



# **ELECTRICITY MARKETS AND THE ROLE OF RENEWABLES & NUCLEAR**

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Praha, 31.1.2023

- 1. Introduction**
- 2. How prices come about (theory)**
- 3. How prices developed in Europe**
- 4. Environmental issues: CO<sub>2</sub>-prices**
- 5. Electricity generation costs**
- 6. Recent developments of nuclear**
- 7. The role of Renewables**

# OUR LIFE: PERMANENTLY UNDER



# ELECTRICITY

Electricity – THE universal technology for  
providing energy services

# WHAT IS IMPORTANT WITH RESPECT TO FUTURE ELECTRICITY?



# 1. INTRODUCTION: CORE OBJECTIVE

- How to provide access to electricity „optimal“ from societies point-of-view?
- What is the optimal political „structure“? Private, price (de-)regulation ....
- How to bring about a transformation to a sustainable electricity system?
- Coal vs nuclear vs renewables vs natural gas?

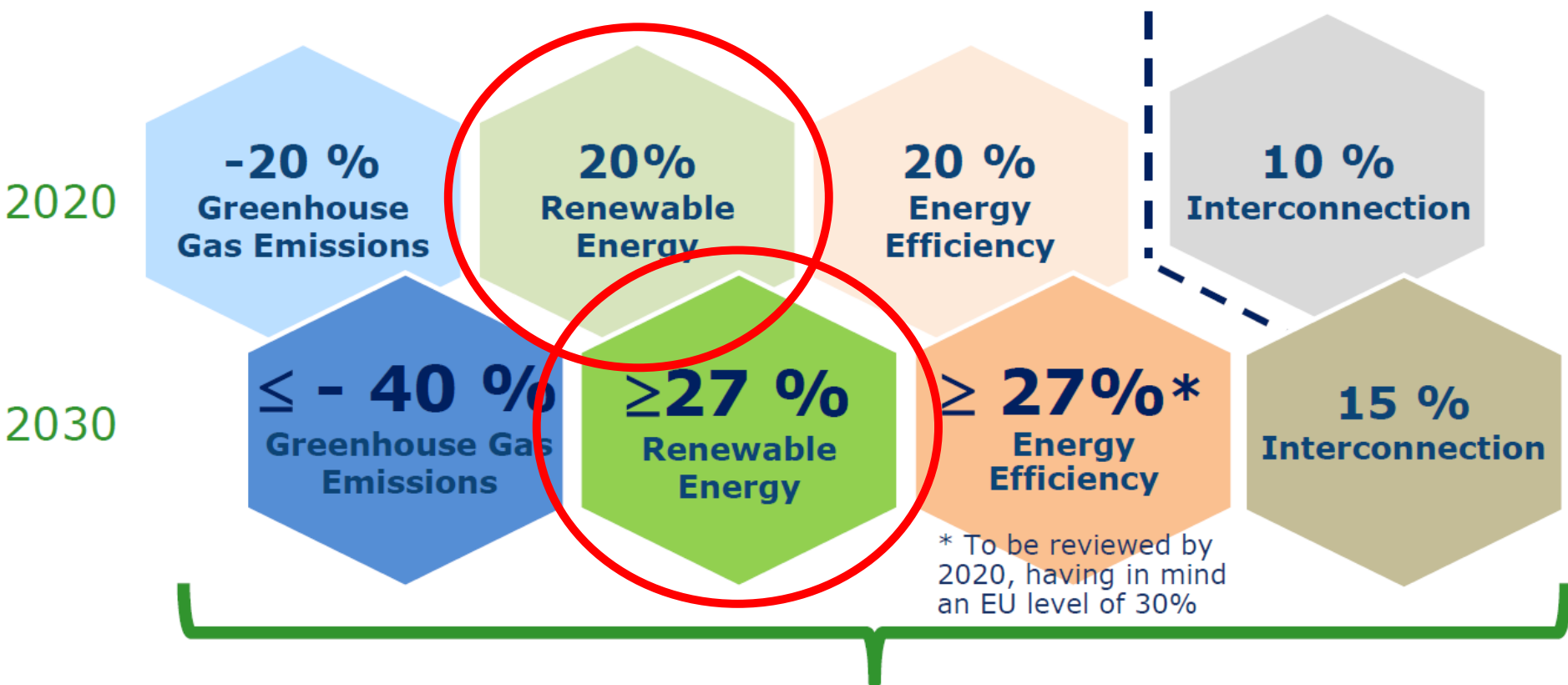
# THE EU-DIRECTIVE(S) 1

**The European Commission's main expectation .... was the belief that**

**“market forces [would] produce a better allocation of resources and greater effectiveness in the supply of services”**

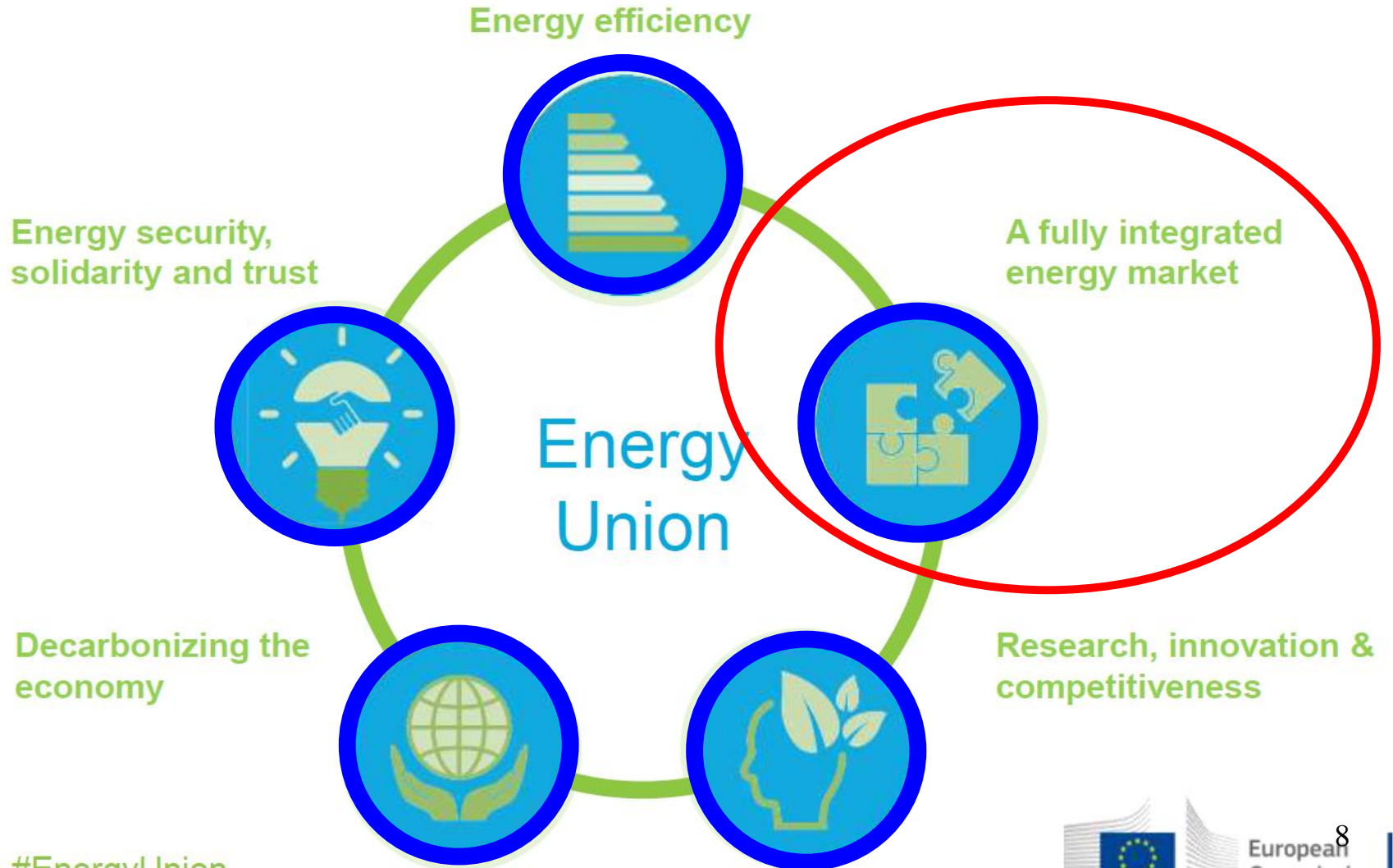
- **Intentions of the EC directive:**
  - **Competitive markets**
  - **lower electricity prices**
  - **more environmentally benign**

## Strategic decision by European Council in 2014



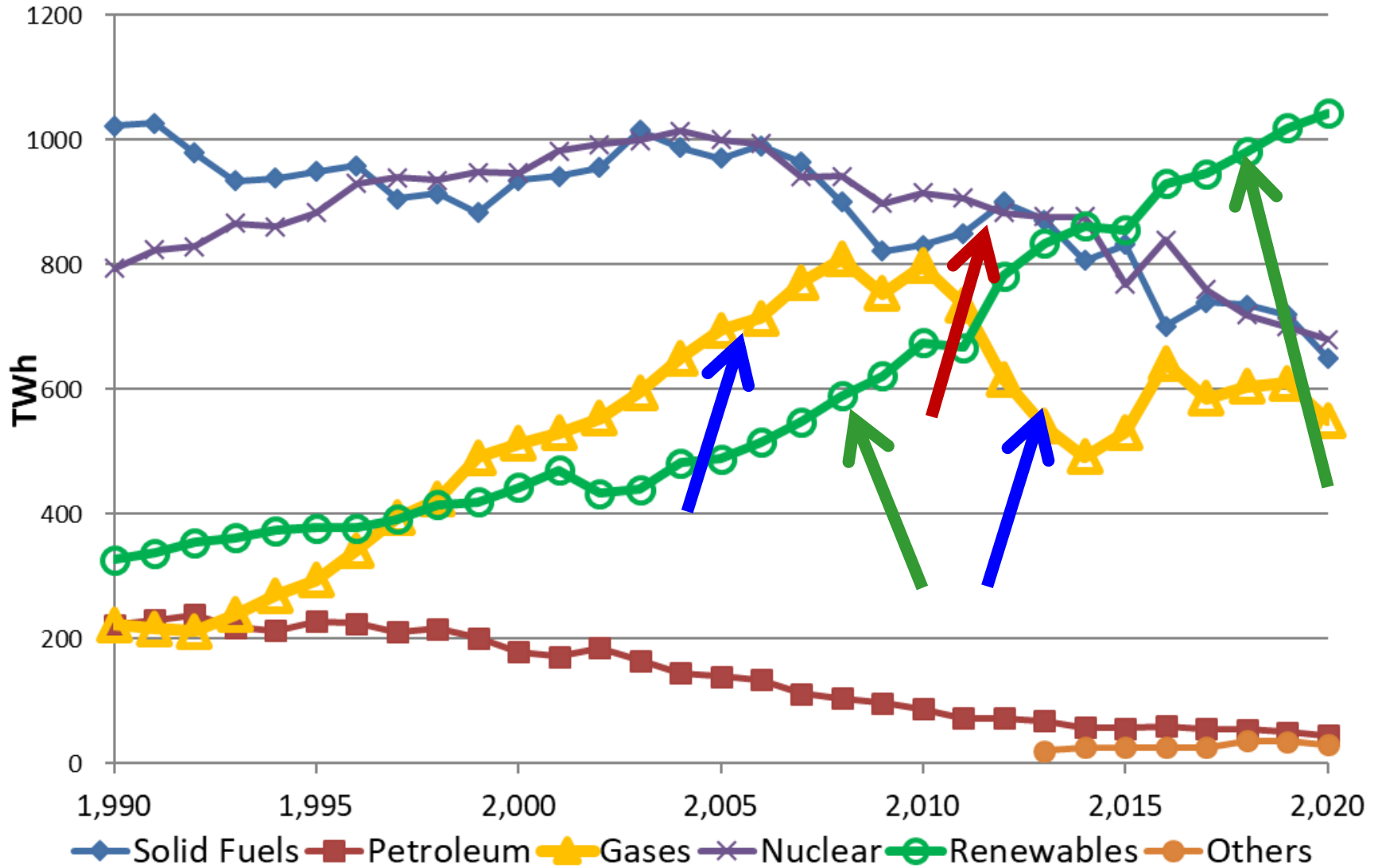
**New governance system + indicators**

# Energy Union Strategy

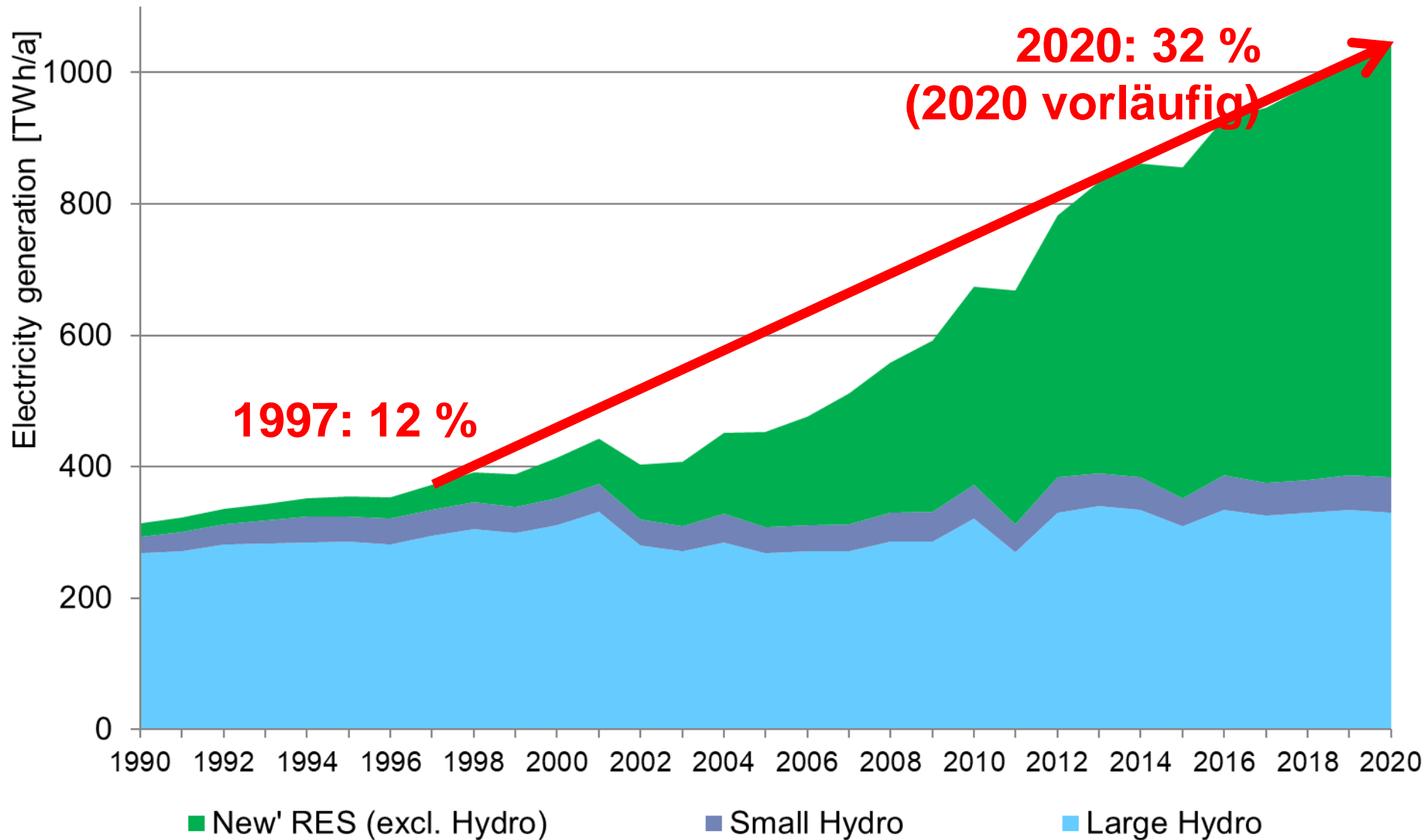




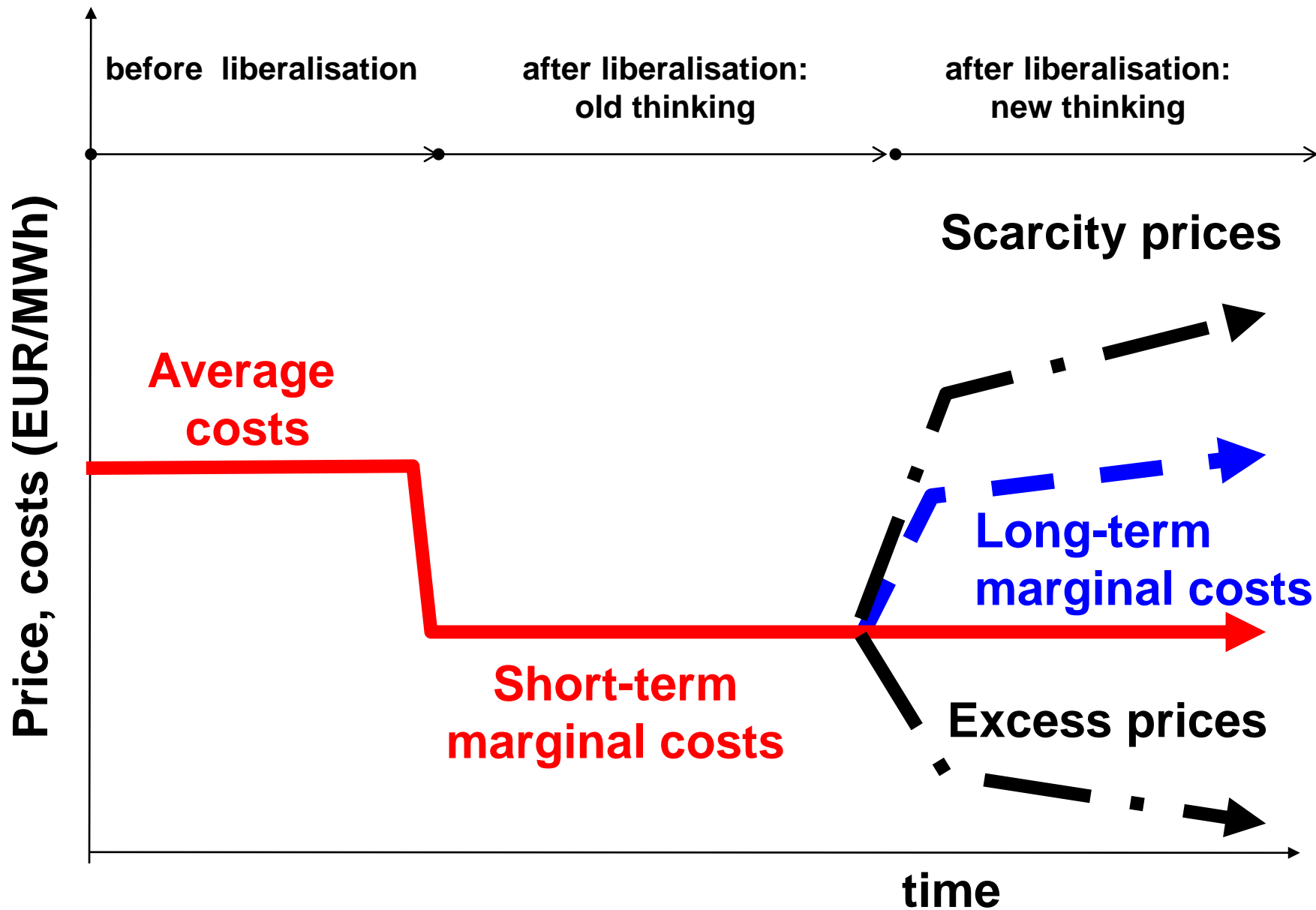
# Electricity generation EU-28



# Electricity generation RES EU-28



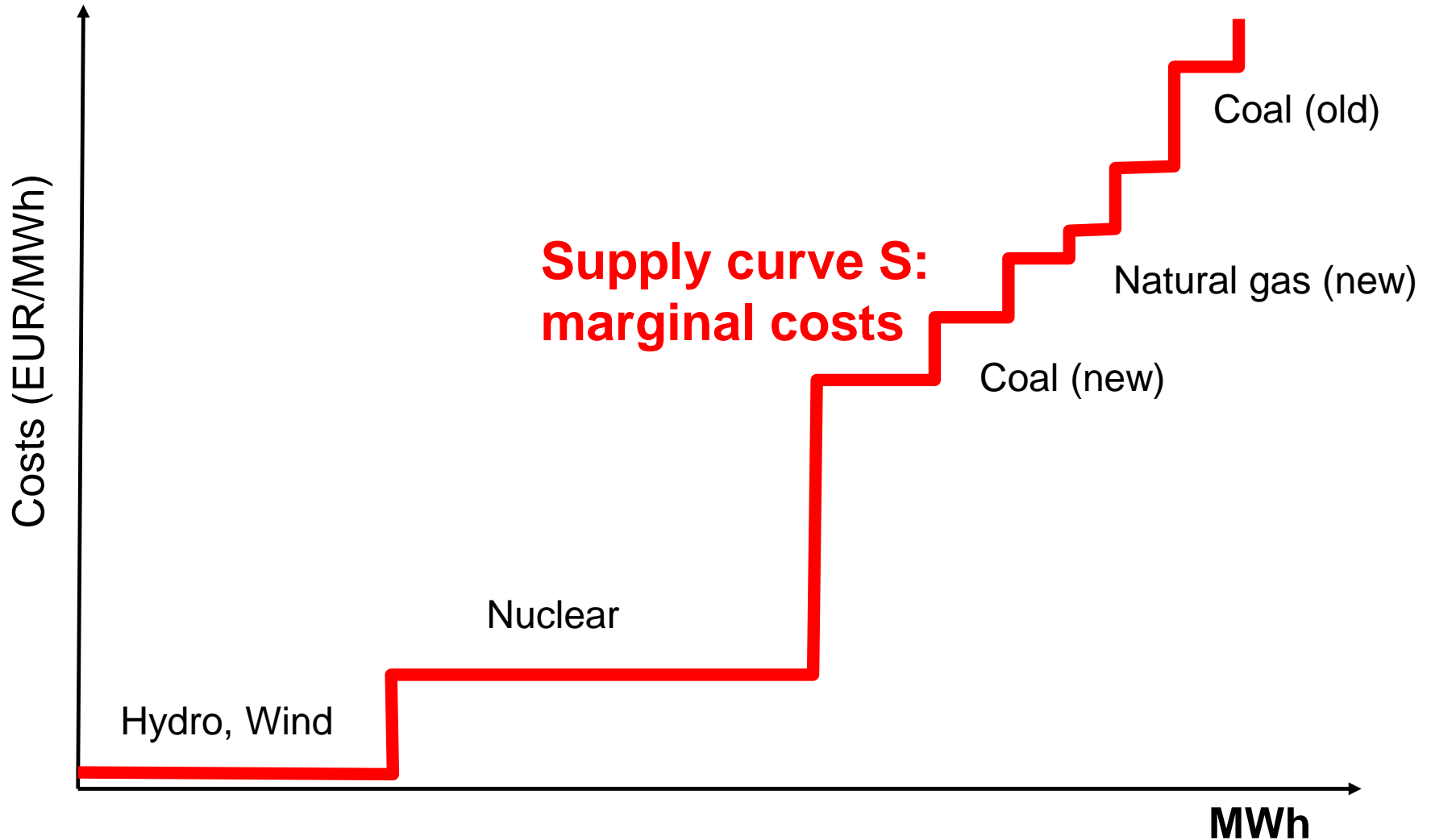
# 2. How prices come about: Three periods of market design



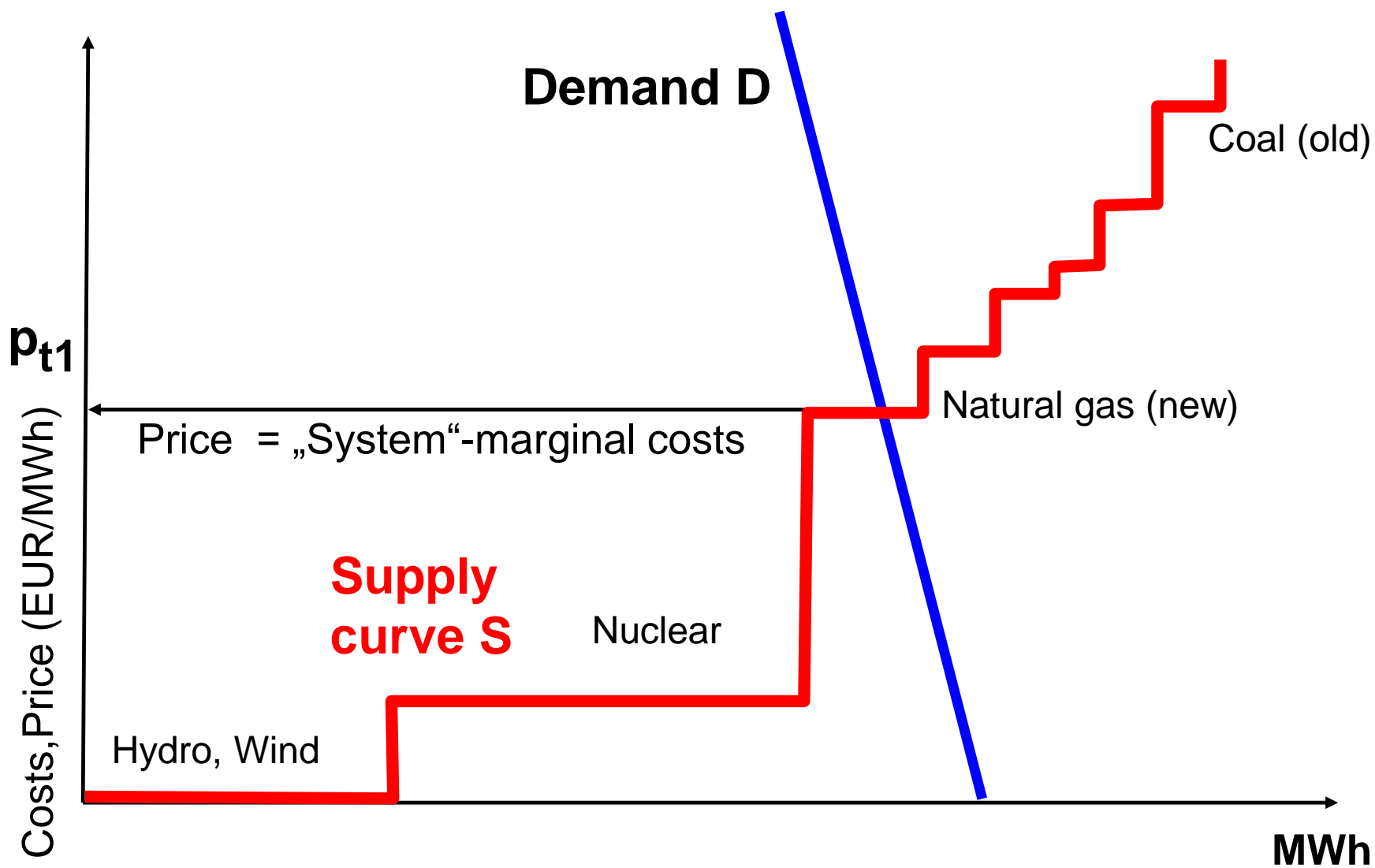
## 2. How prices come about

### THE *MERIT-ORDER* CURVE OF SUPPLY

based on short-term marginal costs (MC)

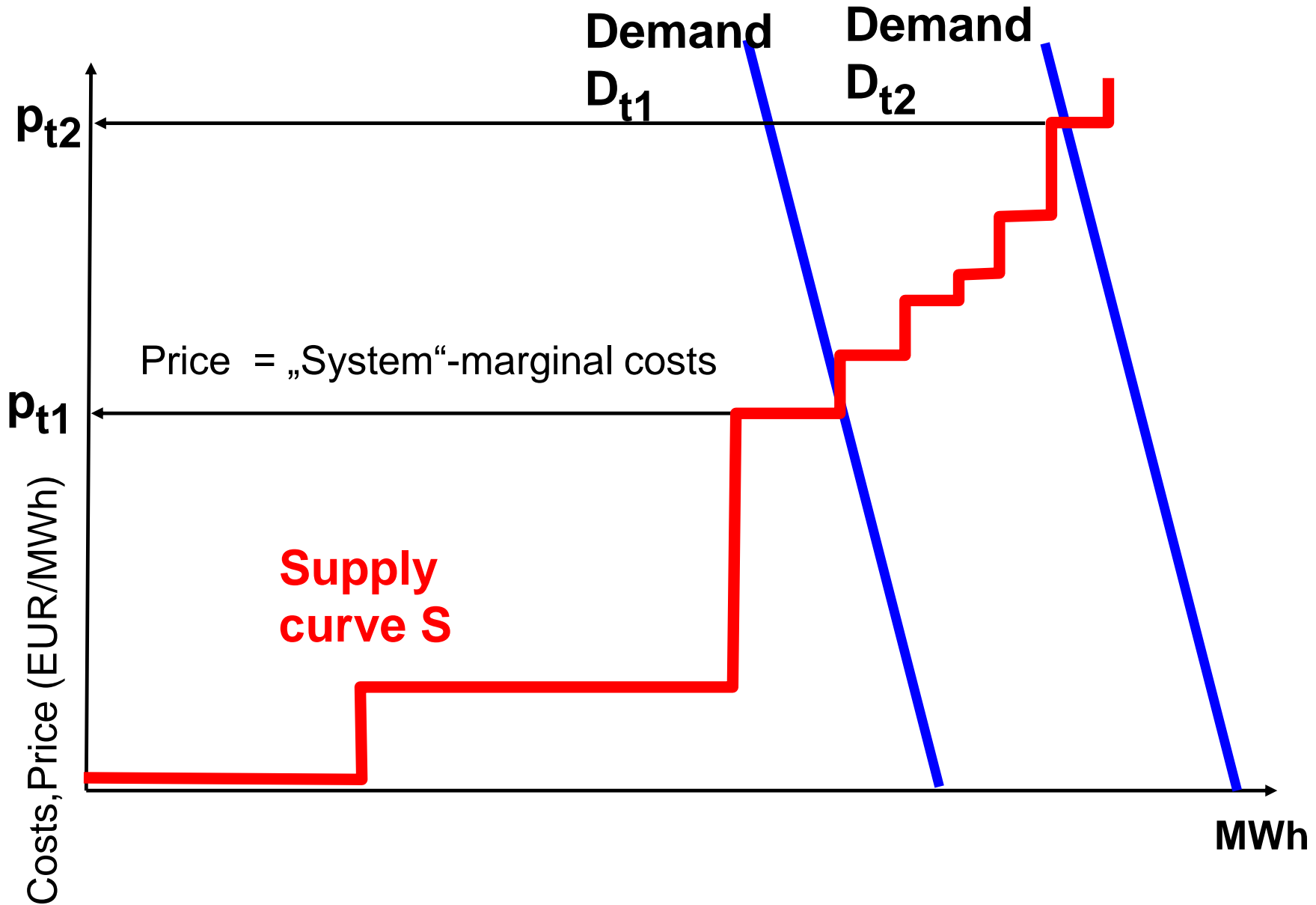


# BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS





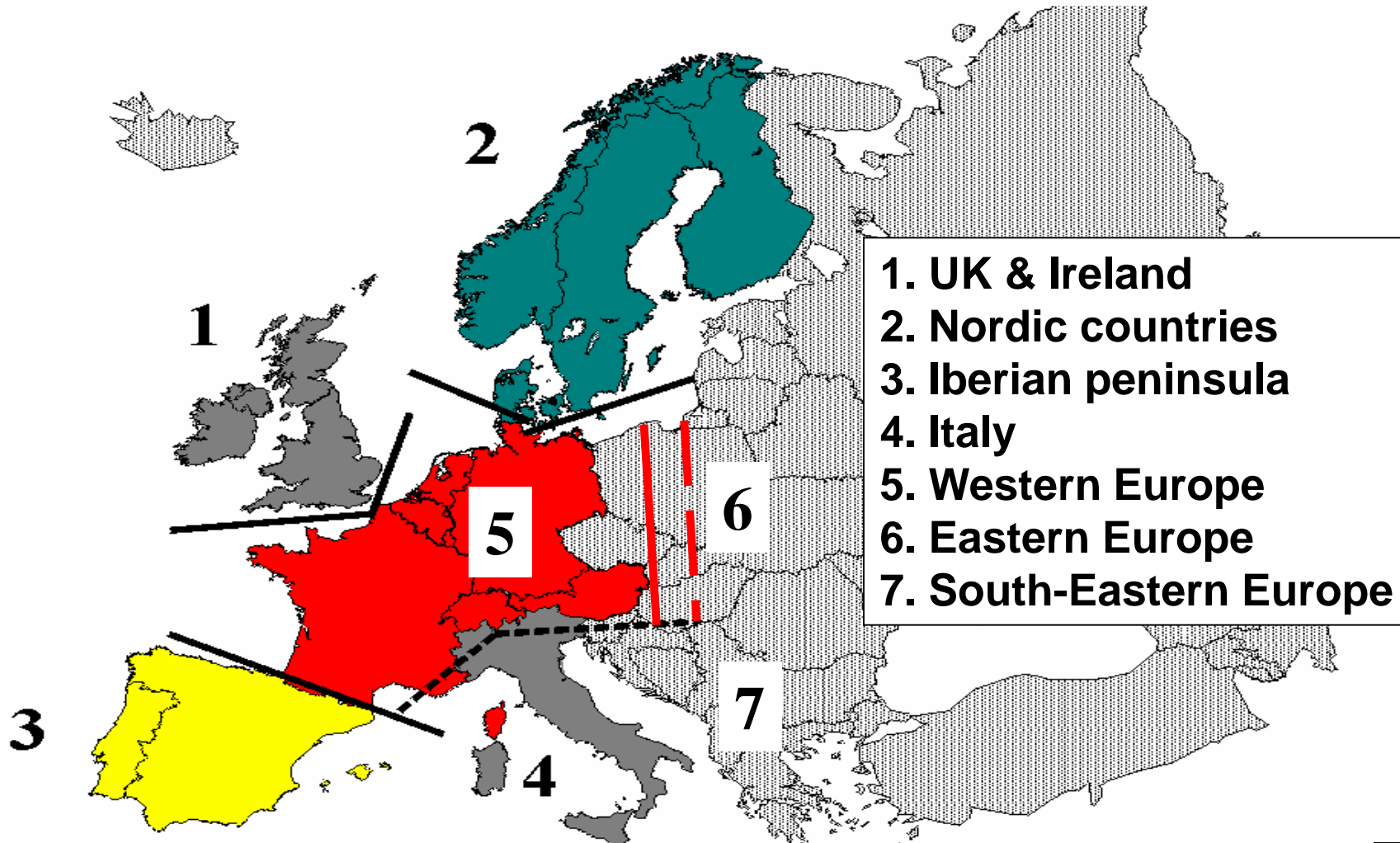
# BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



# WHY A NEW ELECTRICITY MARKET DESIGN?

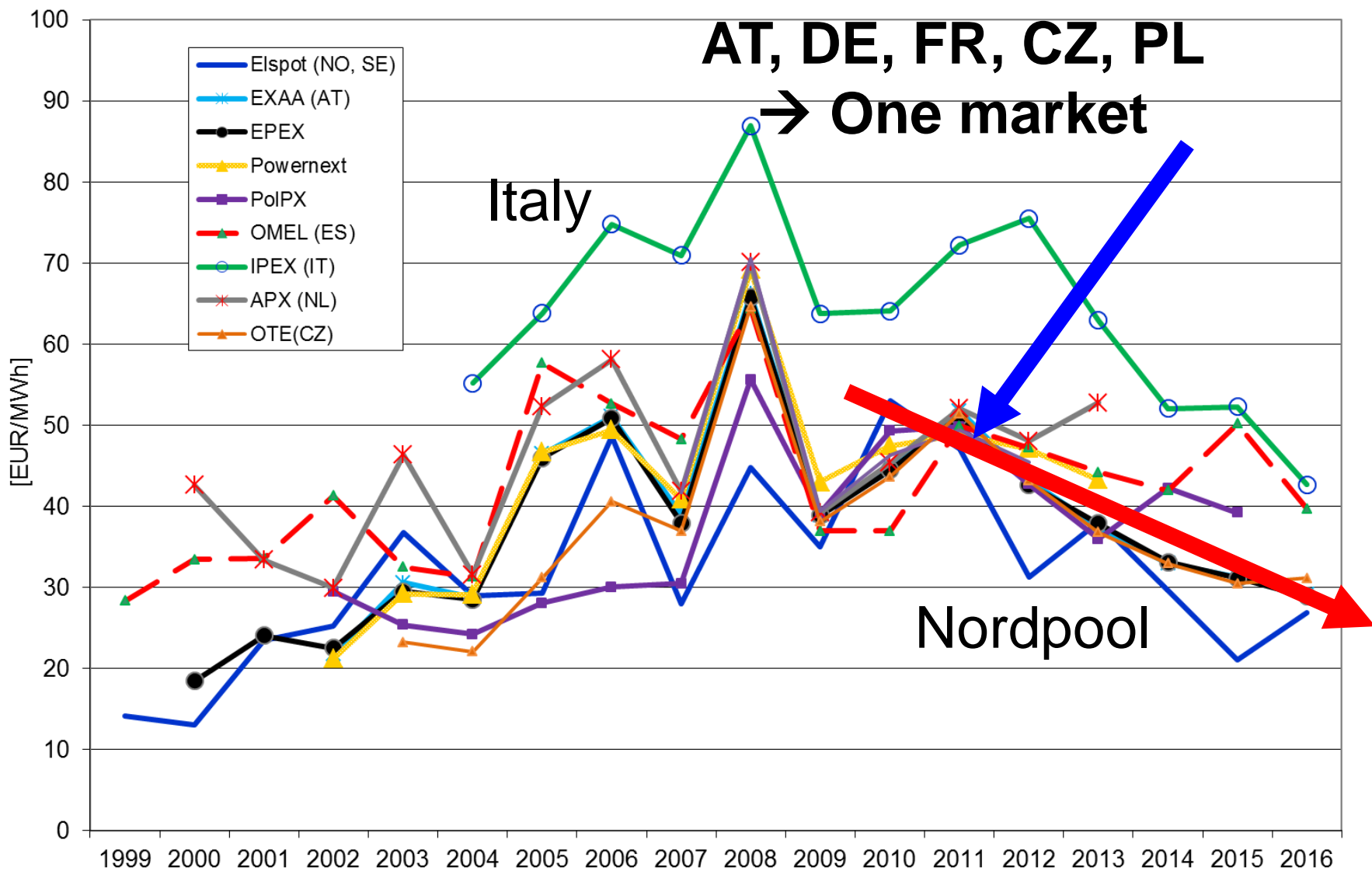
# 3 HOW PRICES DEVELOPED IN EUROPE

## EUROPEAN ELECTRICITY SUB-MARKETS

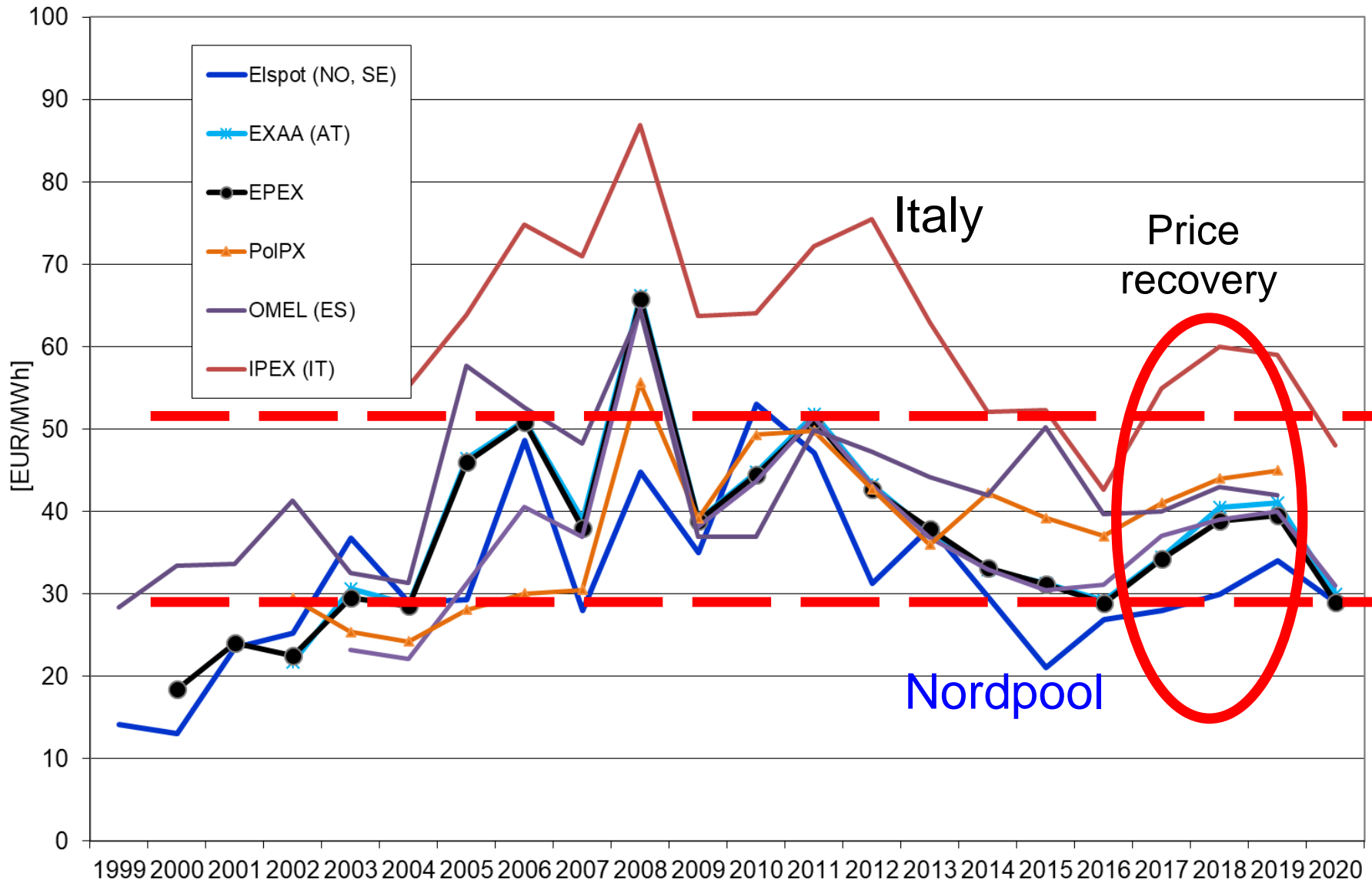


1. UK & Ireland
2. Nordic countries
3. Iberian peninsula
4. Italy
5. Western Europe
6. Eastern Europe
7. South-Eastern Europe

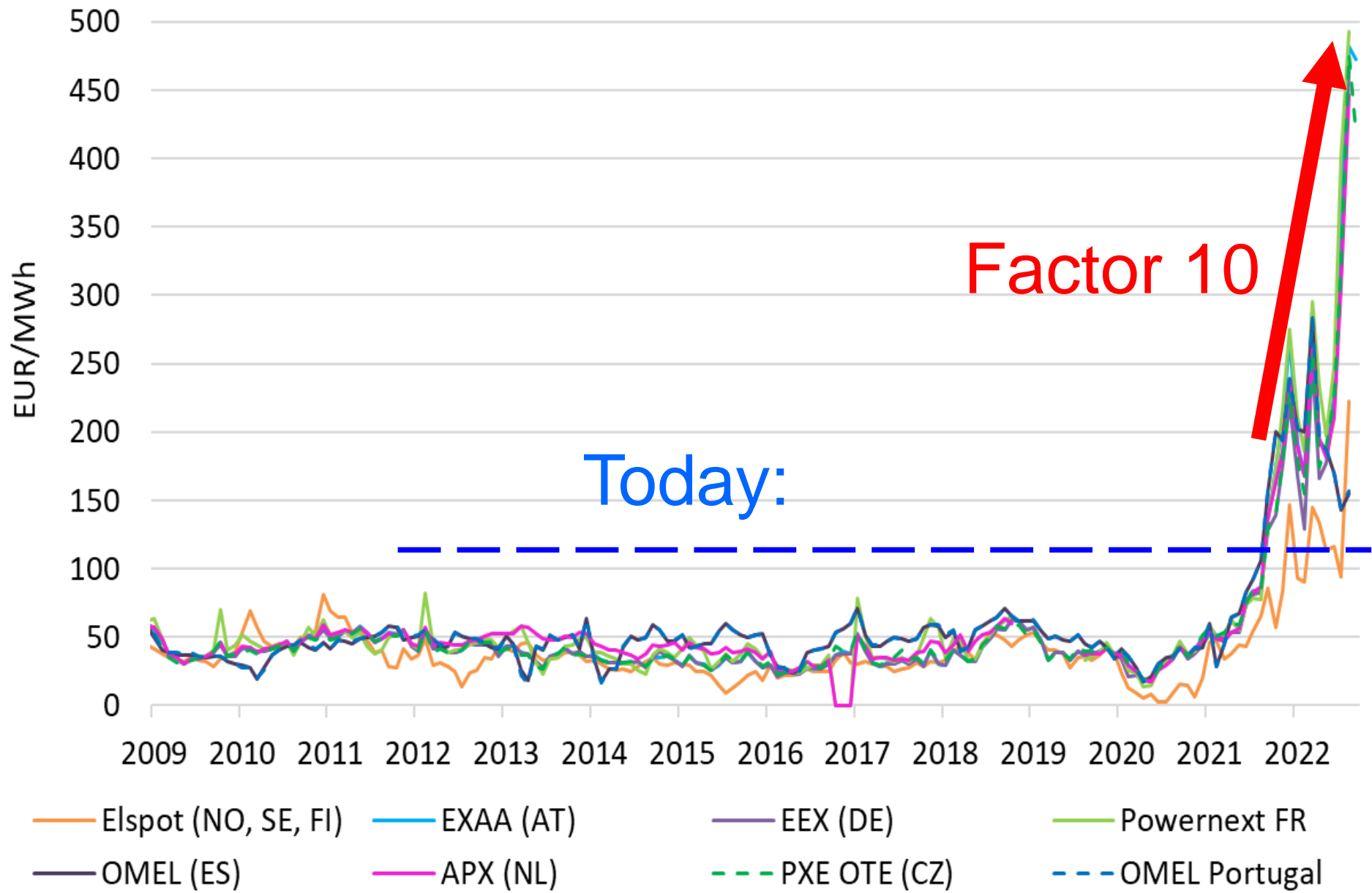
# Development of day-ahead electricity prices in Europe per year (1)



# Development of day-ahead electricity prices in Europe per year (2)



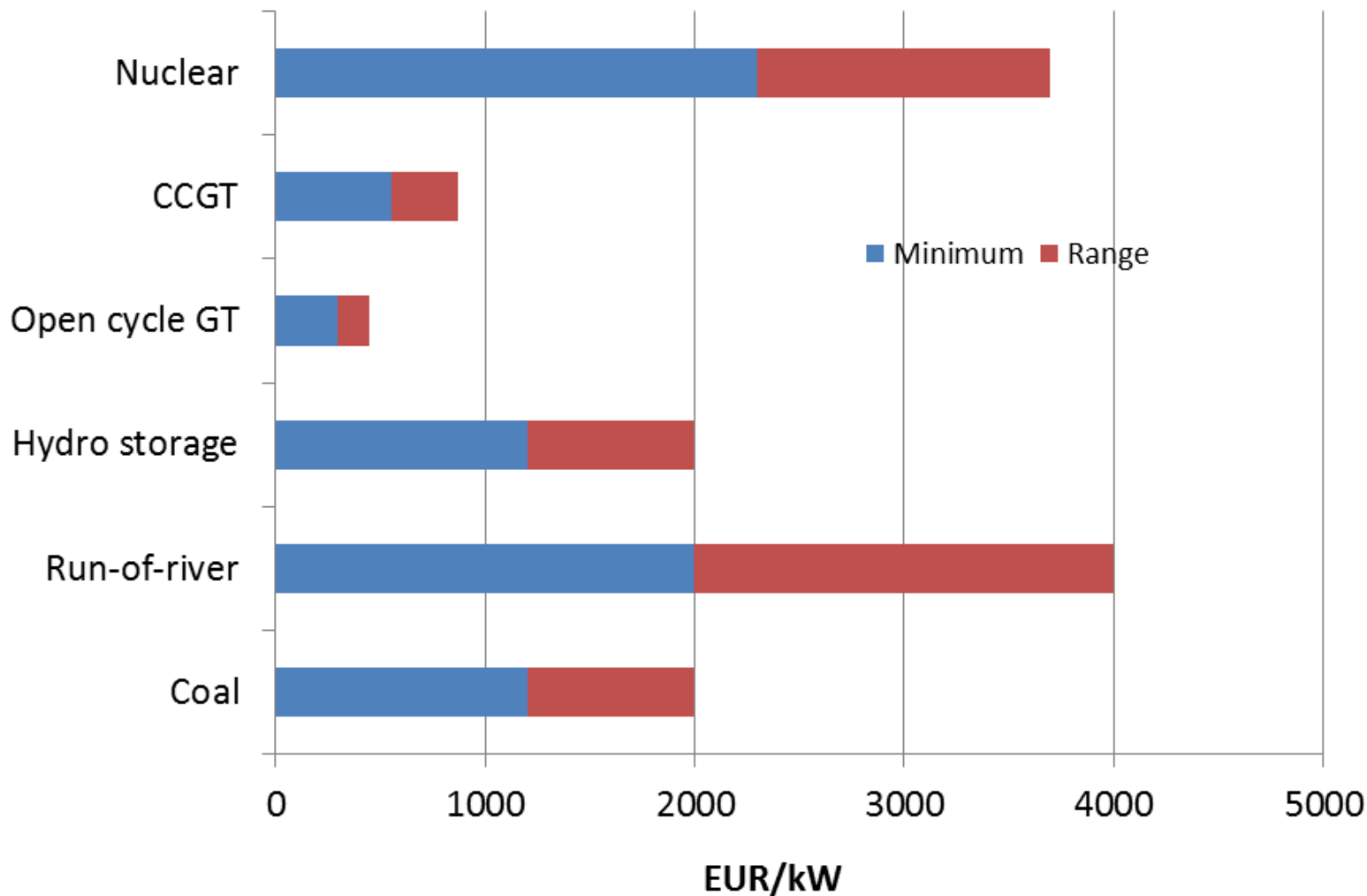




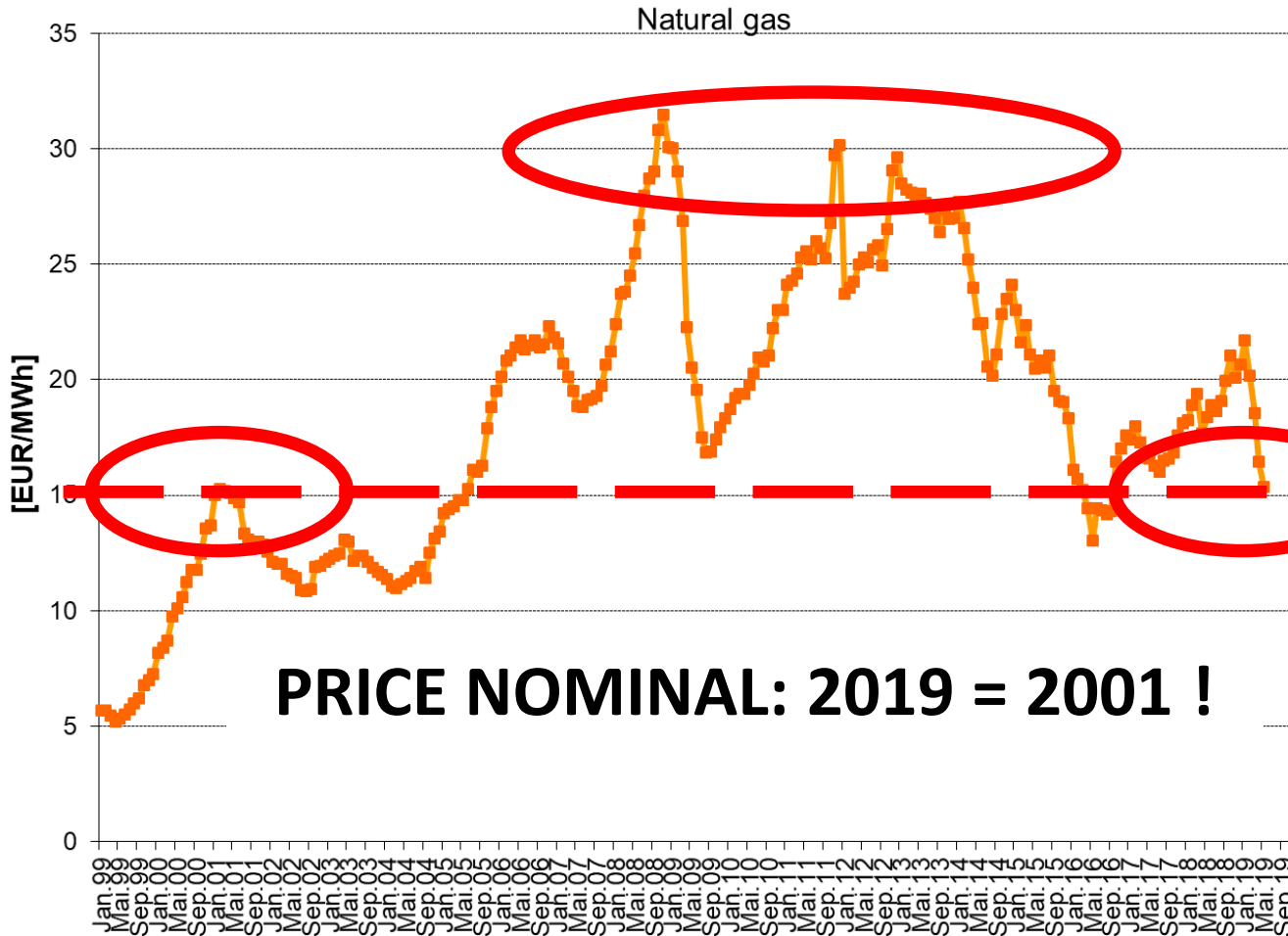
# WHAT ARE IMPORTANT IMPACT PARAMETERS ON ELECTRICITY PRICES AND COSTS?

# Investment costs

## Electricity generation Conventional 2018



# THE MARKET PRICE OF NATURAL GAS




300 !!!

**PRICE NOMINAL: 2019 = 2001 !**

— Natural gas

# Natural Gas Prices in Europe Fall to Pre-Invasion Levels

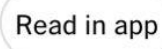
Warm weather, alternatives to Russian gas and a buildup of storage all help. But prices remain high for consumers and industry.

 Give this article





 98

 Read in app

346 €/MWh  
!!!

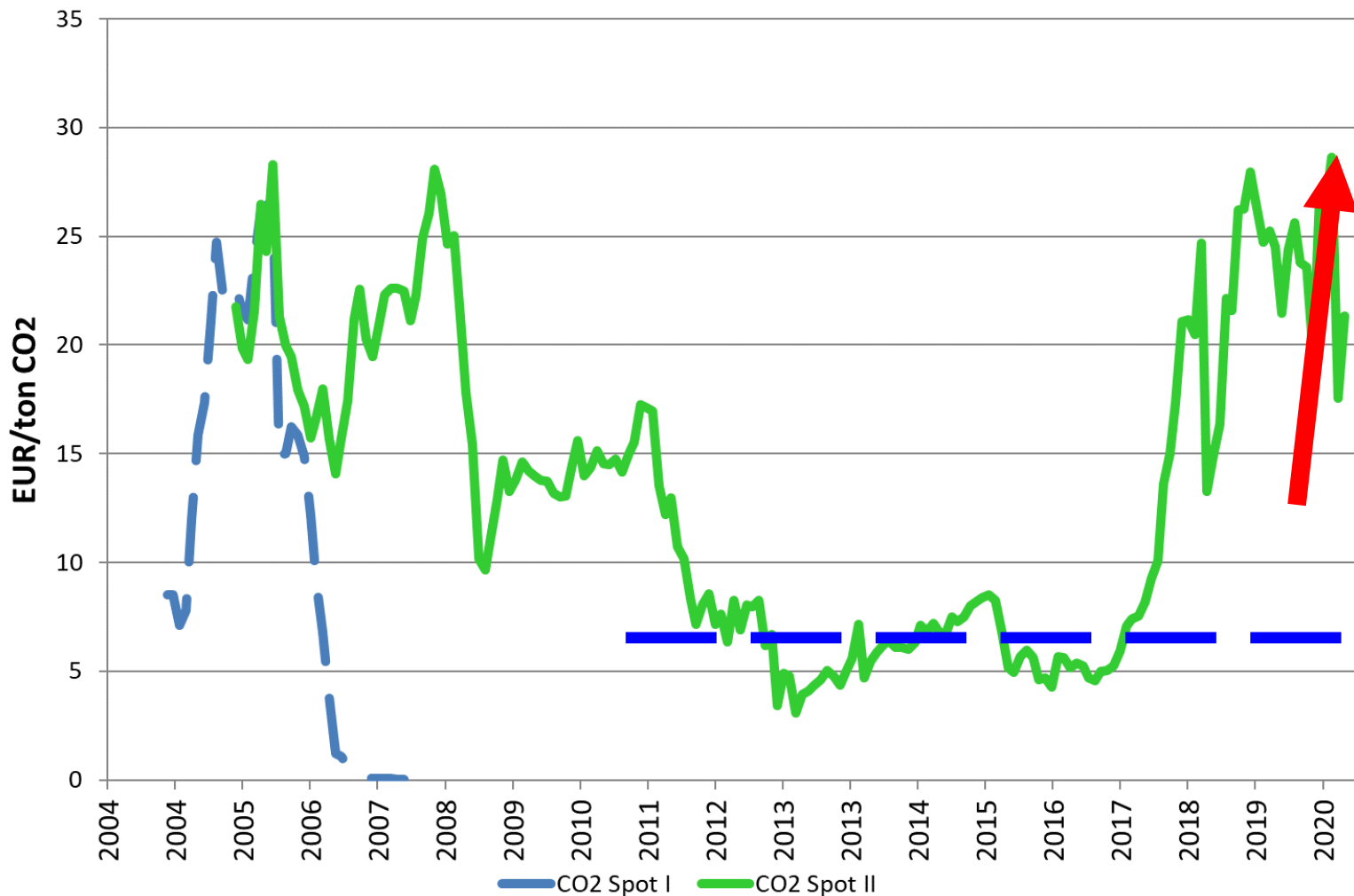
Price of Dutch T.T.F. natural gas, the European benchmark





# 4 ENVIRONMENTAL ASPECTS – THE CO<sub>2</sub>-PRICE

# Der CO2-Preis in Europa





# 5. Costs of electricity generation

$$C = C_F + C_V = \frac{I \alpha + C_{O\&M}}{T} + \frac{p_f}{H \eta} + \frac{C_{CO_2} f_{CO_2}}{\eta} \left[ \frac{\text{cent}}{\text{kWh}} \right]$$

where:

$C$  ... Total costs of electr. Generation (cent per kWh)

$C_F$  ... Fix costs (cent per kWh)

$C_V$  ... Variable costs (cent per kWh)

$C_{O\&M}$  ... Operation & maintenance costs (EUR/kW)

$I$  .... Investment costs (EUR/kW)

$\alpha$  ... C.R.F. (Capital recovery factor, e.g. 0.1 for 15 years, 5% WACC)

$T$  .... Full load hours (hours per year)

$p_f$  ... Fuel price (cent/kg or  $m^3$ )

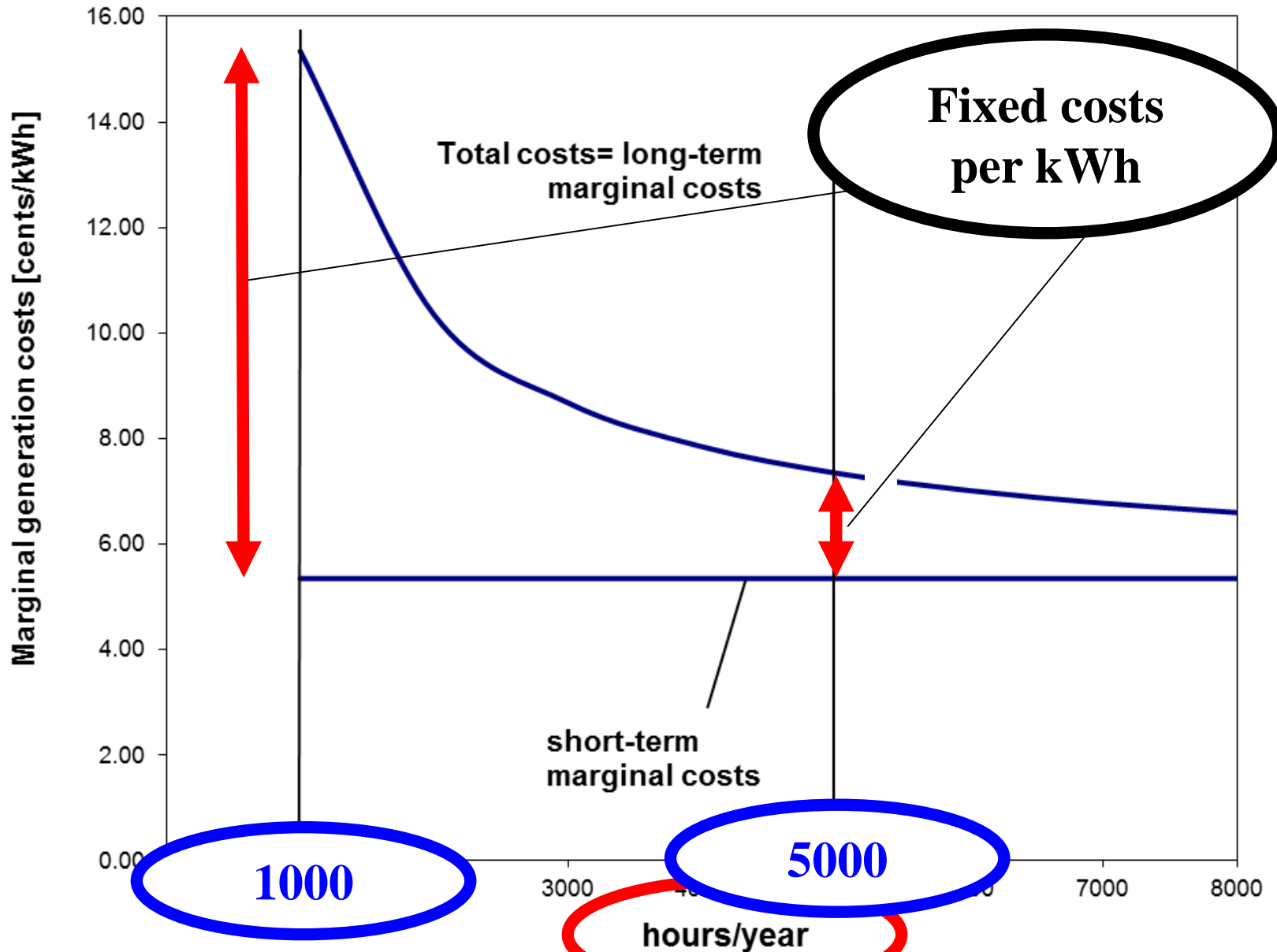
$H$  ... Caloric heat content (e.g. 10 kWh per  $m^3$  for gas)

$\eta$  ... Efficiency of power plant

$C_{CO_2}$  ... Price of CO2 (e.g. 25 EUR/ton Carbon)

$f_{CO_2}$  ... CO2-factor of fuel (0.2 kg Carbon/kWh)

# Generation costs CCGT



# Example 1: Costs of electricity generation from CCGT

- I ....Investment costs = 800 EUR/kW
- $\alpha$  ... C.R.F. = 0.1 for 15 years and 5% interest rate
- T ....Full load hours = 5000/1000 hours per year
- $C_{O\&M}$ ... Operation & maintenance costs = 20 EUR/kW
- $p_f$  ... Fuel price (e.g. 30 cents/m<sup>3</sup> natural gas)
- H ... Caloric heat content (e.g. 10 kWh per m<sup>3</sup> for gas)
- $\eta$  ... Efficiency of CCGT plant = 0.58
- $C_{CO_2}$  ... Price of CO<sub>2</sub>: 5 EUR/ton Carbon)
- $f_{CO_2}$  ... CO<sub>2</sub>-factor of fuel (0.2 kg Carbon/kWh)



# Example 1: Costs of electricity generation

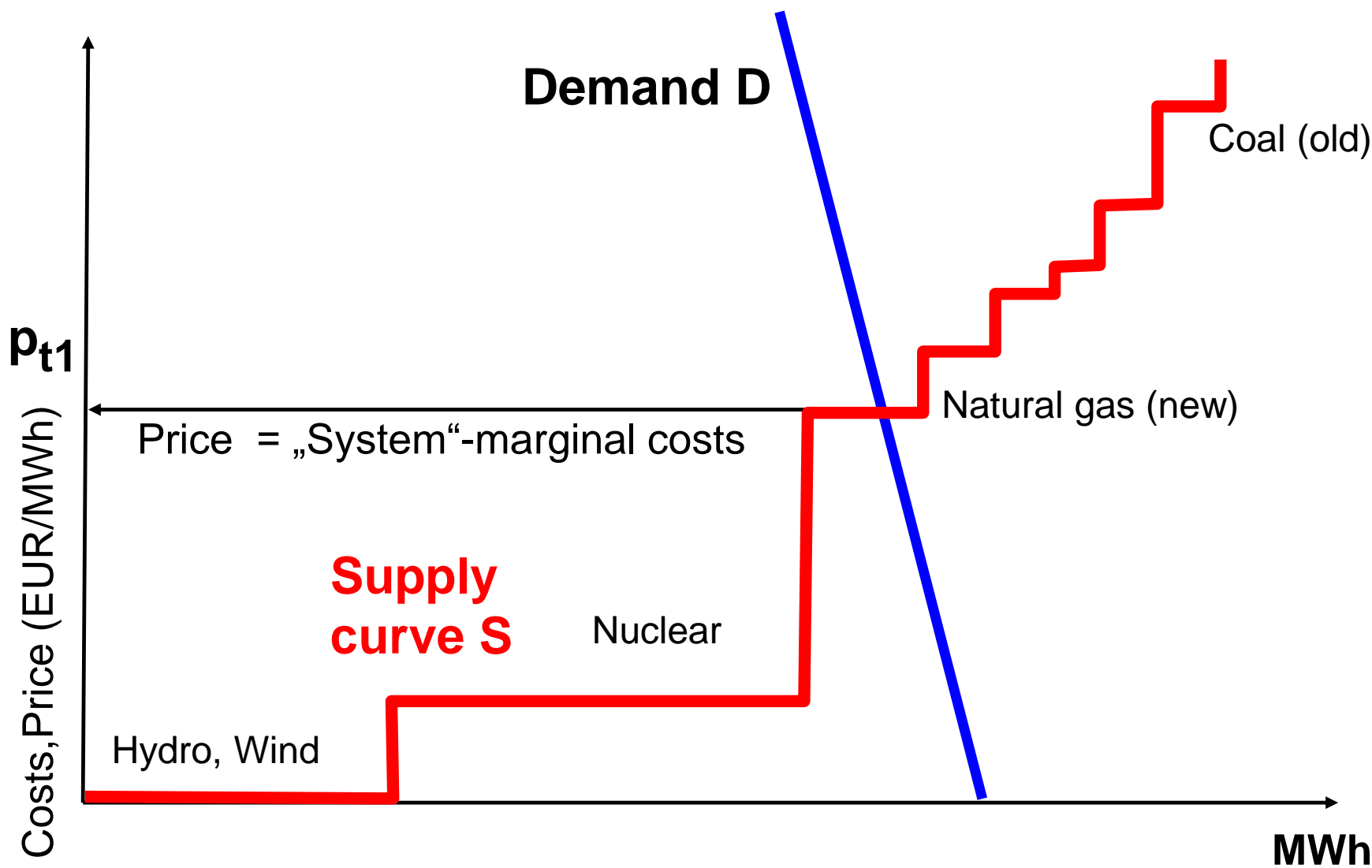
$$C = \frac{80000 * 0.1 + 2000}{5000} + \frac{30}{10 * 0.58} + \frac{0.5 * 0.2}{0.58} \left[ \frac{\text{cent}}{\text{kWh}} \right] =$$
$$= 1.6 + 0.4 + 5.17 + 0.17 = 7.34 \text{ cent/kWh}$$

=====

# Example 2: Marginal costs of electricity generation from CCGT

- $p_f$  ... Fuel price (e.g. 60 cents/m<sup>3</sup> natural gas)
- $H$  ... Caloric heat content (e.g. 10 kWh per m<sup>3</sup> for gas)
- $\eta$  ... Efficiency of CCGT plant = 0.50
- $C_{CO_2}$  ... Price of CO<sub>2</sub>: 50 EUR/ton Carbon)
- $f_{CO_2}$  ... CO<sub>2</sub>-factor of fuel (0.2 kg Carbon/kWh)

# BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



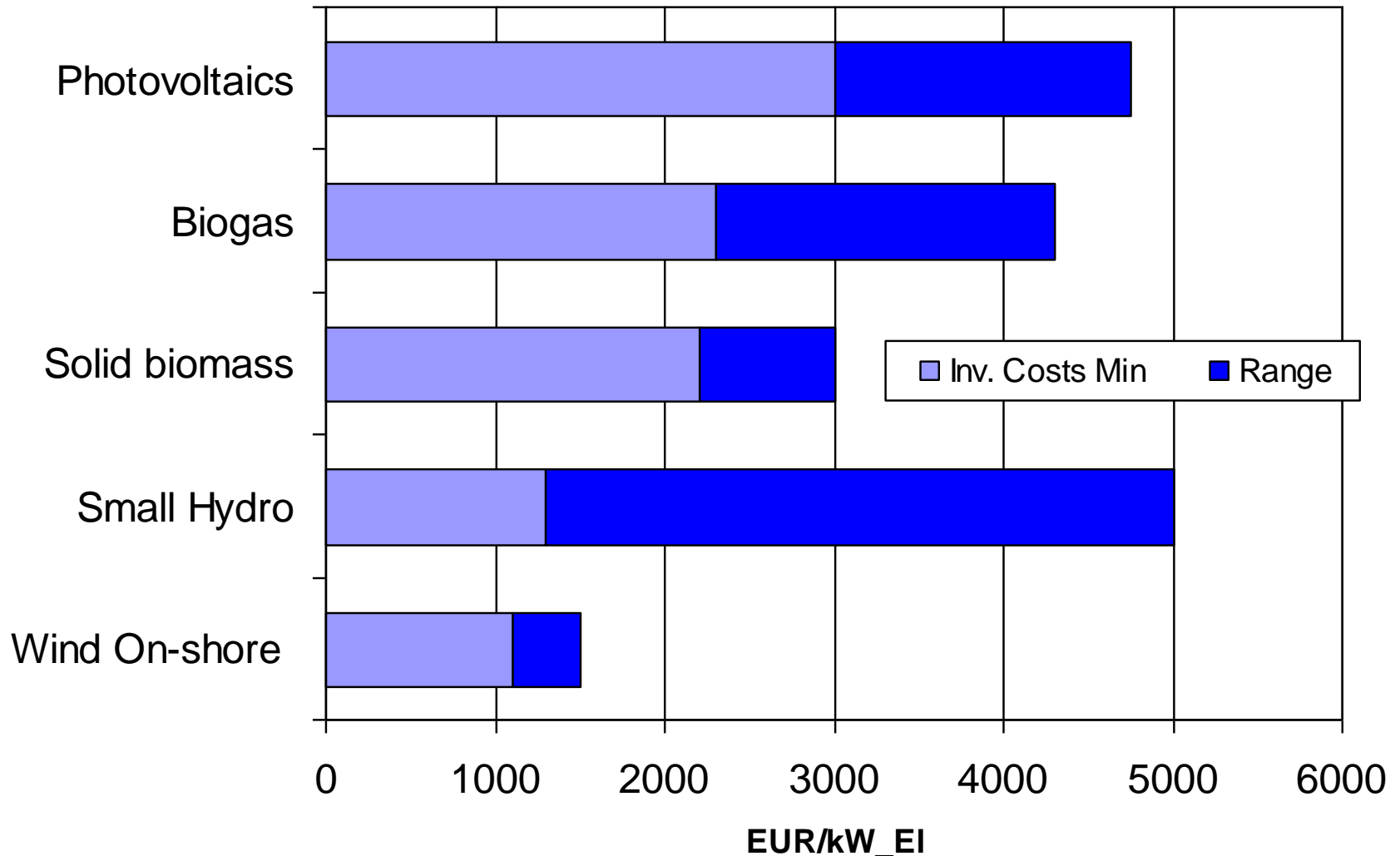
# Example 2: Marginal costs of electricity generation

$$C = \frac{60}{10 * 0.5} + \frac{5 * 0.2}{0.5} \left[ \frac{\text{cent}}{\text{kWh}} \right] =$$
$$= 12.0 + 2.0 = 14.0 \text{ cent/kWh}$$

=====

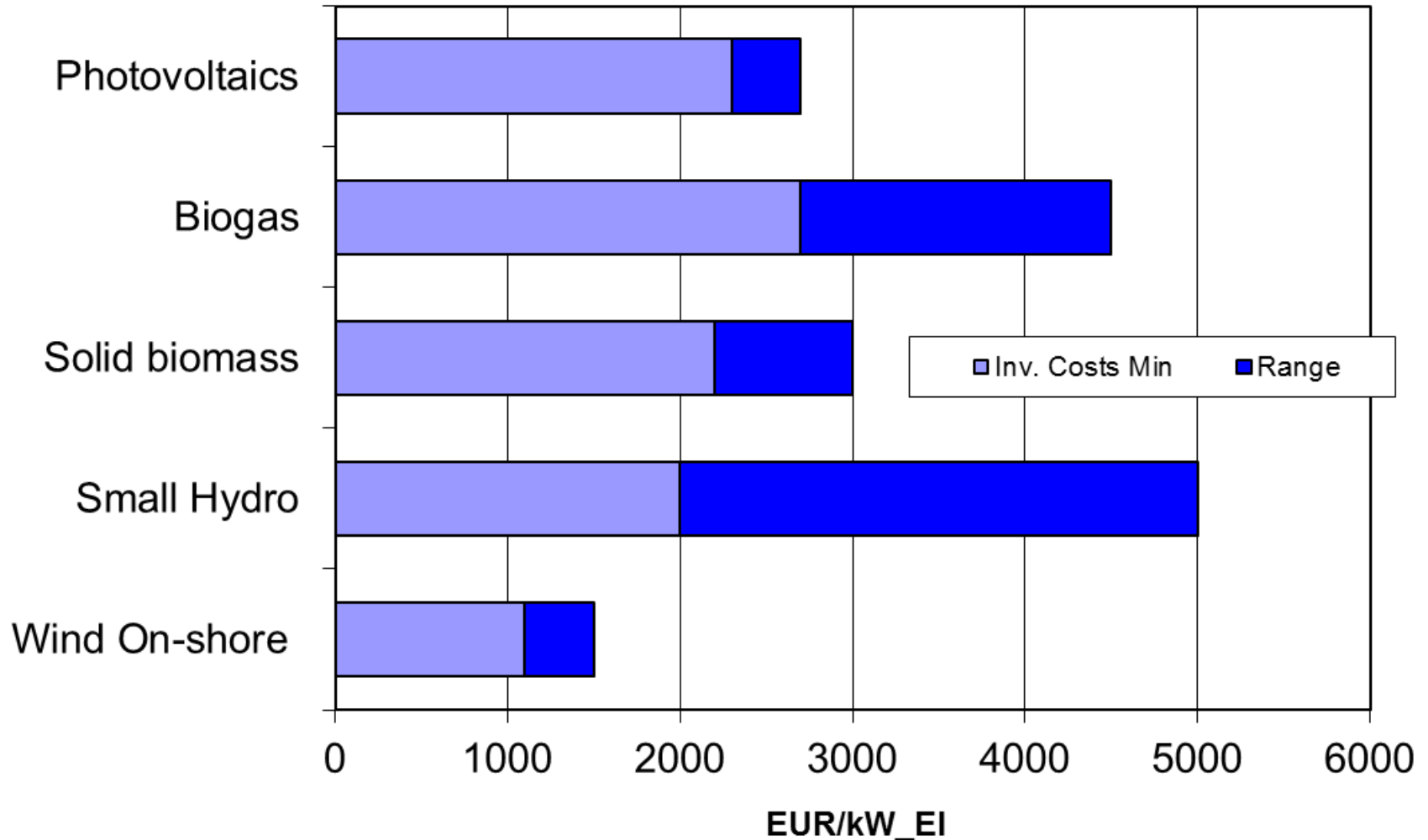
# Investment costs

## Electricity from new renewables 2020



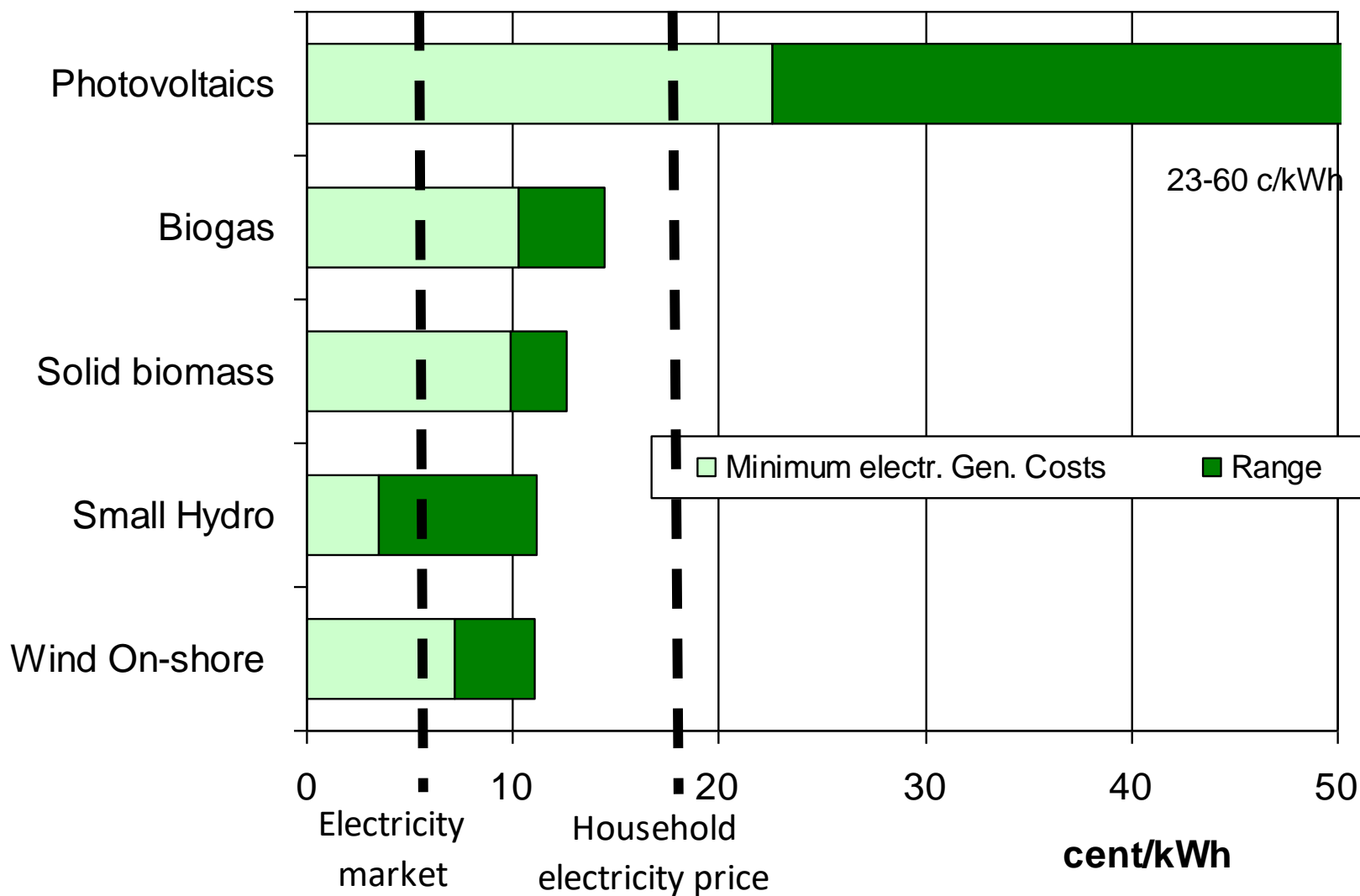
# Investment costs

## Electricity from new renewables 2018



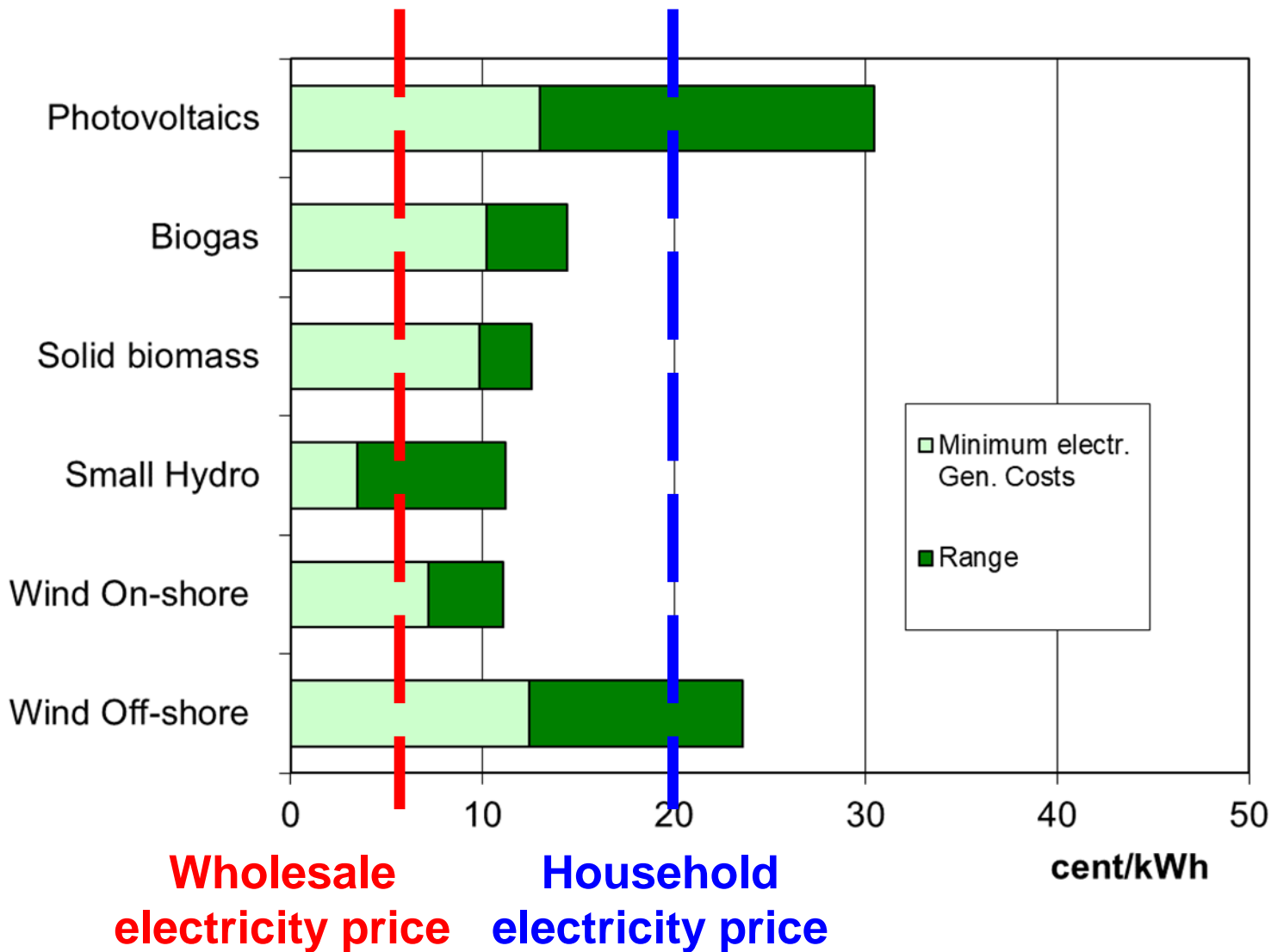
# Generation costs

## Electricity from new renewables 2010



# Generation costs

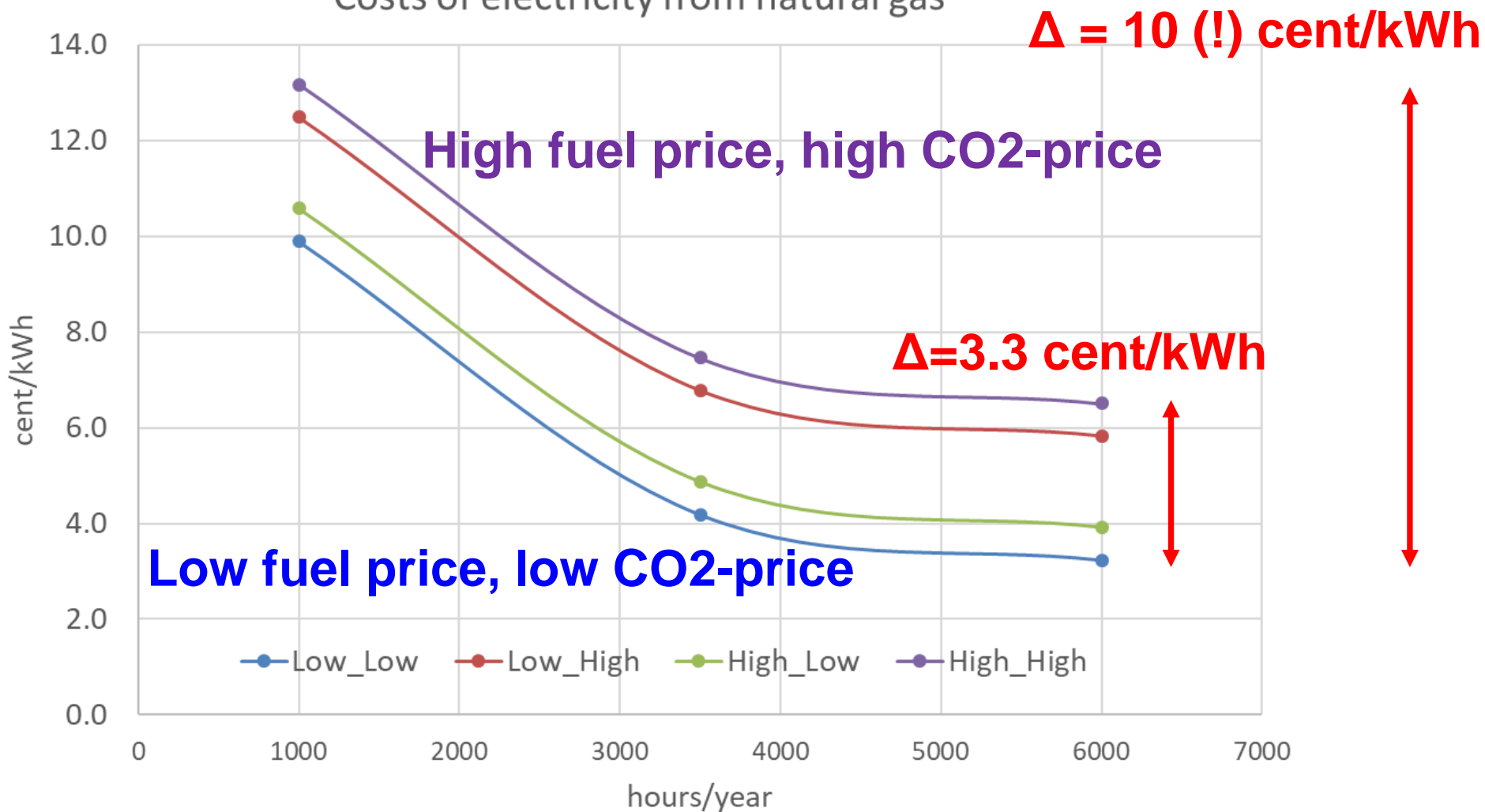
## Electricity from new renewables 2020





# Example: Costs of electricity generation from CCGT

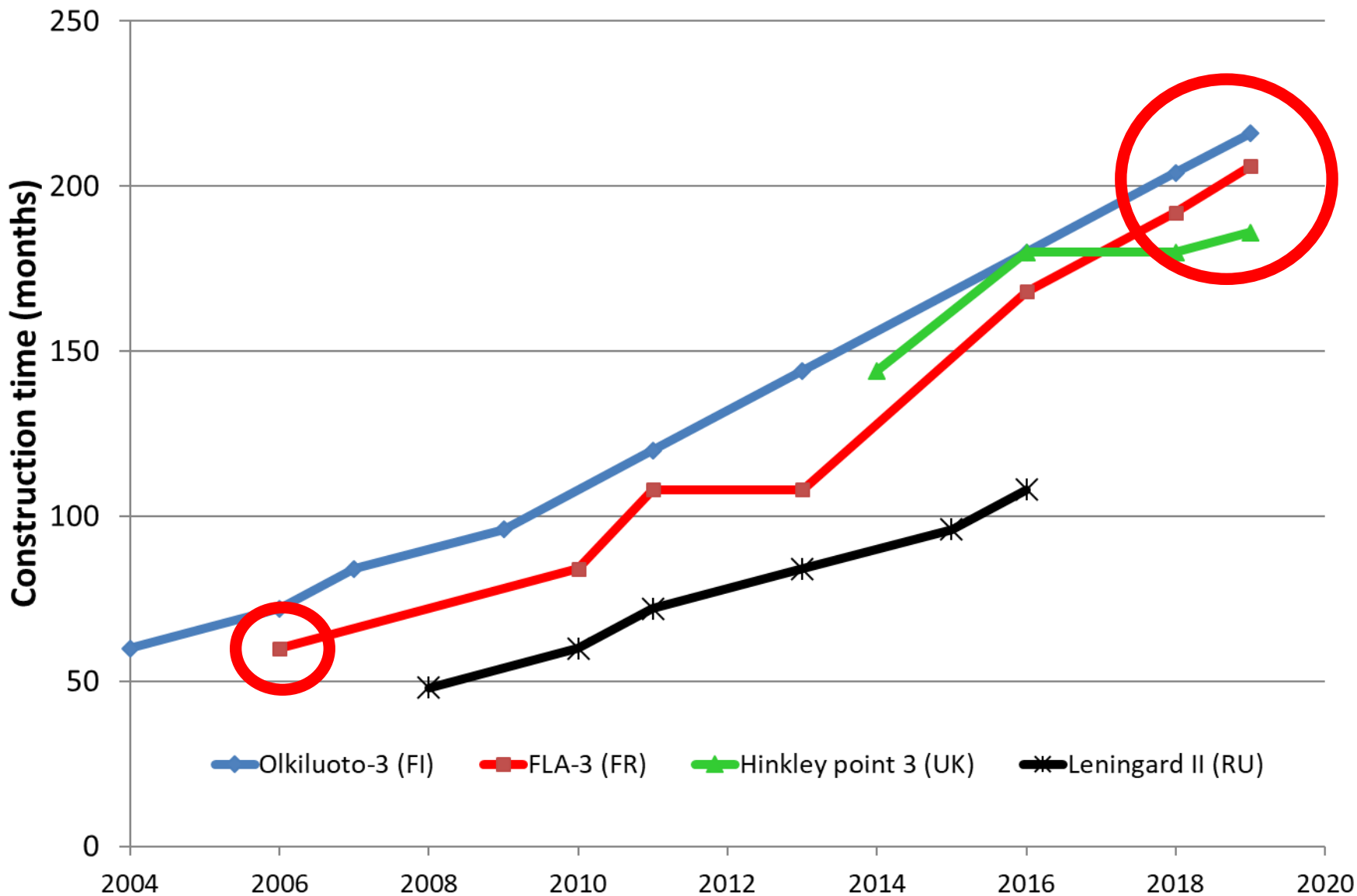
Costs of electricity from natural gas



## 6. RECENT DEVELOPMENT OF NUCLEAR COSTS

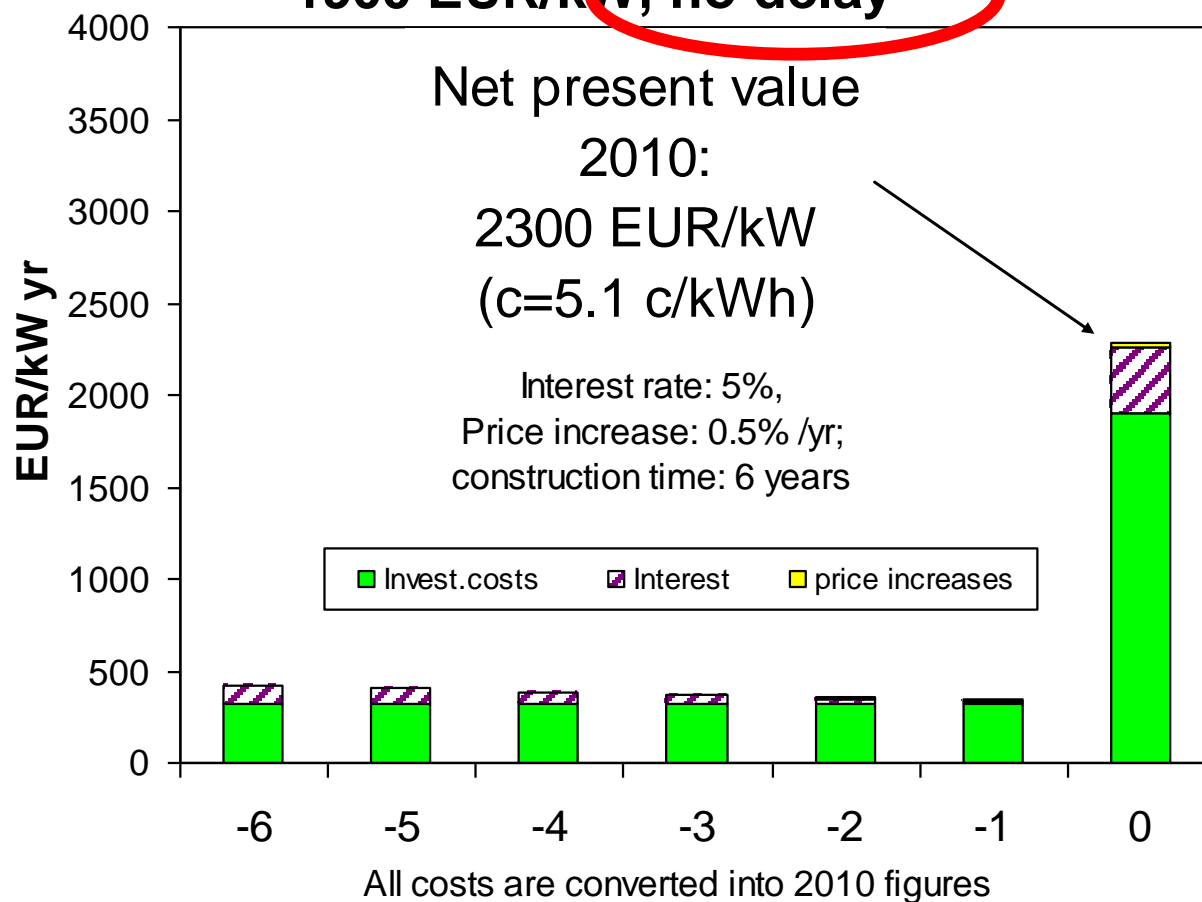
- **Olkiluoto-3 (Finland): Construction started in 2004, now expected to be completed 2019 (originally: 2009); 1600 MW**
- **Flamanville-3 (France): Construction started in 2006, now expected to be completed 2019 (originally: 2011); 1600 MW**
- **Hinkley point (UK): Construction start expected in 2022, 1600 MW**

# Construction times



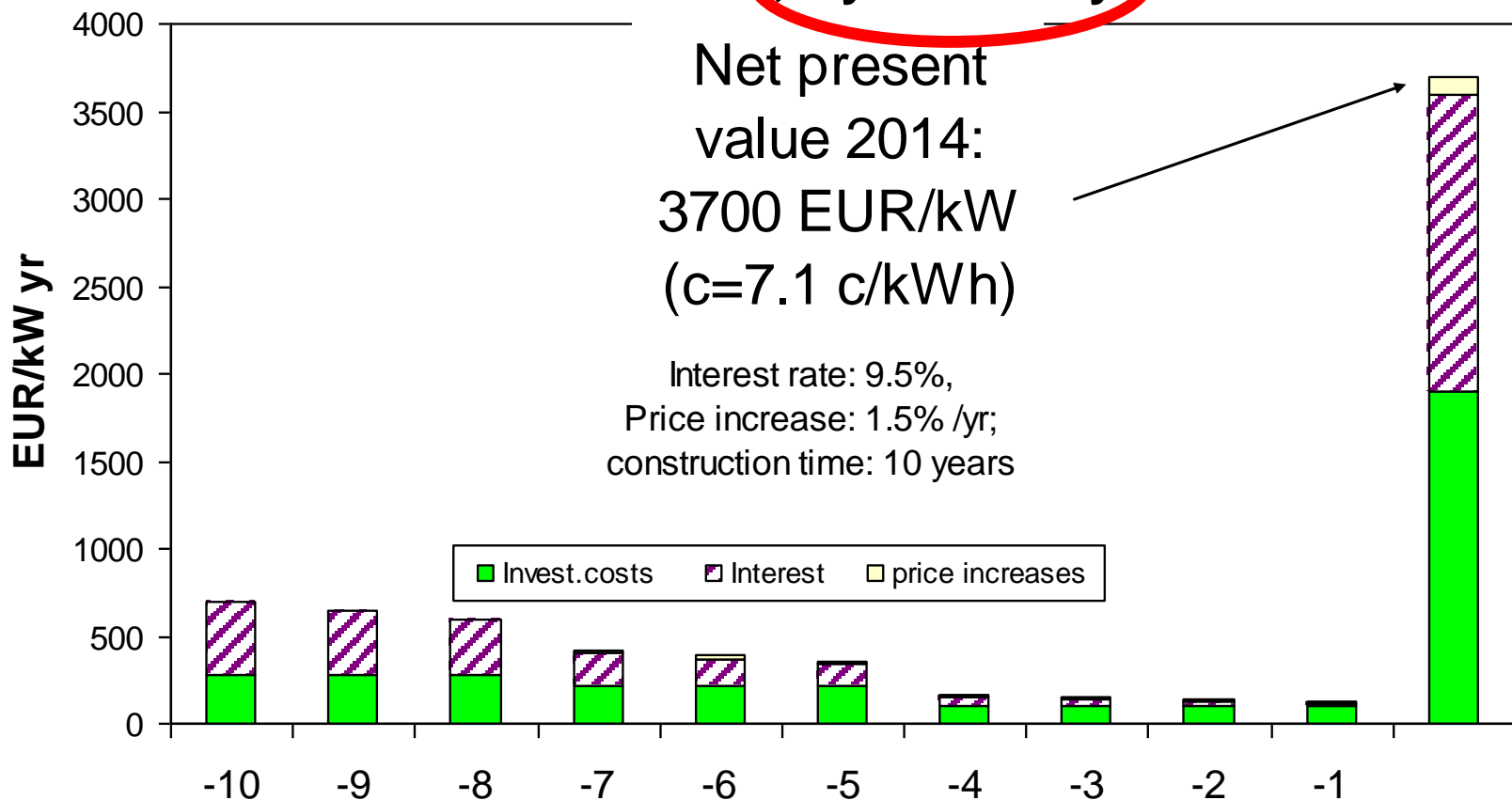
# Impact of construction time on investment costs: Example Olkiluoto

Olkiluoto: Overnight costs 2004:  
1900 EUR/kW, no delay



# Impact of construction time on investment costs: Example Olkiluoto

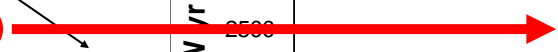
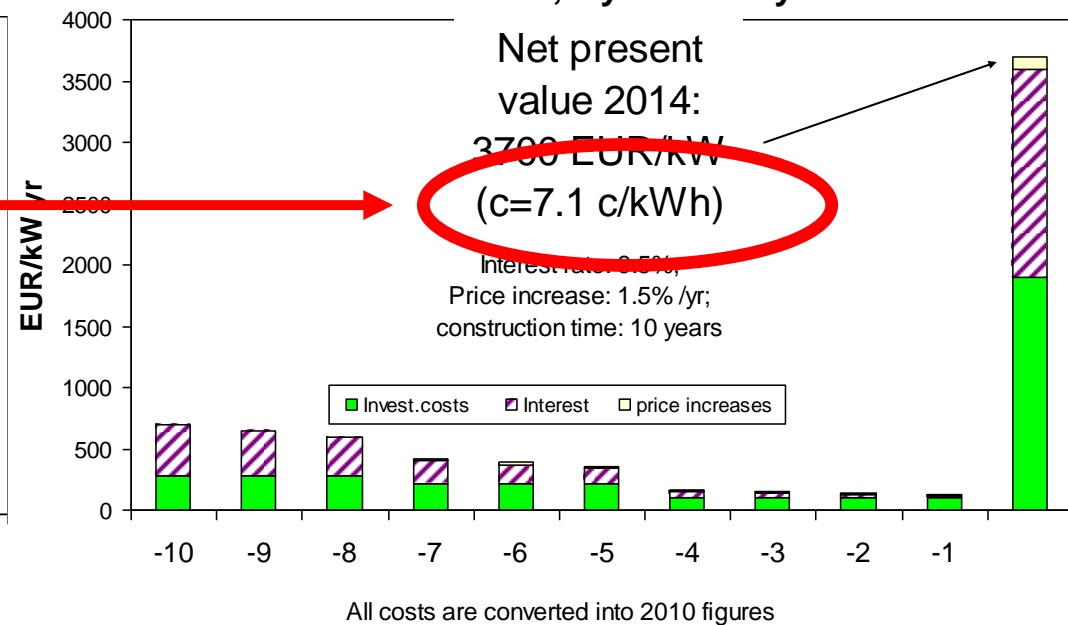
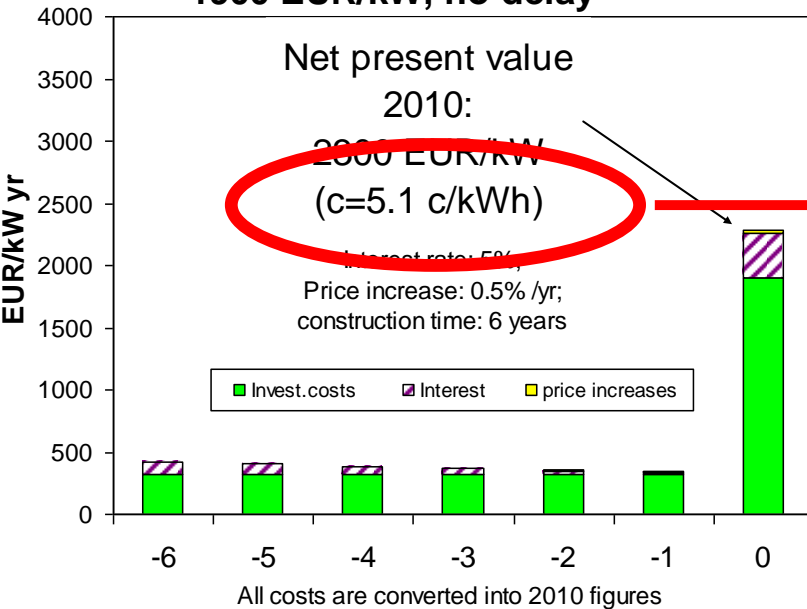
Olkiluoto: Overnight costs 2004:  
1900 EUR/kW, 4 years delay



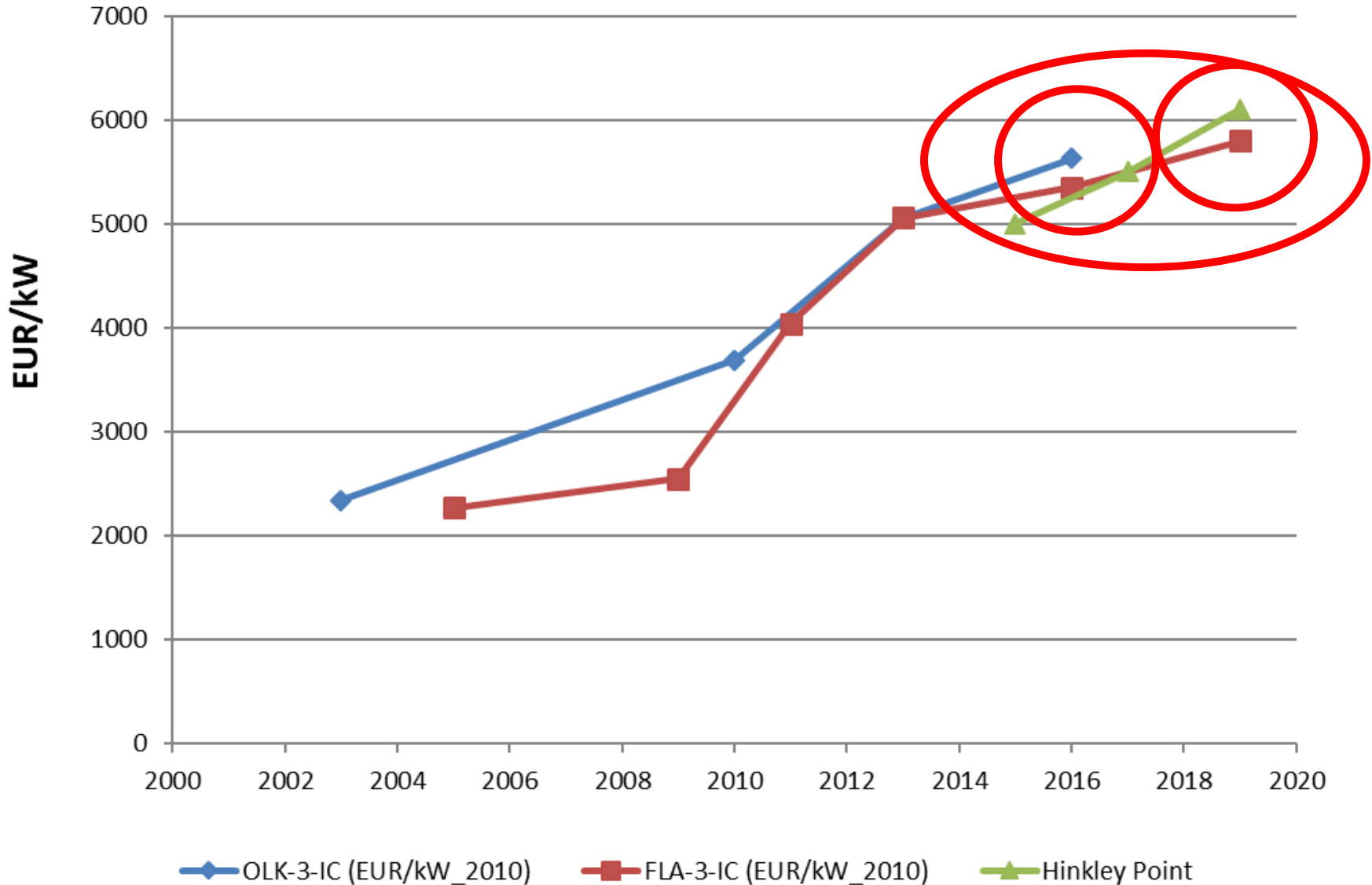
All costs are converted into 2010 figures

**Olkiluoto: Overnight costs 2004:  
1900 EUR/kW, no delay**

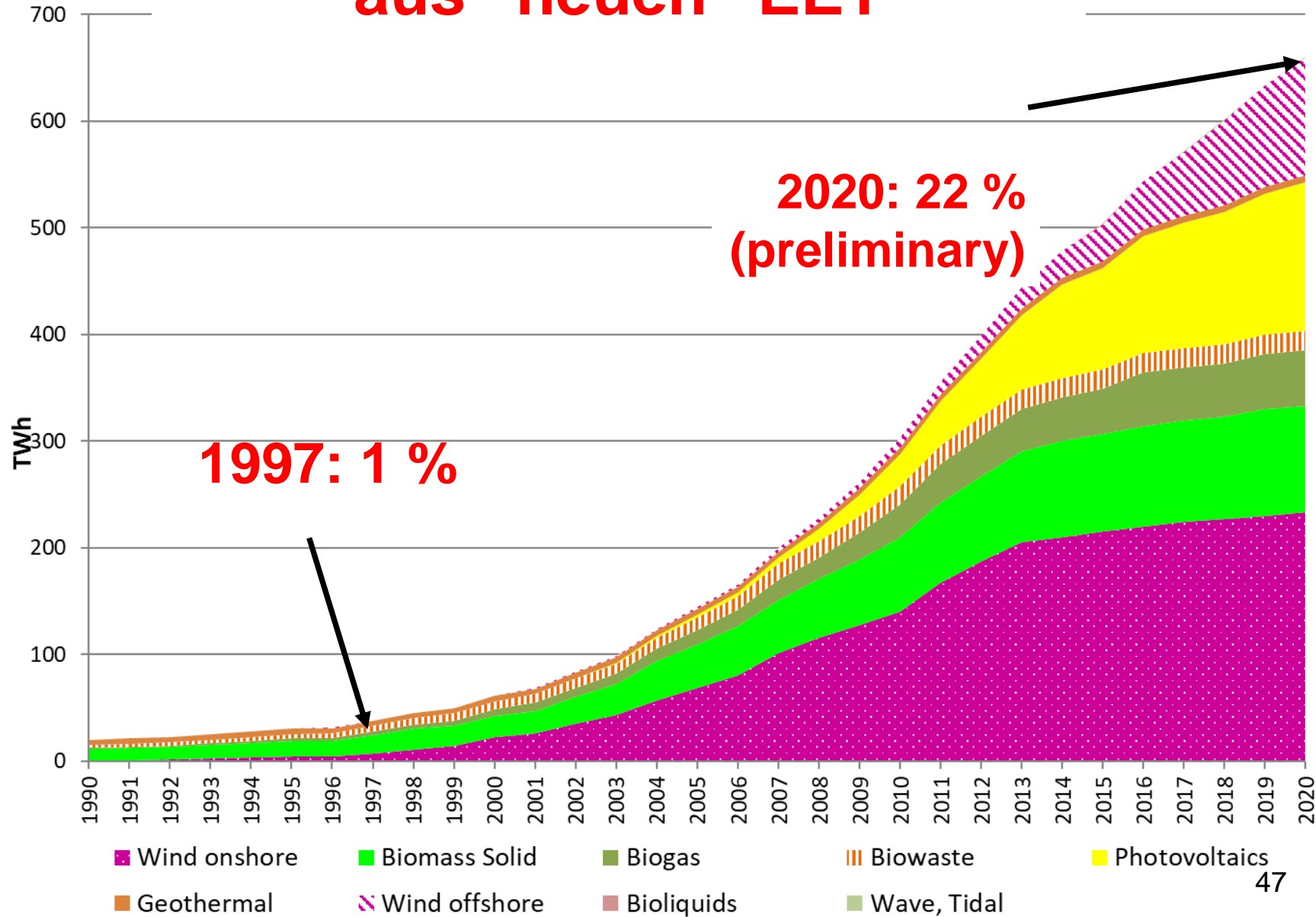
**Olkiluoto: Overnight costs 2004:  
1900 EUR/kW, 4 years delay**



# Investment cost development Olkiluoto 3 vs Flamanville 3 vs HP

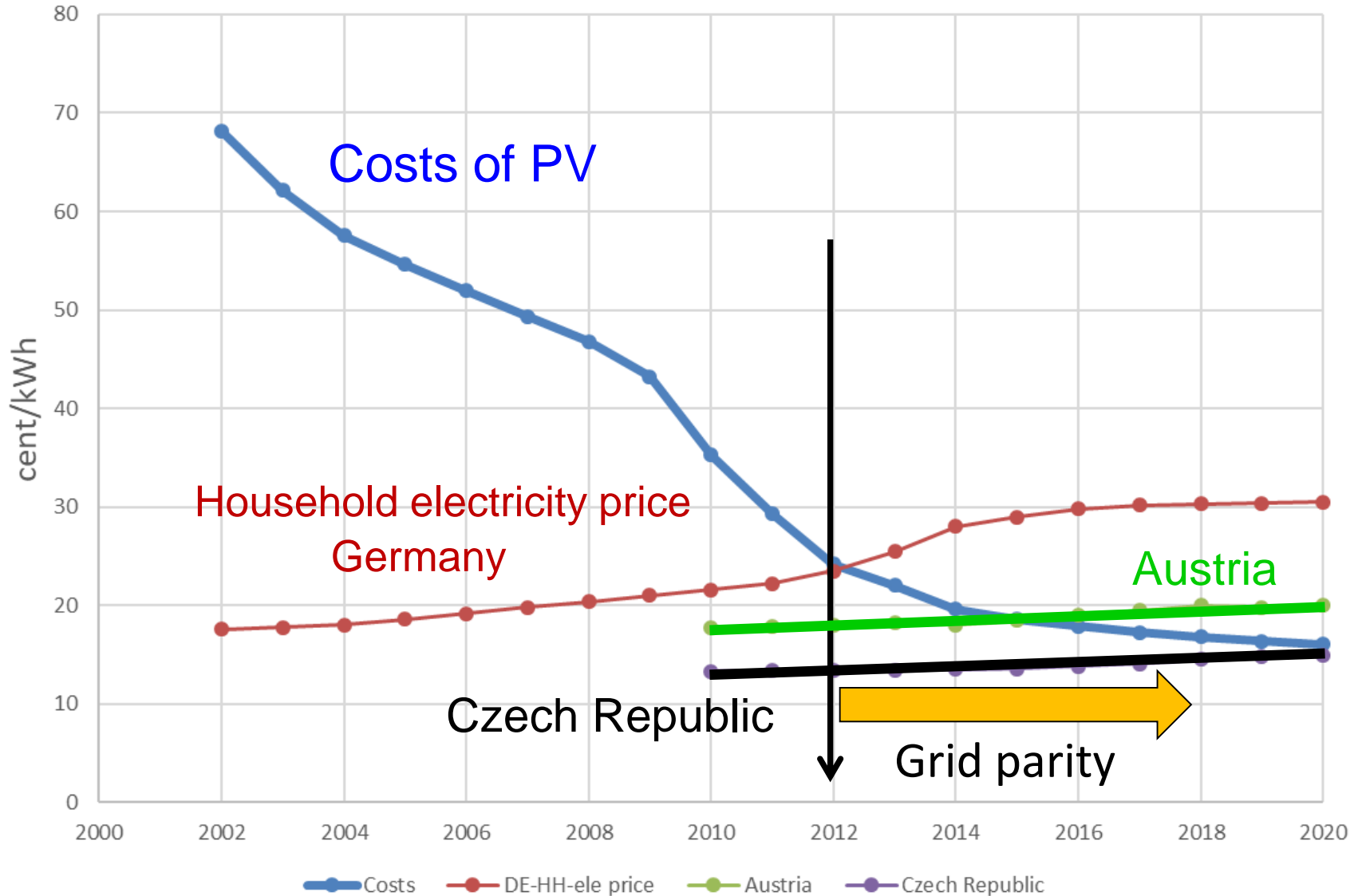


# 7. EU-28: Stromerzeugung aus "neuen" EET





# Grid parity: PV-costs and household electricity prices



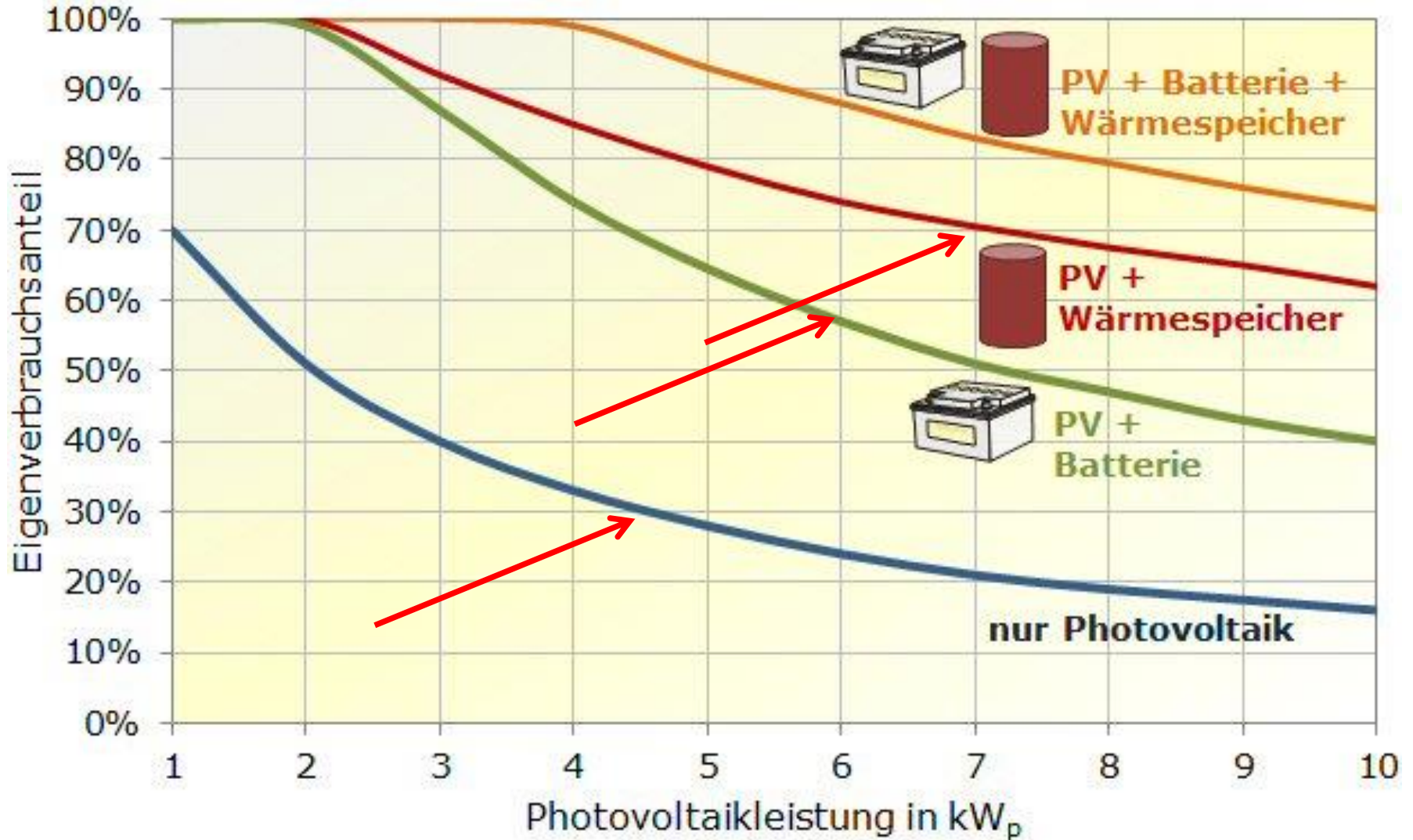
# Assessment of Grid Parity

$$\begin{array}{c}
 \text{Savings/revenues} \qquad \qquad \qquad \text{Costs} \\
 \hline
 \text{E}_{\text{Own}} * \text{P}_{\text{HH}} + \text{E}_{\text{Feed-in}} * \text{P}_{\text{feed-in}} > \text{Annuity}
 \end{array}$$

Grid parity term

Subsidy still necessary?

# Share of own consumption

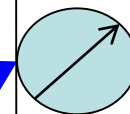


# Tenant electricity model and Blockchain

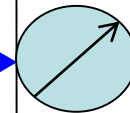
PV-System on the roof

Tenant electricity model:  
Contracted PV-electricity

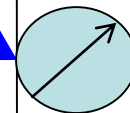
**Balancing  
Group/  
Supplier**



Customer 1



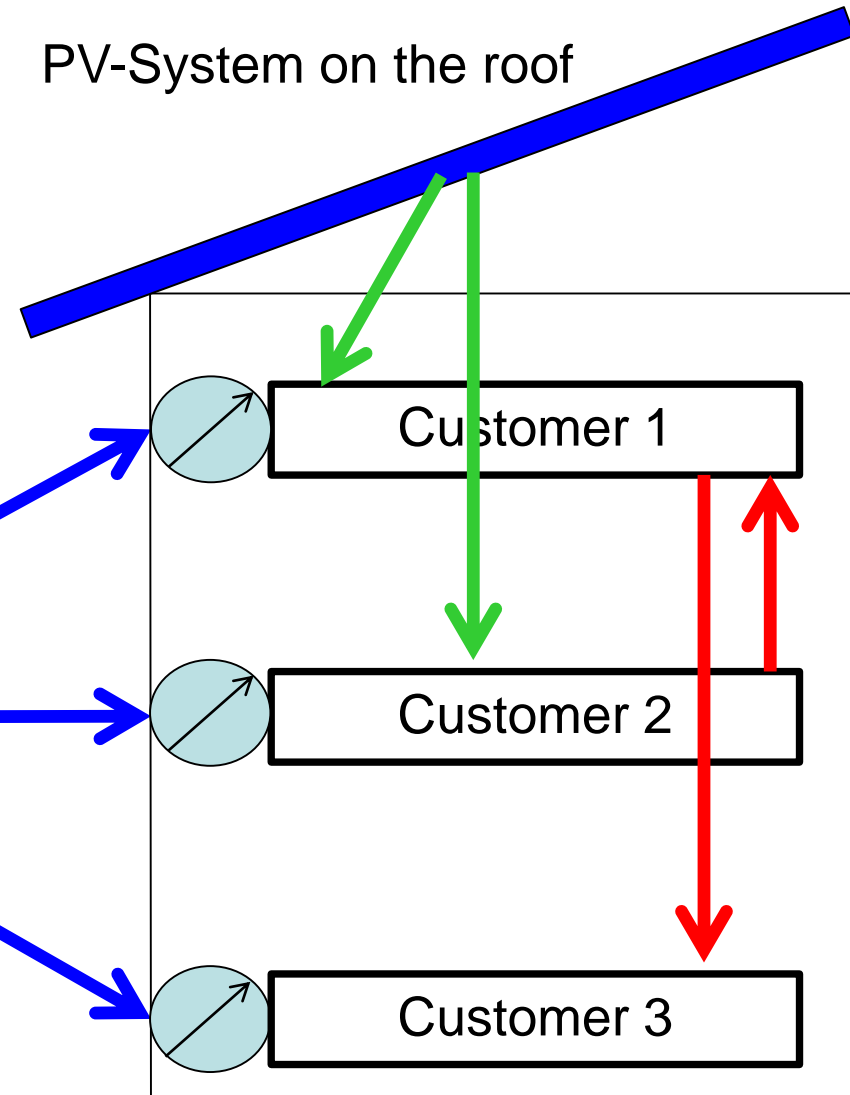
Customer 2



Customer 3

Meter

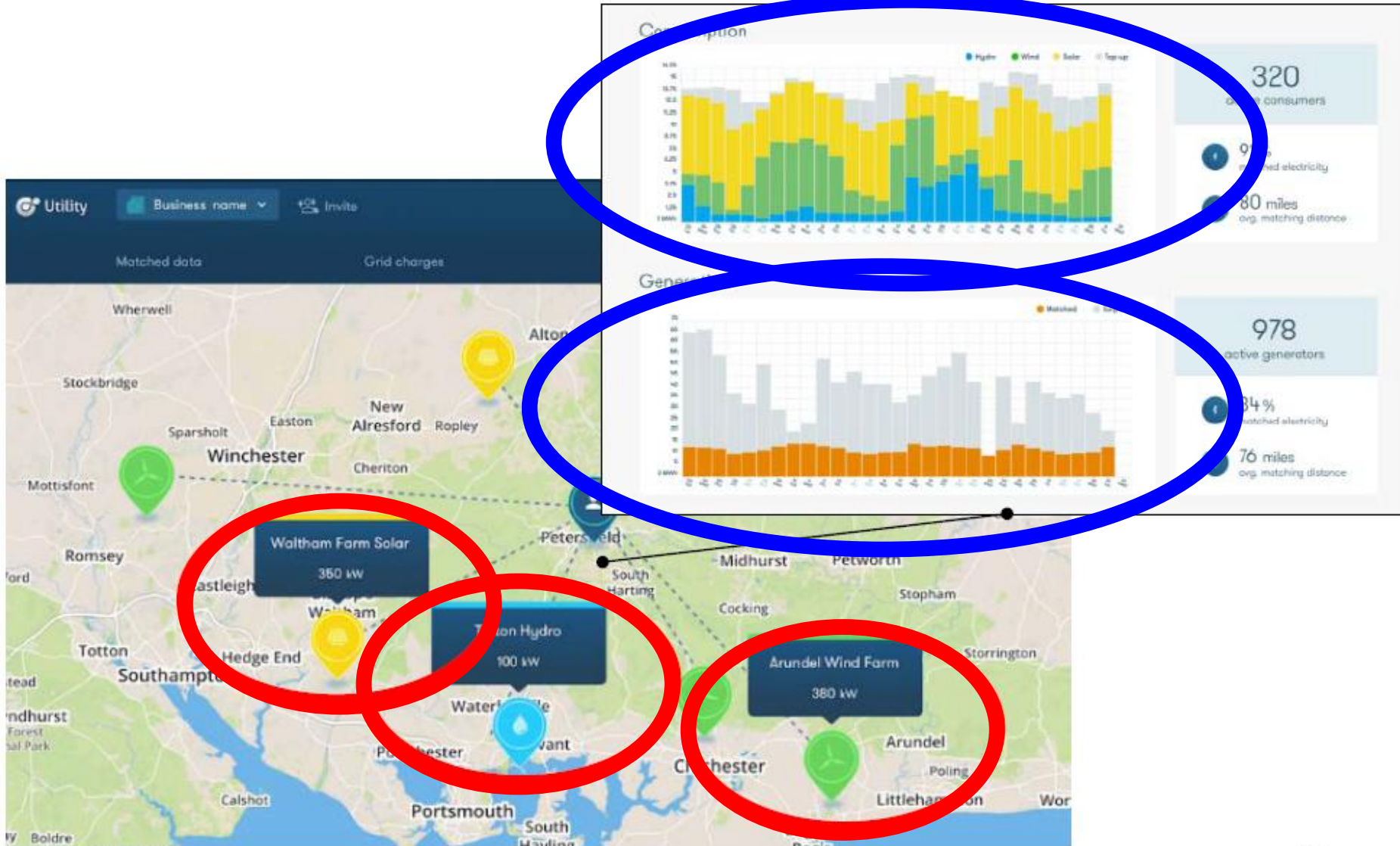
Blockchain



# Promotion of decentralized PV in Czech Republic

- Program is opened for family houses and blocks of flats
- Currently 3rd call for family houses includes:
  - PV systems for power: \*below 10 kWp,  
\* should be connected to the grid
- Systems with and without batteries with utilization of excess electricity for hot water or general own use are subsidized
- Generated power should be used on site of generation at least by 70%

# Peer-to-peer

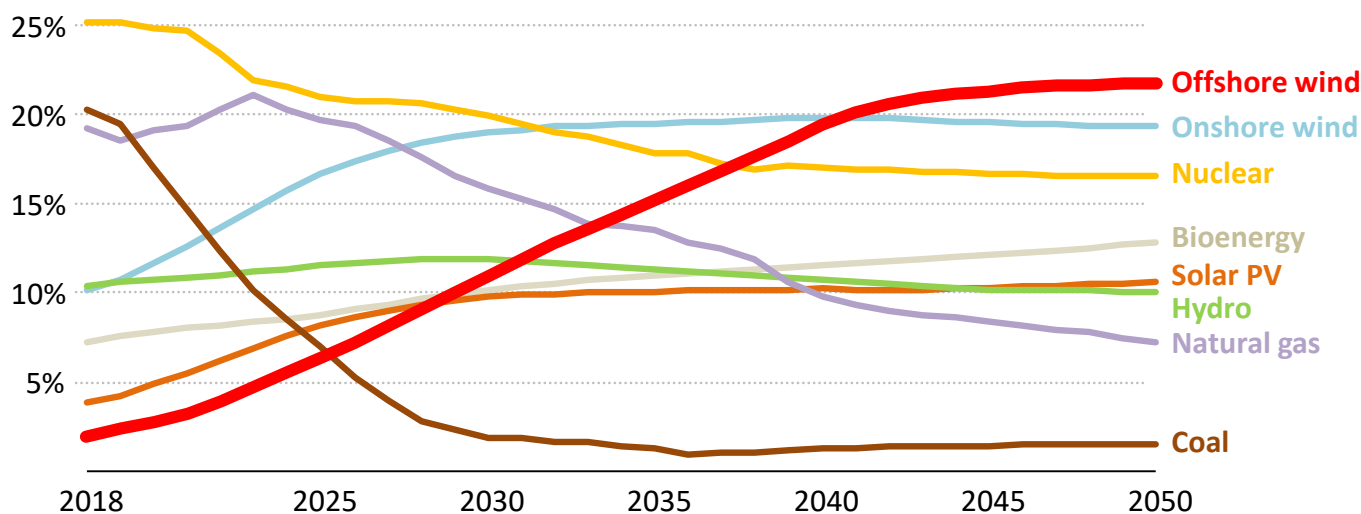


12/04/2017

Source: piclo.co.uk

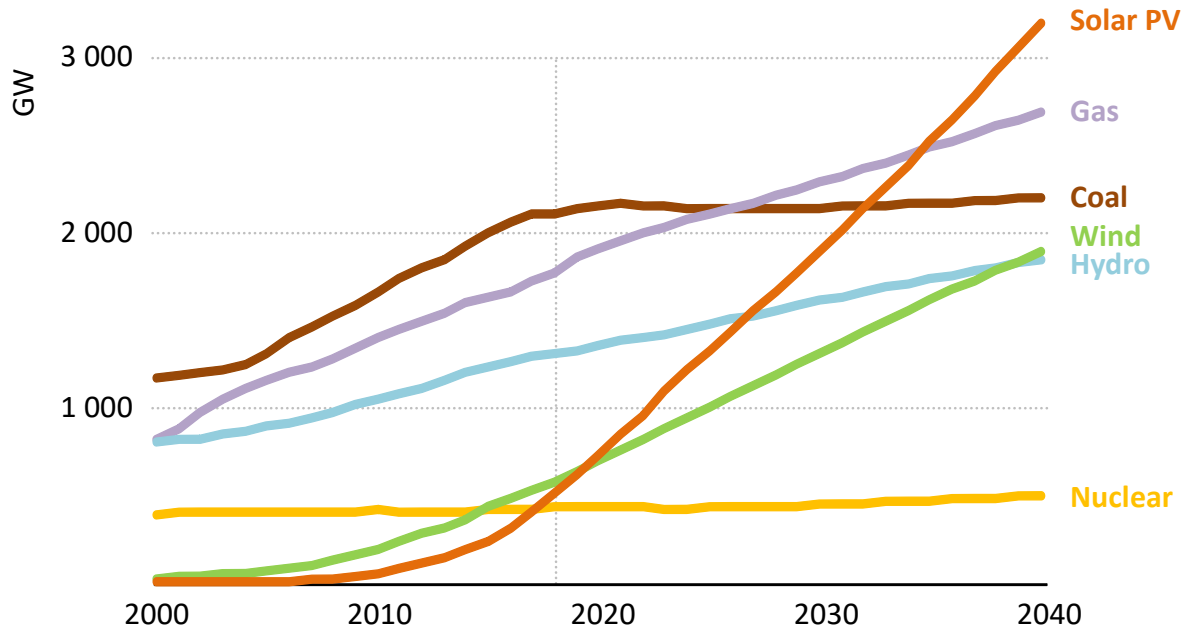
## A carbon neutral Europe puts offshore wind in front

Shares of electricity generation by technology in the European Union, Sustainable Development Scenario



Offshore wind is set to become the largest source of electricity in the European Union by 2040, complementing other renewables towards a fully decarbonised power system

Global power capacity by source in the Stated Policies Scenario



The power mix is being re-shaped by the rise of renewables and natural gas. In 2040, renewables account for nearly half of total electricity generation.





# Example: Costs of electricity generation from CCGT

6000 h/yr:

Low fuel & CO<sub>2</sub>-price:

$$C = 1.0 + 0.33 + 1.72 + 0.17 = 3.22 \text{ cent/kWh}$$

High fuel & CO<sub>2</sub>-price:

$$C = 1.0 + 0.33 + 4.31 + 0.86 = 6.50 \text{ cent/kWh}$$

1000 h/yr:

Low fuel & CO<sub>2</sub>-price:

$$C = 6.0 + 2.0 + 1.72 + 0.17 = 9.89 \text{ cent/kWh}$$

High fuel & CO<sub>2</sub>-price:

$$C = 6.0 + 2.0 + 4.31 + 0.86 = 13.17 \text{ cent/kWh}$$