A market form in which a single company or group owns all or nearly all of the market for a given type of product or service.

- Characteristics:
 - **Profit Maximiser:** Maximizes profits. Price higher than cost of last unit produced.
 - **Price Maker:** Decides the price of the good or product to be sold.
 - **High Barriers to Entry:** Other sellers are unable to enter the market of the monopoly.
 - **Single seller:** In a monopoly there is one seller of the good that produces all the output.
 - **Price Discrimination:** A monopolist can change the price and quality of the product depending on the elasticity of the market.

Monopolies need to be regulated or broken up!

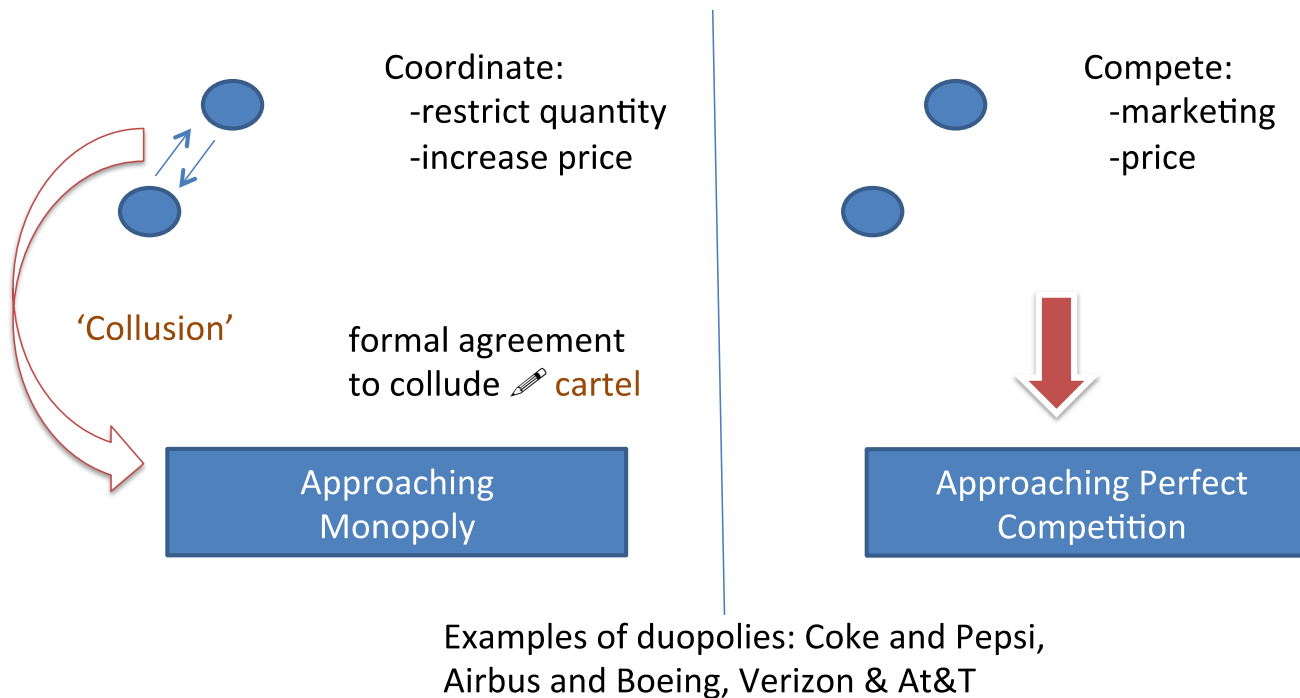


Types of Monopolies

- **Natural Monopoly** – if the least cost solution for the production is always a single supplier
 - E.g. sewage systems, electricity grids, telecommunication grids, roads.
- **Geographic Monopolies** - occur when there is only one company that offers a particular good or service in an area.
 - Because of the small size of the area, it may not be financially feasible for another company to come in - if the profits were split neither business would make money.
- **Government-granted Monopoly** - government grants exclusive privilege to a private individual or company to be the only provider of a commodity.
 - Electricity suppliers in non liberalized markets

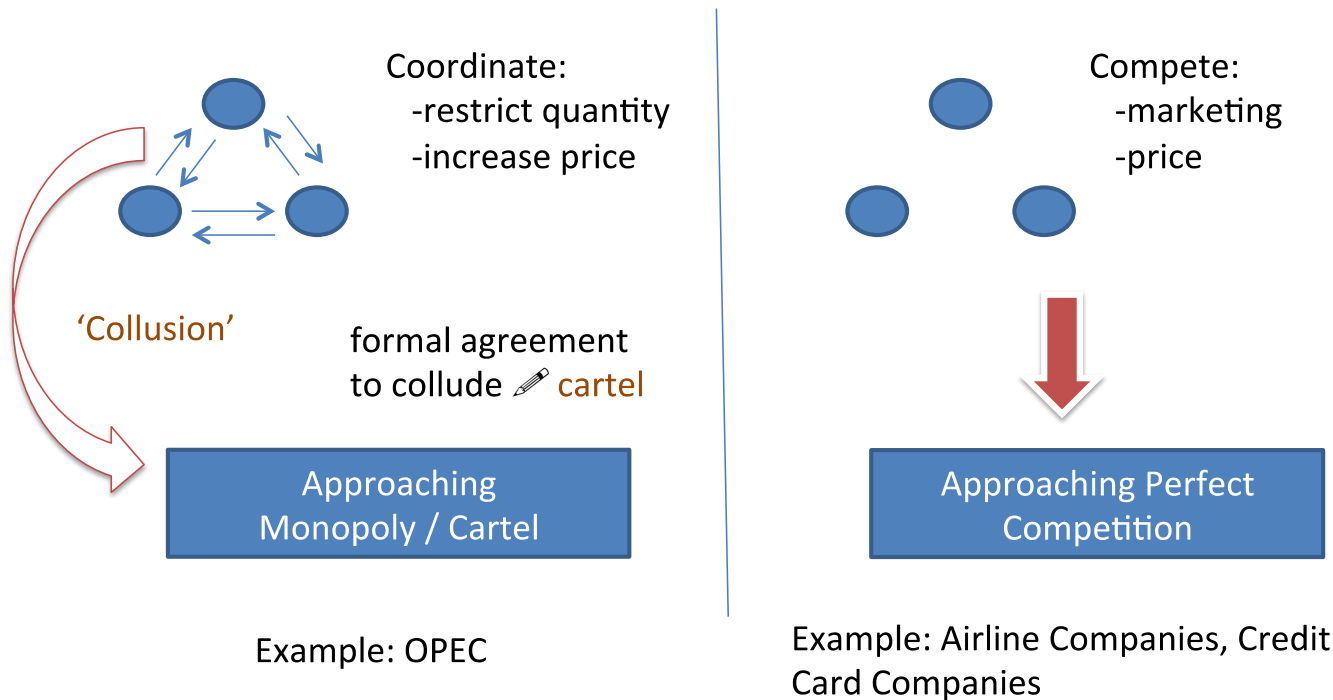
Duopolies

- is a market form in which a **market is dominated** by two **sellers**.



Oligopolies

- is a market form in which a **market is dominated** by a **small number of sellers** (oligopolists).



Organisation of Petroleum Exporting Countries (OPEC)

- OPEC is an intergovernmental cartel organization of twelve oil-producing countries which was founded 1960.
- Hosts regular meetings among the oil ministers of its Member Countries.
- Attempt to control world crude oil prices well above competitive prices since the 1970es by setting production quota for each member state.
- OPEC members collectively hold 79% of world crude oil reserves and 44% of the world's crude oil production capacity, affording them some control over the global market (2012).
- Problem of leakage of quota by some states.



- OPEC's 12 member countries'



Competitive Markets

In order to have a competitive market we need perfect competition

Perfect competition:

- Many buyers and many sellers
- All firms have a relatively small market share
- All firms are price takers (no impact on the price level)
- All firms sell an identical (homogeneous) product
- Low-entry and exit barriers
- Buyers know the nature of the product being sold and the prices charged by each firm (Perfect Information)
- No externalities in production and consumption

Conclusion

- Energy markets are increasingly globalised and highly connected to global political, economical and social developments
- The understanding of energy markets is crucial to estimate long term developments and therefore for smart development of the energy system
- Depleting Reserves are continuously increasing the need for renewable energies even though short term factors are influencing the current energy prices
- Liberalisation of (electricity) markets including physical power exchange adds competition, transparency and investment signals to a market

Thanks for your attention!

