ELECTRICITY MARKETS AND THE ROLE OF RENEWABLES & NUCLEAR

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SURVEY

1. Introduction
2. How prices come about (theory)
3. How prices developed in Europe
4. Environmental issues: CO2-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?

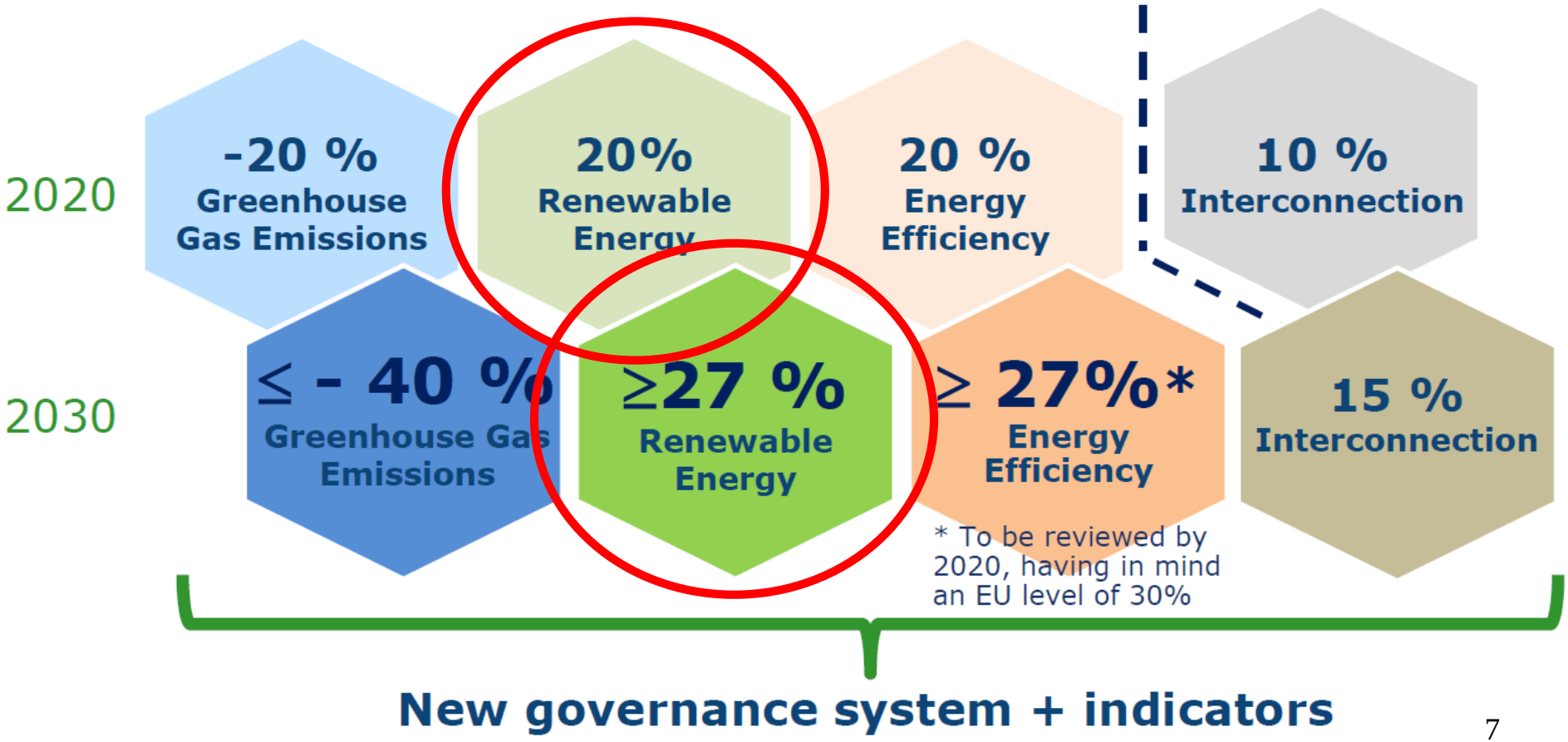
THE EU-DIRECTIVE(S) 1

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

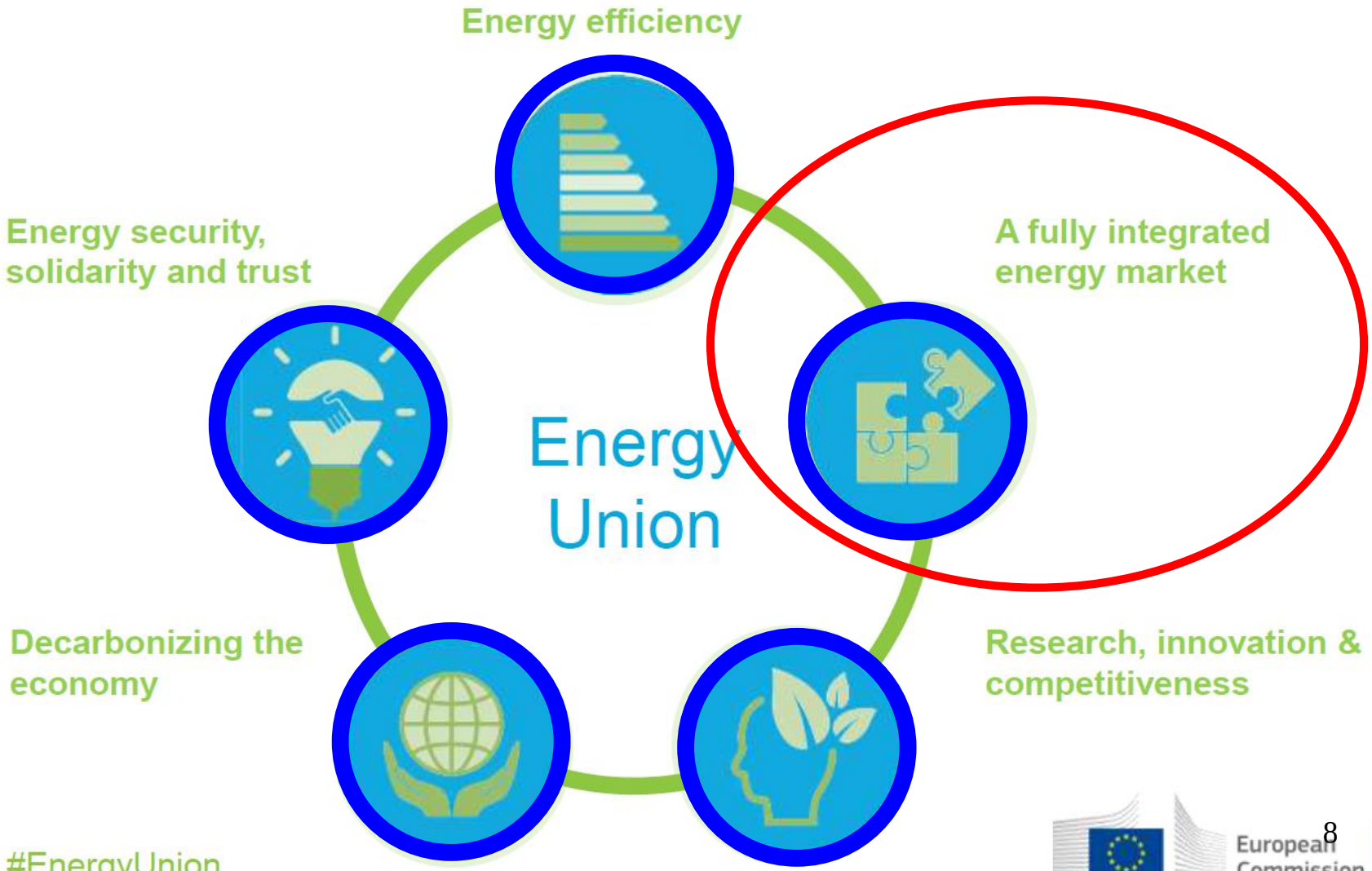
"market forces [would] produce a better allocation of resources and greater effectiveness in the supply of services"

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

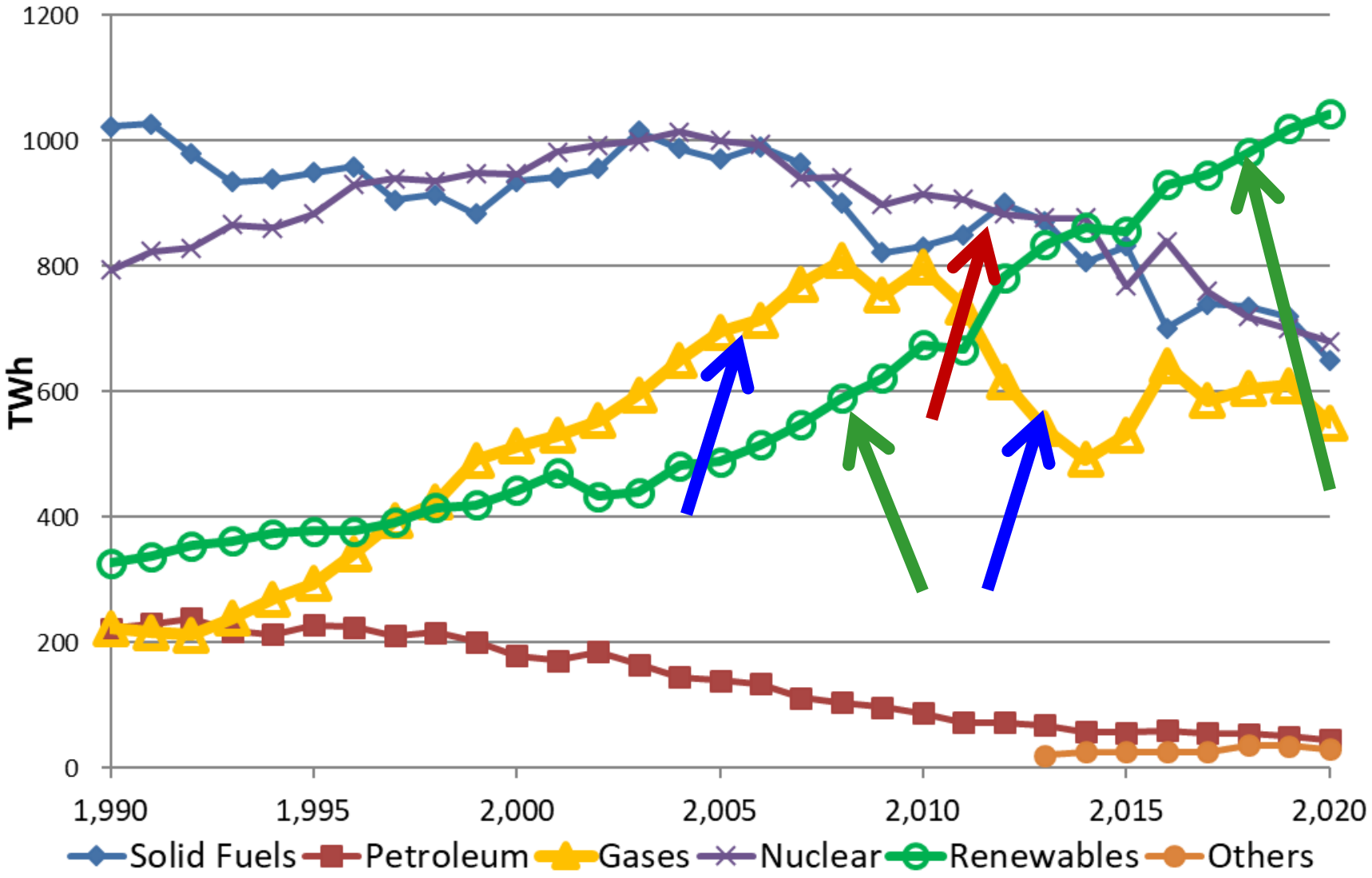
Strategic decision by European Council in 2014



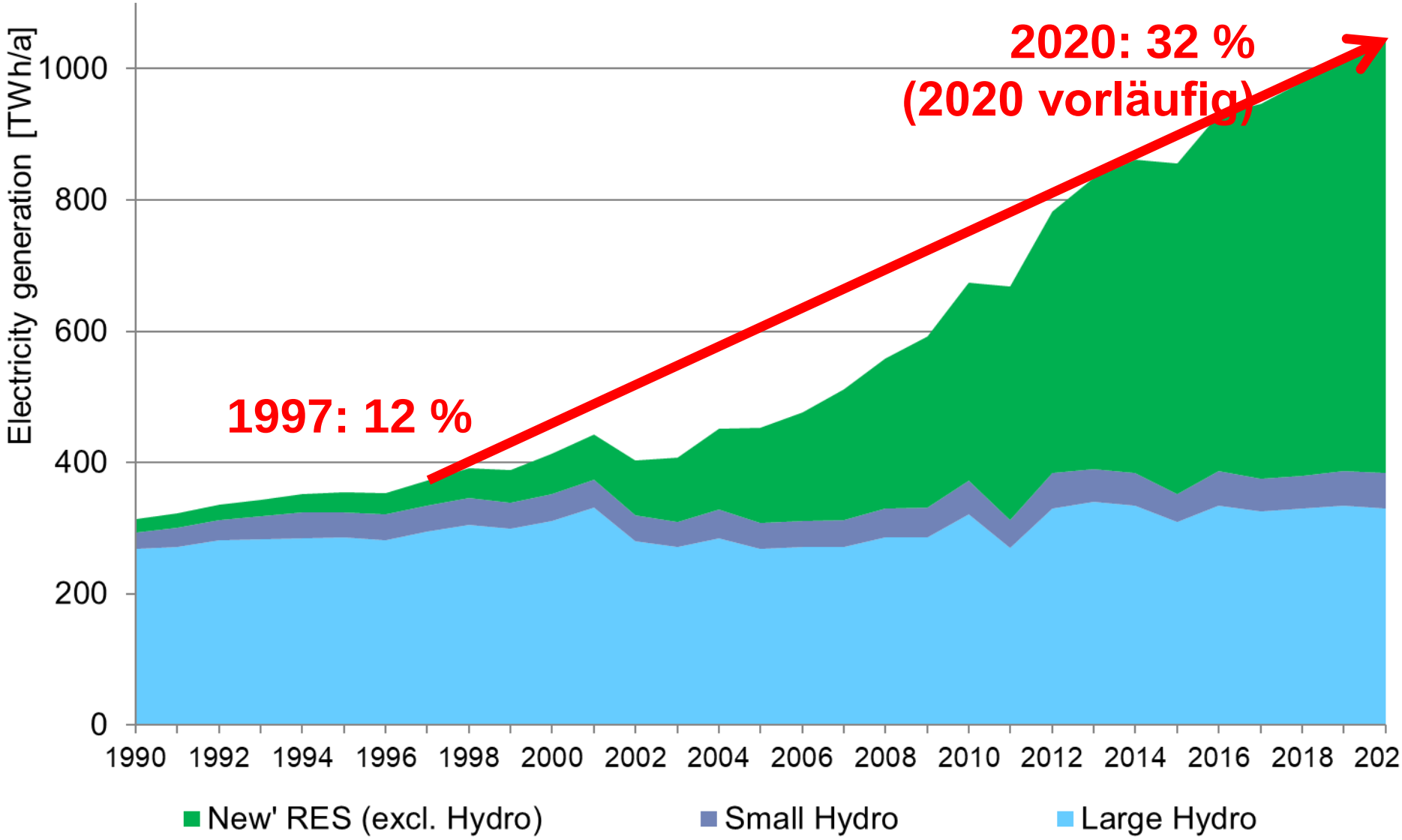
Energy Union Strategy



Electricity generation EU-28

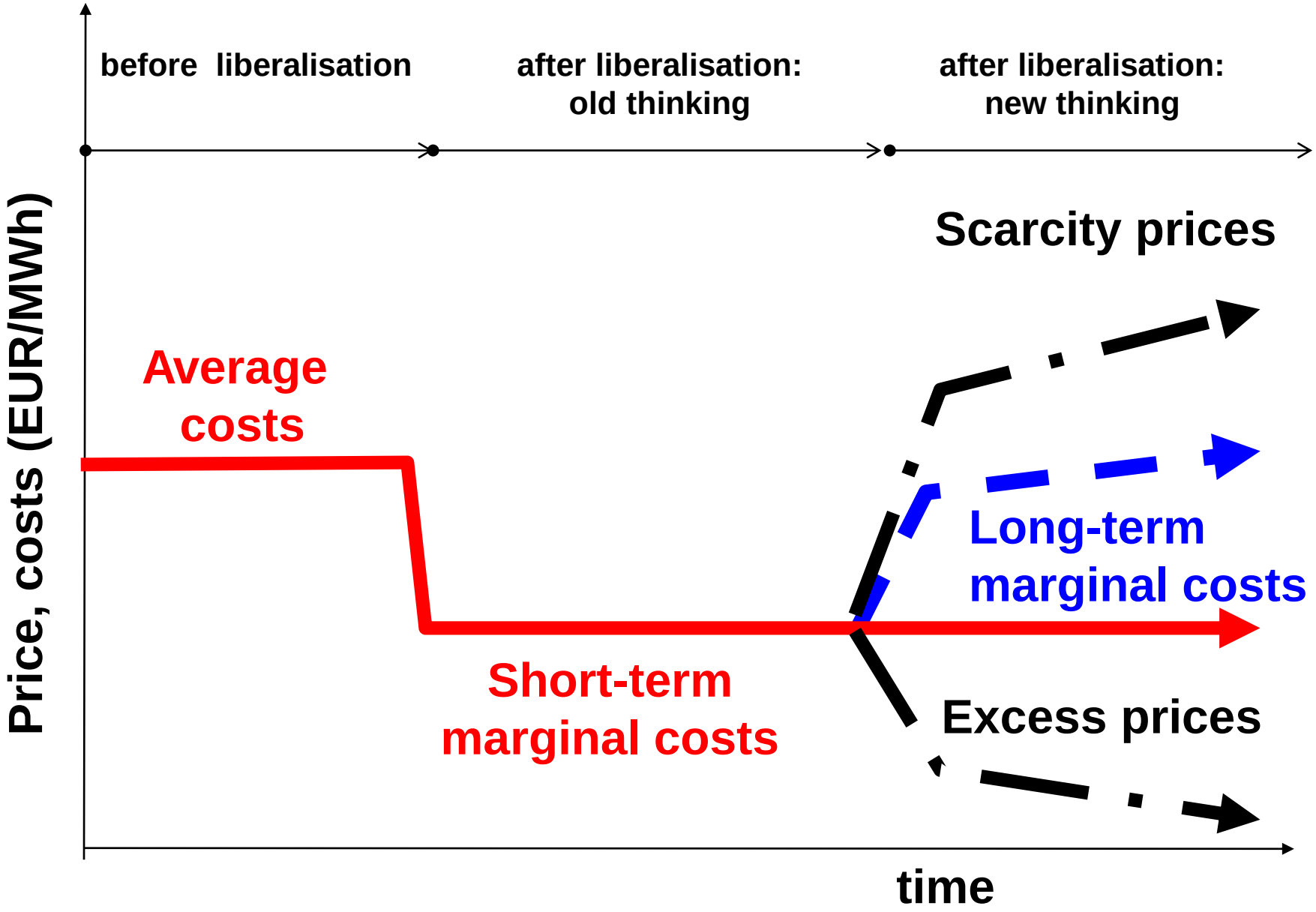


Electricity generation RES EU-28



Source: EUROSTAT, own estimations

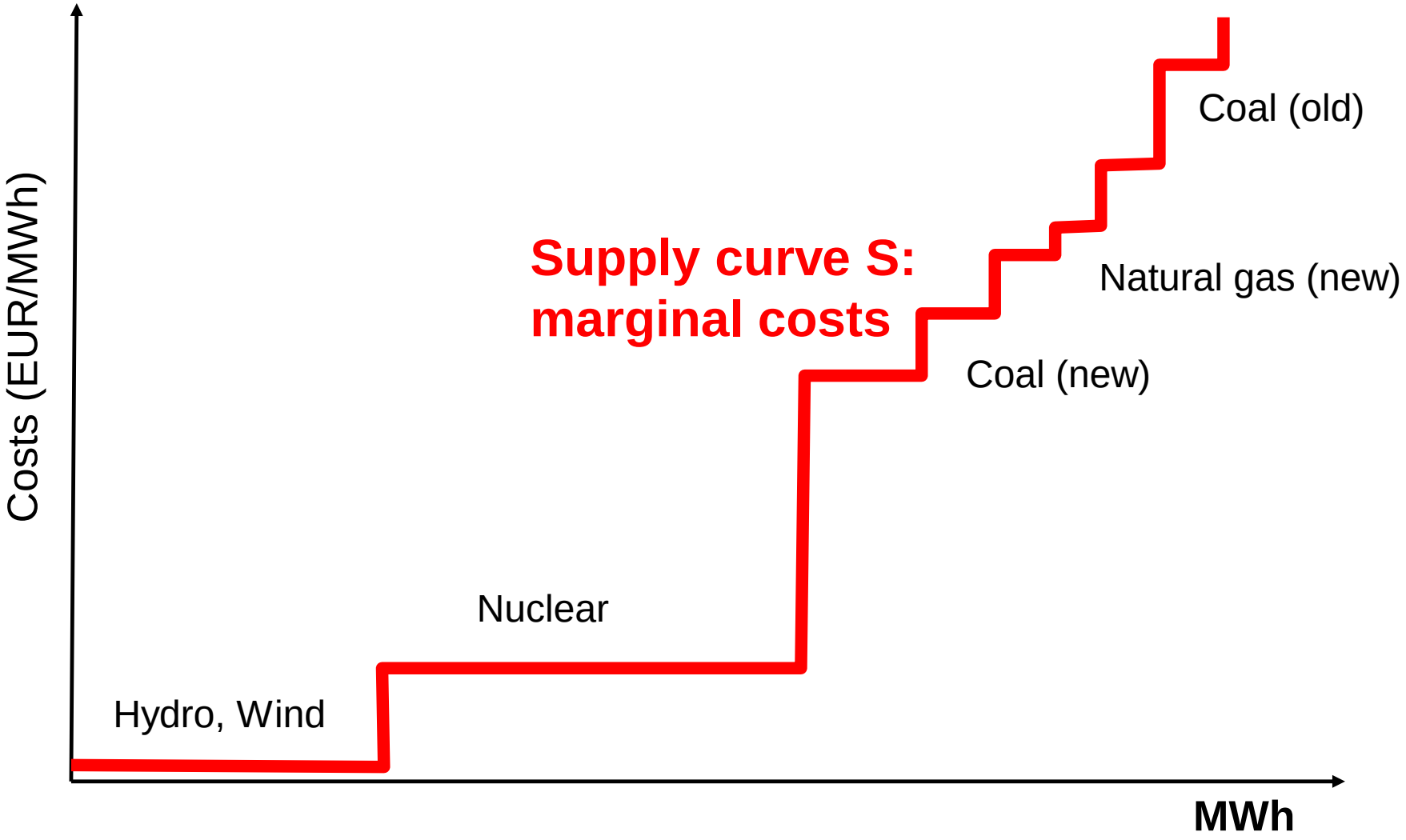
2. How prices come about: Three periods of market design



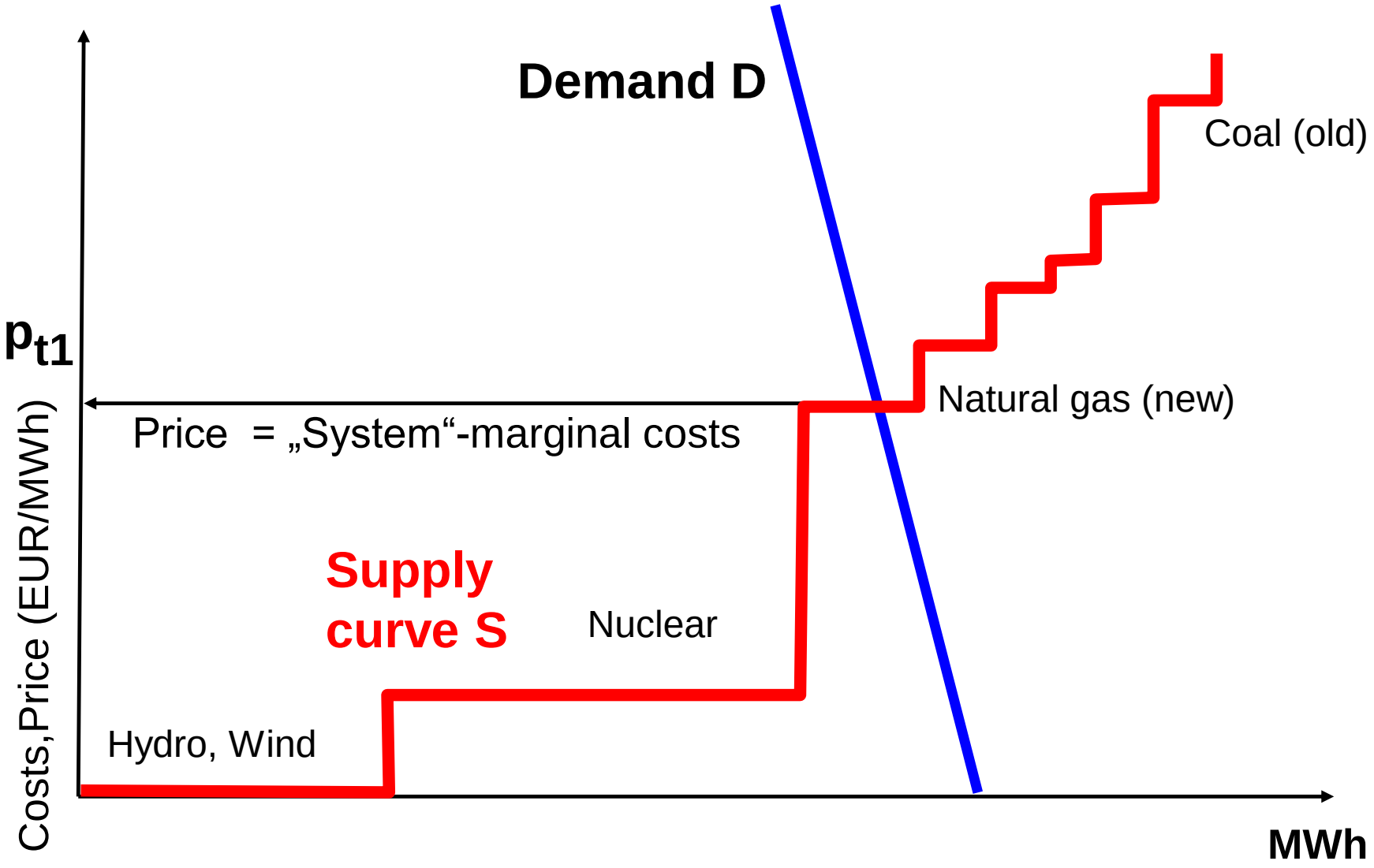
2. How prices come about

THE *MERIT-ORDER* CURVE OF SUPPLY

based on short-term marginal costs (MC)



BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



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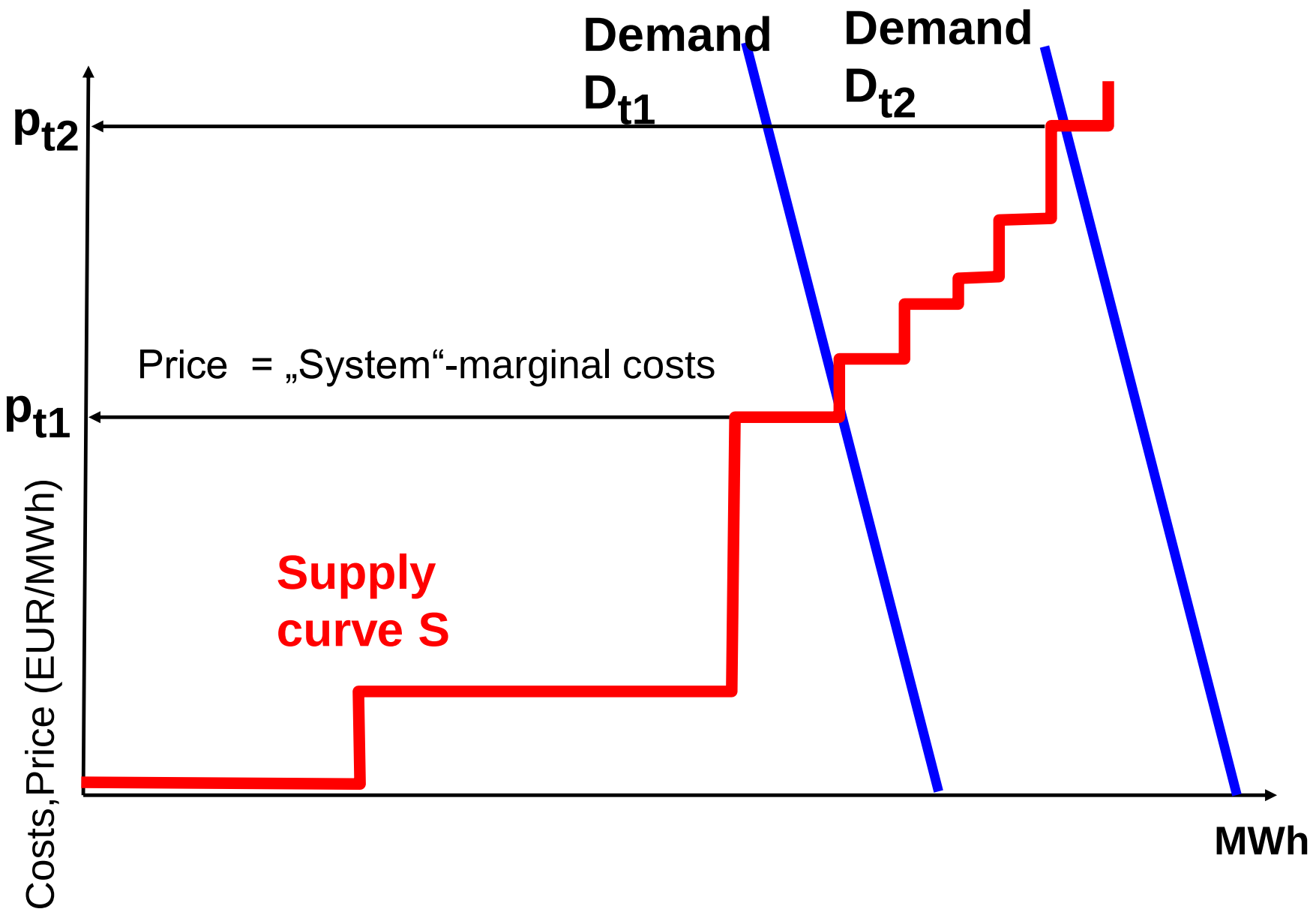


LONG-TERM
VS
SHORT-TERM
MARGINAL COSTS

What are marginal costs (MC)?

$$MC = C'(X) = dC(x)/dX$$

Marginal costs are the increment of costs due to a generation of one additional unit of kWh

$$P = MC$$

Short-term marginal costs (STMC):

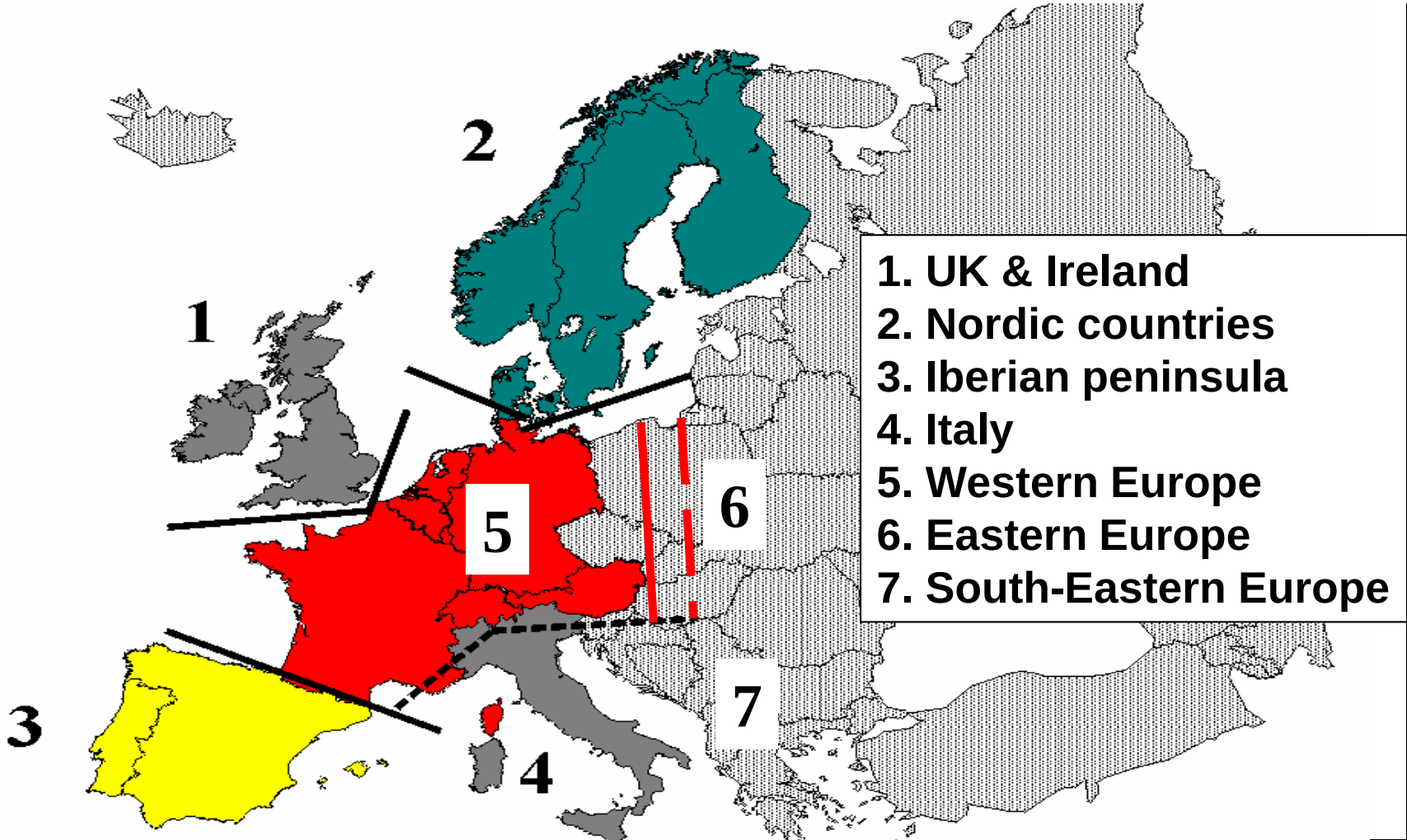
STMC= Fuel costs + CO2 costs

Long-term marginal costs (LTMC):

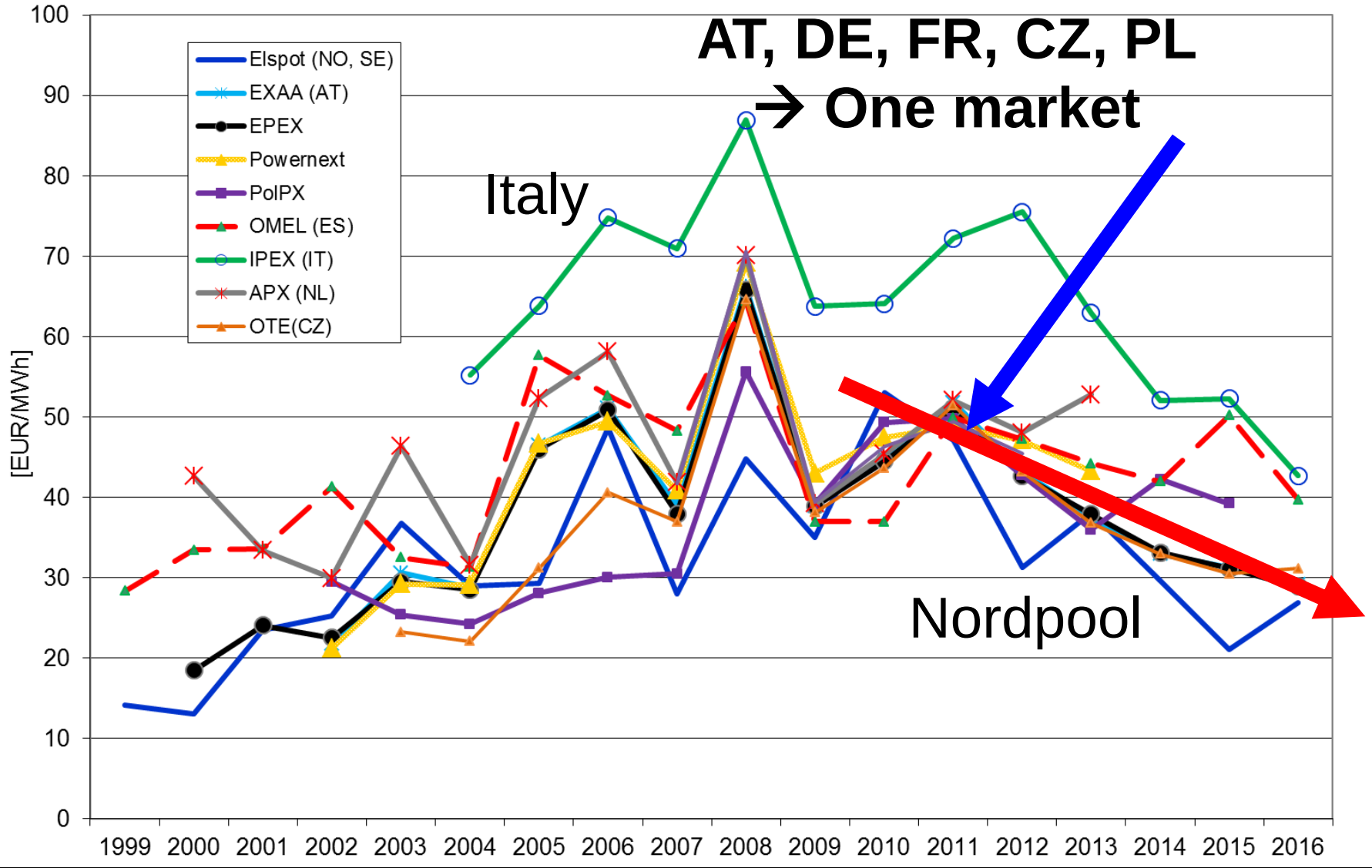
LTMC= STMC + Capital costs + O&M costs

3 HOW PRICES DEVELOPED IN EUROPE

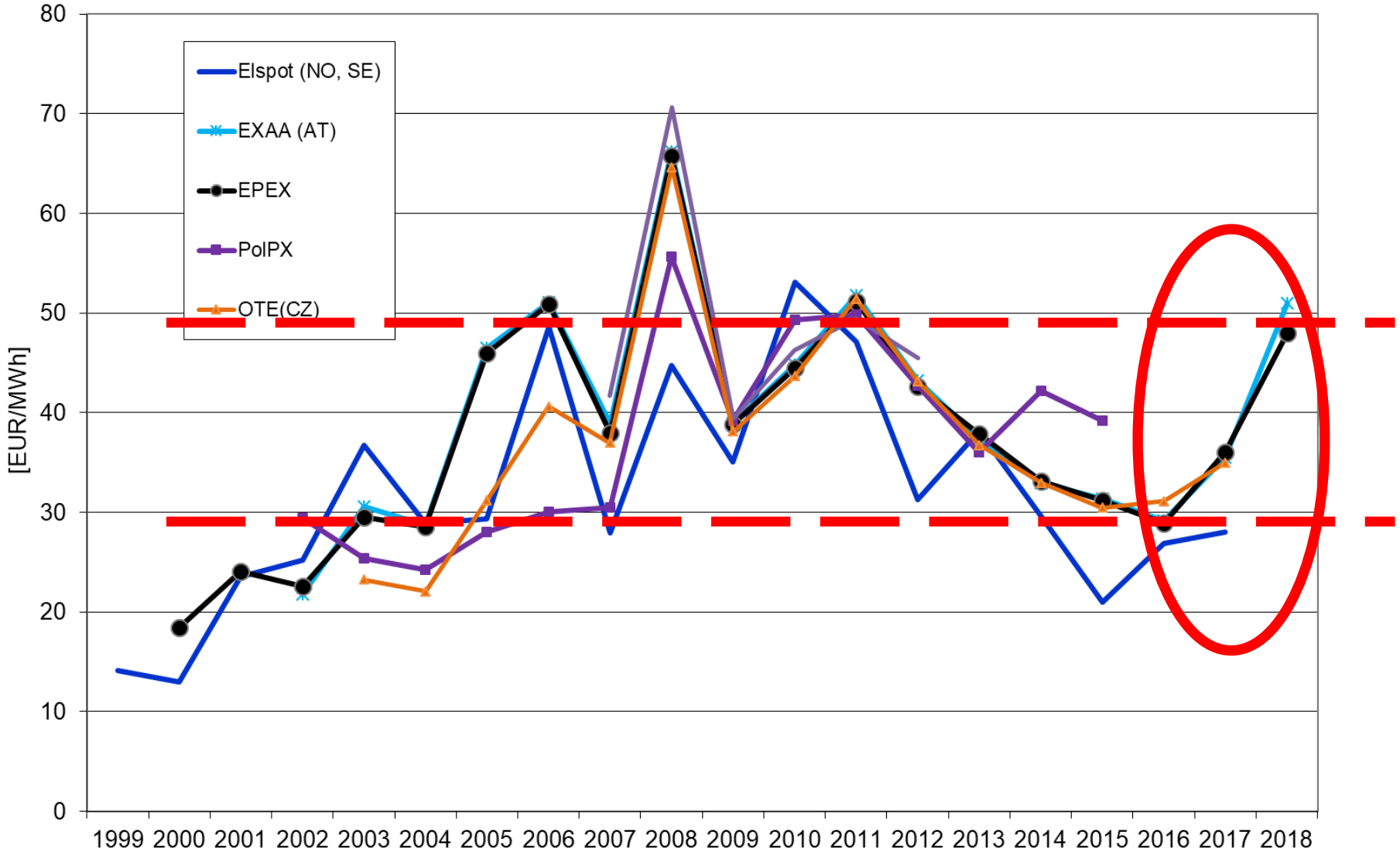
EUROPEAN ELECTRICITY SUB-MARKETS



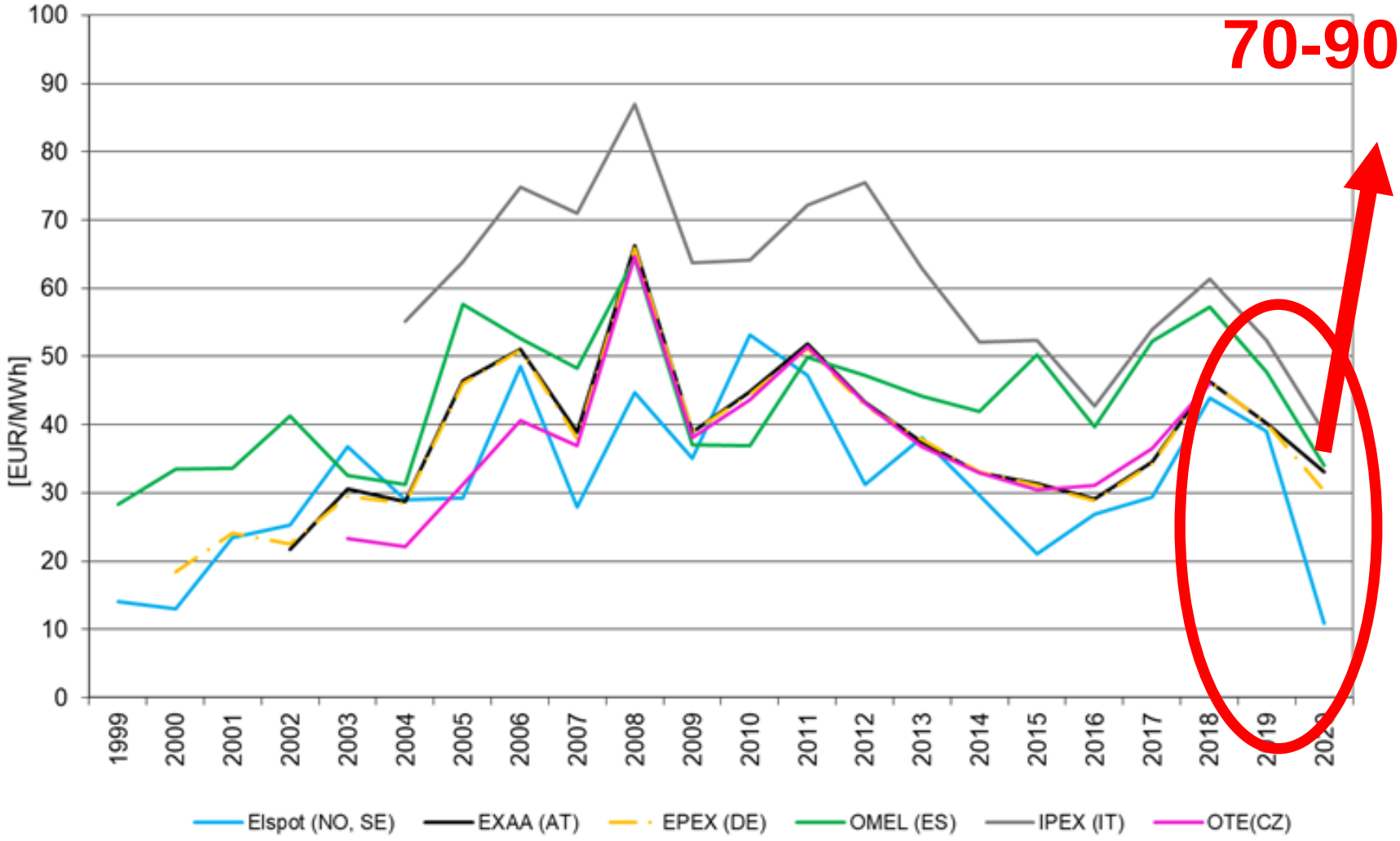
Development of day-ahead electricity prices in Europe per year (1)



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



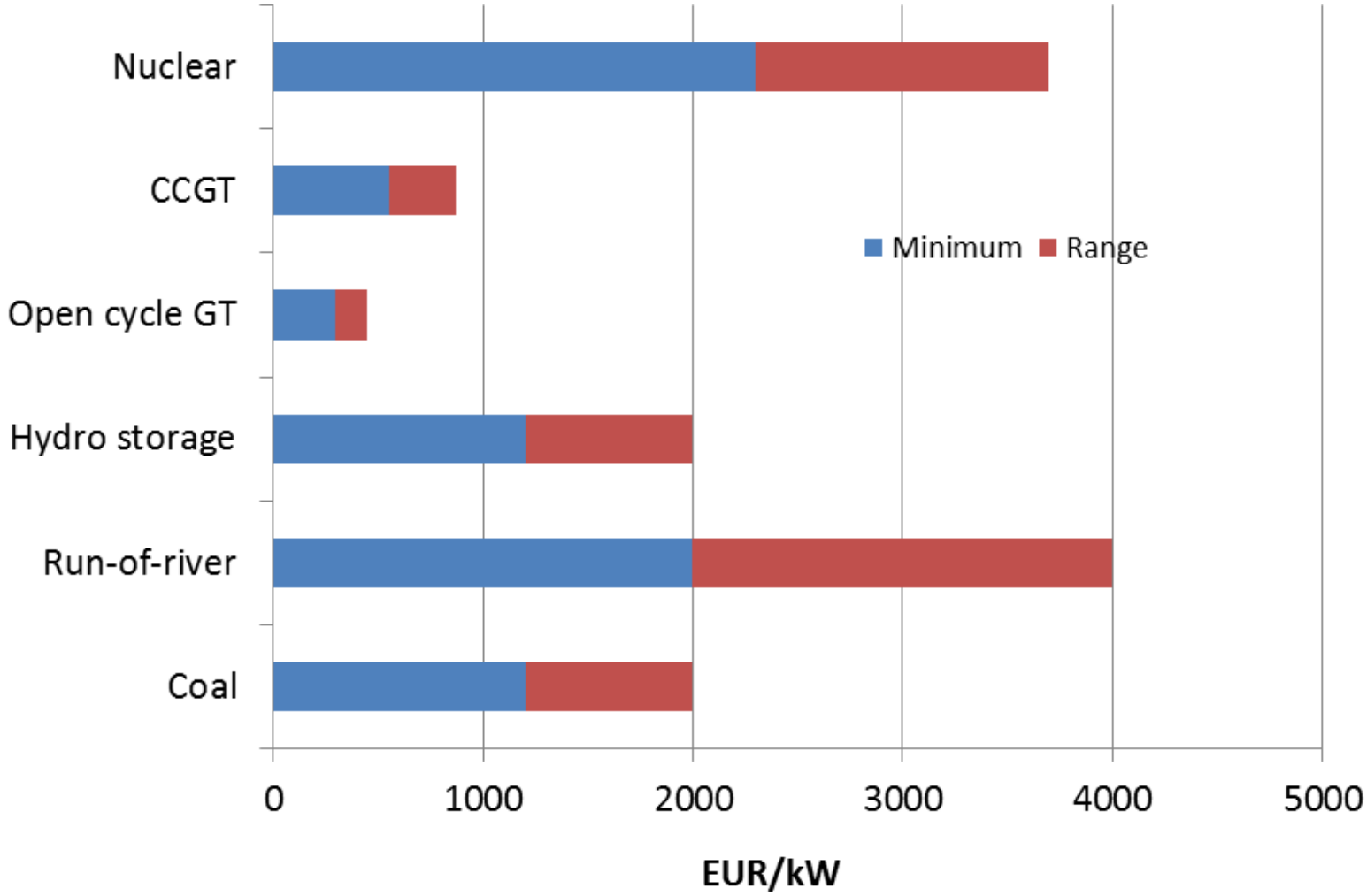
Development of electricity prices in Europe up to 2020 (3)



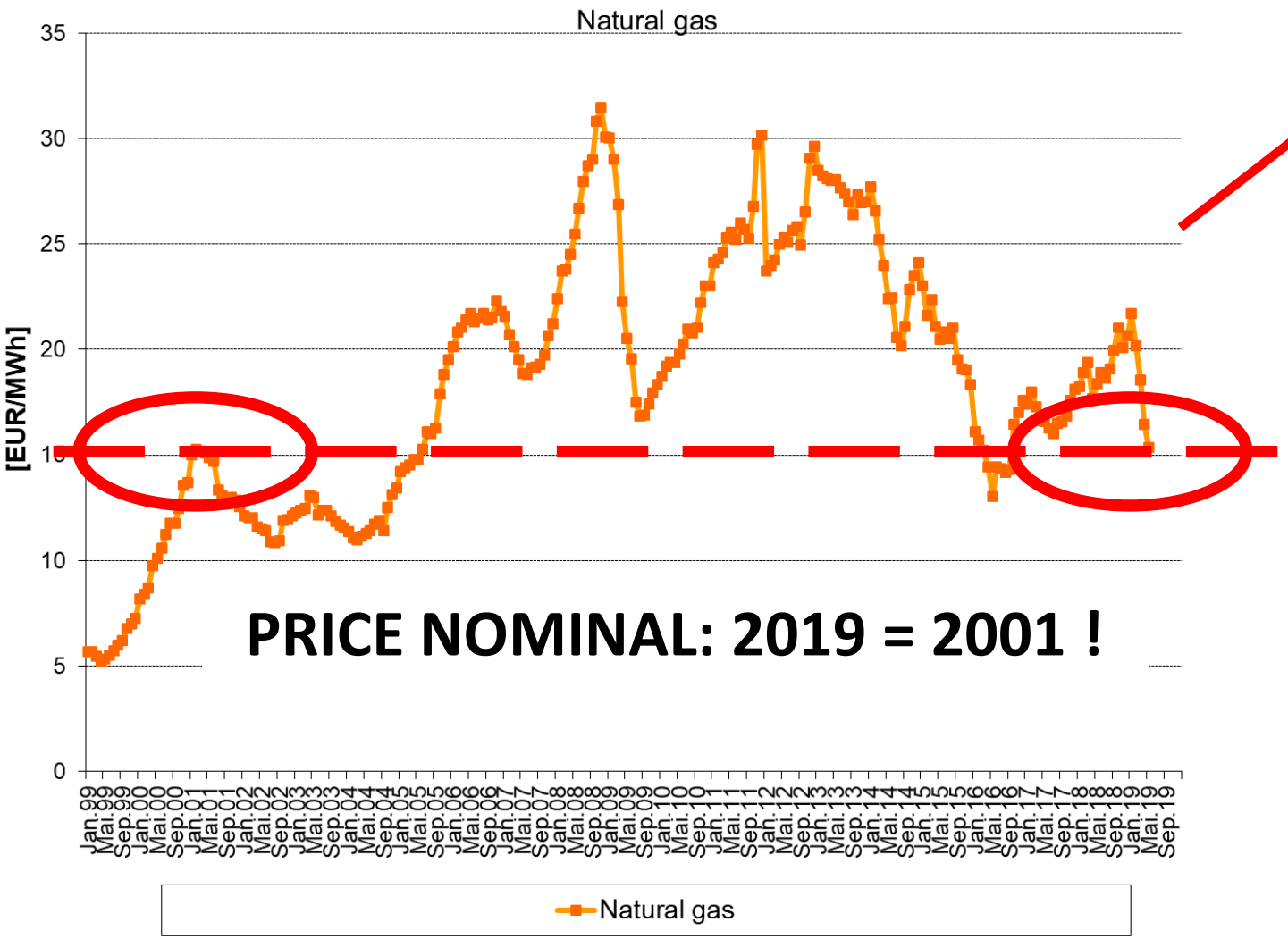
WHAT ARE IMPORTANT IMPACT PARAMETERS ON ELECTRICITY PRICES AND COSTS?

Investment costs

Electricity generation Conventional 2018



THE MARKET PRICE OF NATURAL GAS

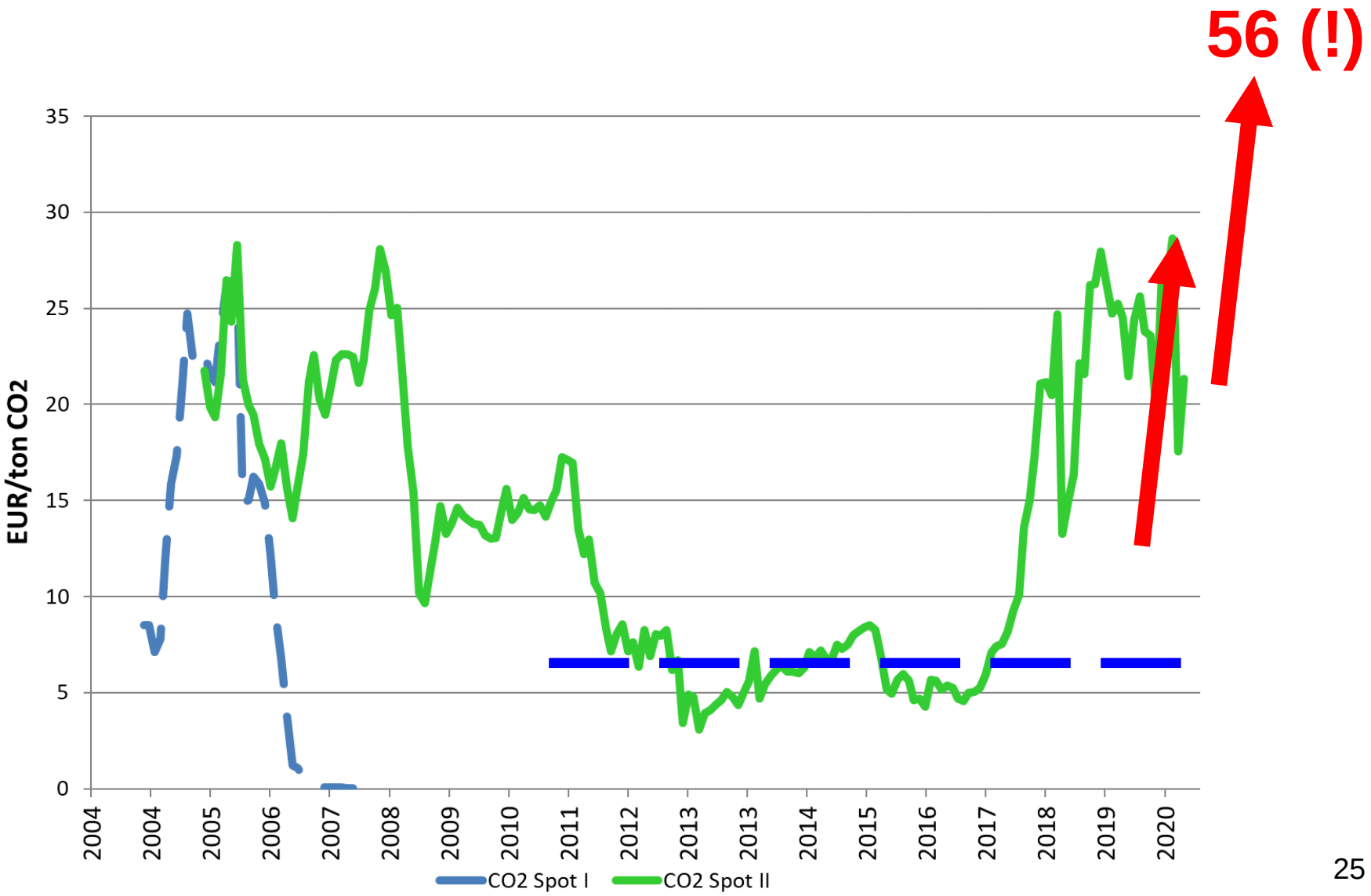


PRICE NOMINAL: 2019 = 2001 !

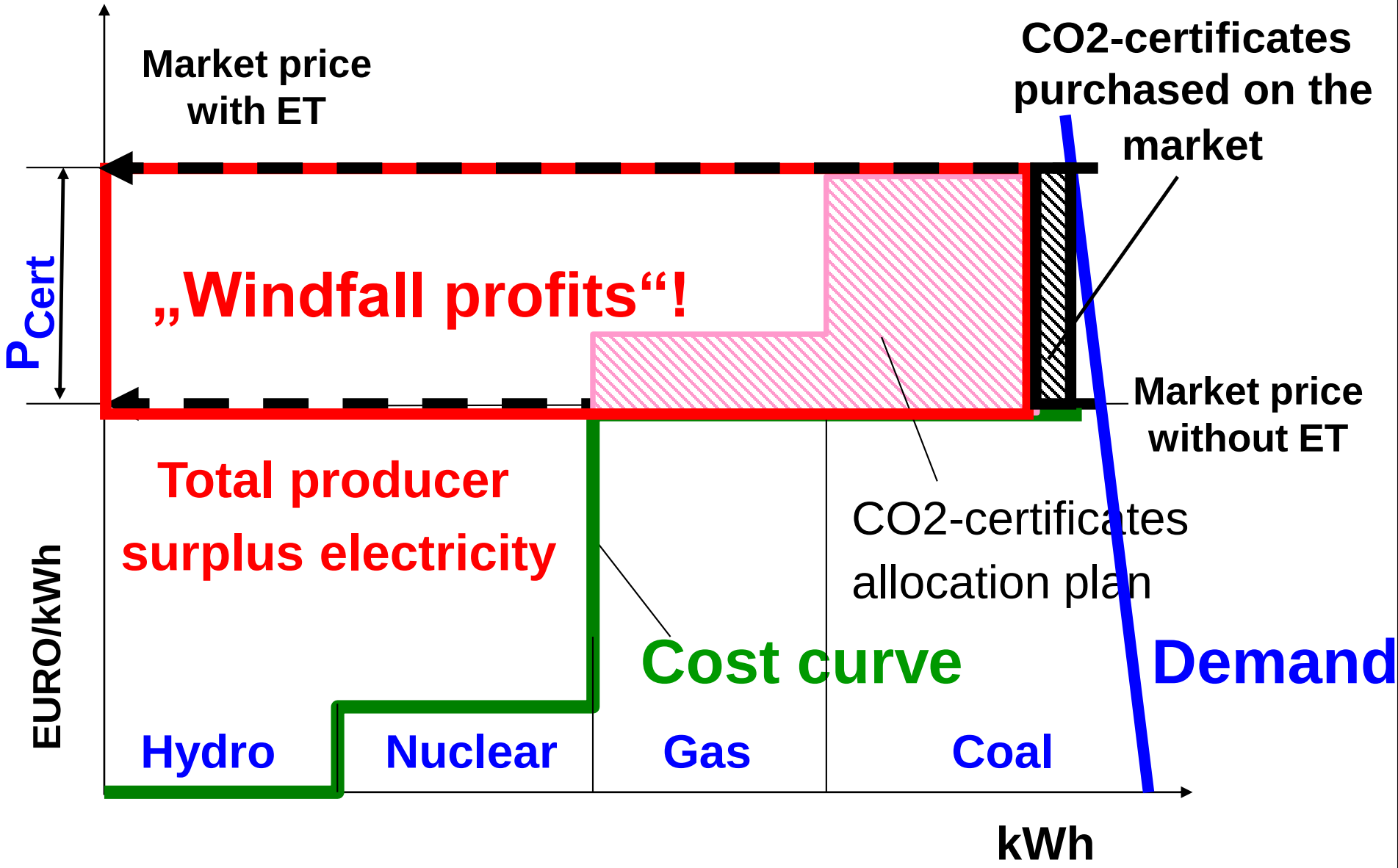
60
???

4 ENVIRONMENTAL ASPECTS – THE CO2-PRICE

The CO2-Price in Europe



EMISSION TRADING'S BENEFIT FOR ELECTRIC UTILITIES



5. Costs of electricity generation

$$C = C_F + C_V = \frac{I\,\alpha + C_{O\&M}}{T} + \frac{p_f}{H\,\eta} + \frac{C_{CO2}\,f_{CO2}}{\eta} \quad \left[\frac{\text{cent}}{\text{kWh}}\right]$$

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)

α … 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 m³)

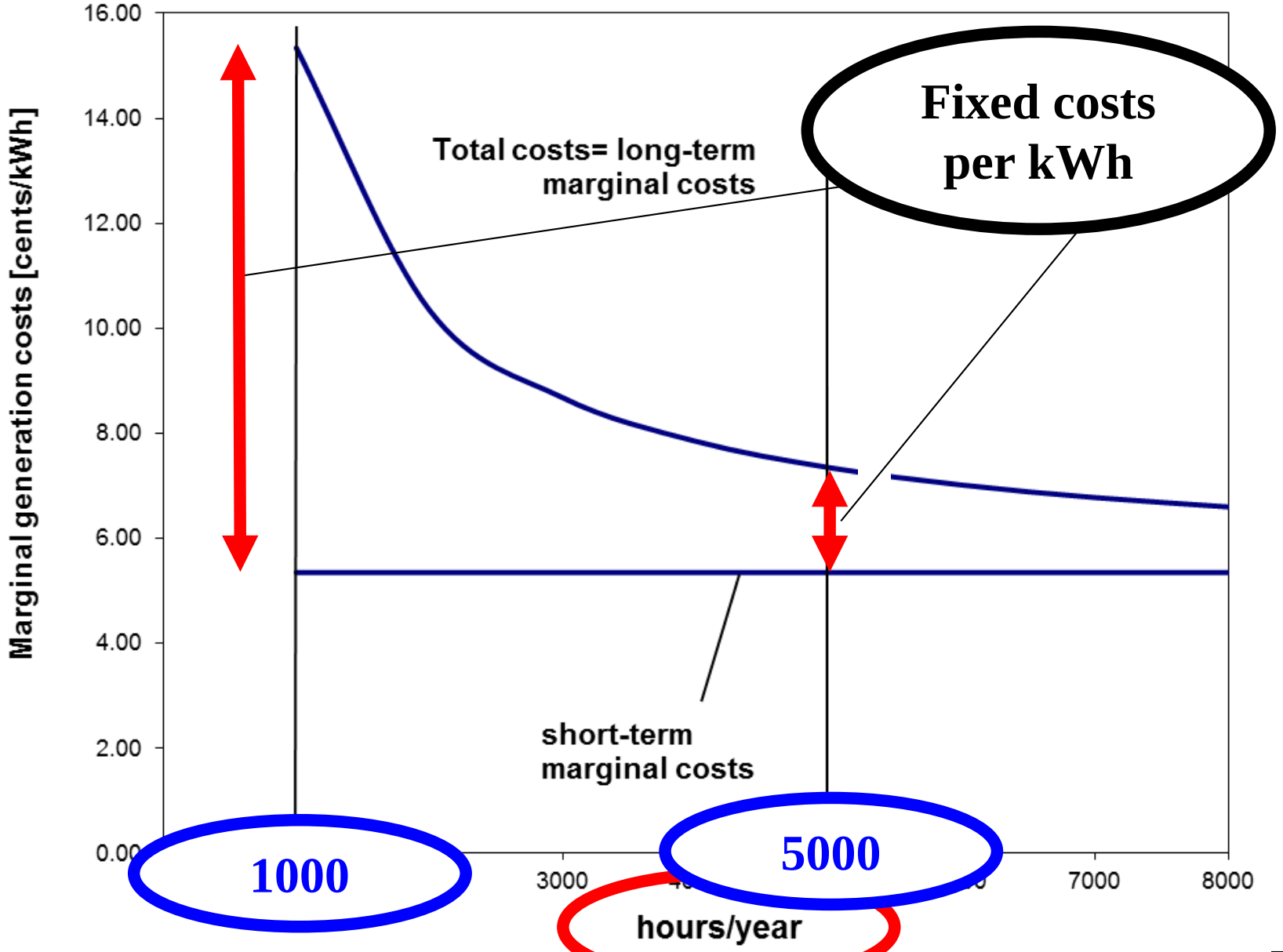
H …Caloric heat content (e.g. 10 kWh per m³ for gas)

η …Efficiency of power plant

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

f_{CO2} … 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

α … 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/m³ natural gas)

H …Caloric heat content (e.g. 10 kWh per m³ for gas)

η …Efficiency of CCGT plant = 0.58

C_{CO2} …Price of CO2: 5 EUR/ton Carbon)

f_{CO2} … CO2-factor of fuel (0.2 kg Carbon/kWh)

Example 1: Costs of electricity generation

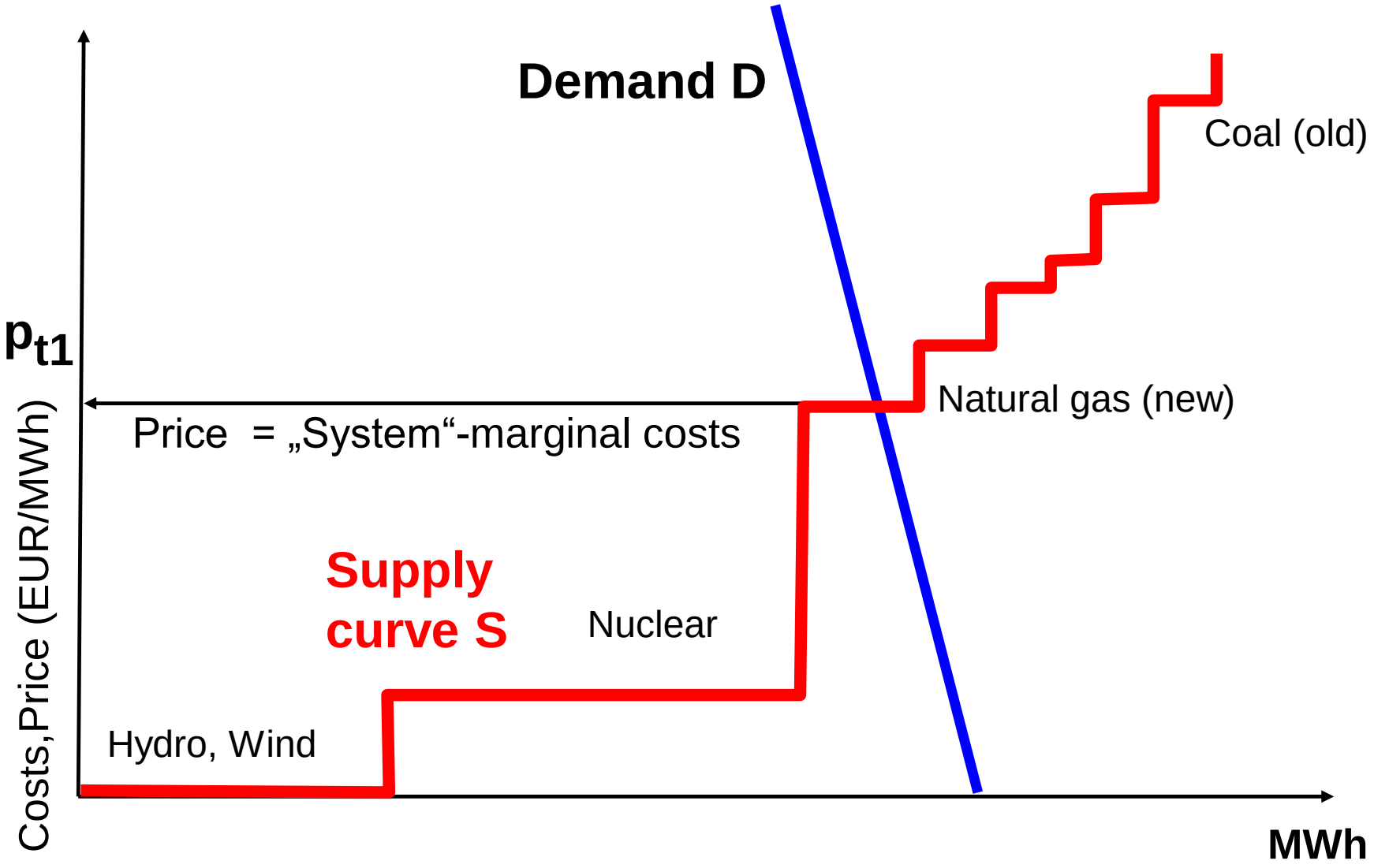
$$C = \frac{80000 * 0.1 + 2000}{5000} + \frac{30}{10 * 0.58} + \frac{0.5 * 0.2}{0.58} \left[\frac{\text{cent}}{\text{kWh}}\right] =$$

$$= 1.6 + 0.4 + 5.17 + 0.17 = 7.34 \text{ cent/kWh}$$

Example 2: Marginal costs of electricity generation from CCGT

p_f …Fuel price (e.g. 60 cents/m³ natural gas)
H …Caloric heat content (e.g. 10 kWh per m³ for gas)
η …Efficiency of CCGT plant = 0.50
C_{CO2} …Price of CO2: 50 EUR/ton Carbon)
f_{CO2} … CO2-factor of fuel (0.2 kg Carbon/kWh)

BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



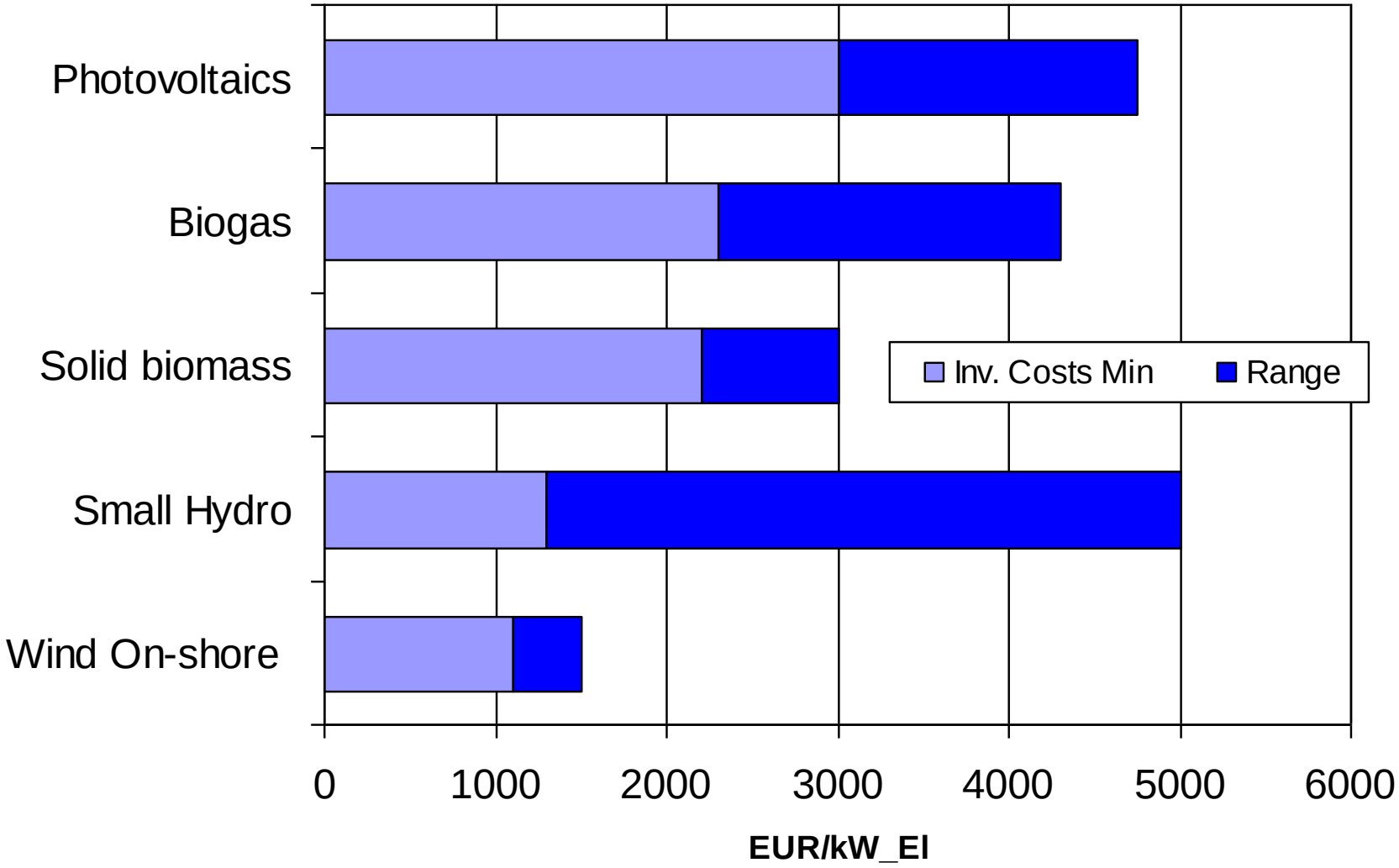
Example 2: Marginal costs of electricity generation

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

$$= 12.0 + 2.0 = 14.0 \text{ cent/kWh}$$

Investment costs

Electricity from new renewables 2010



Investment costs

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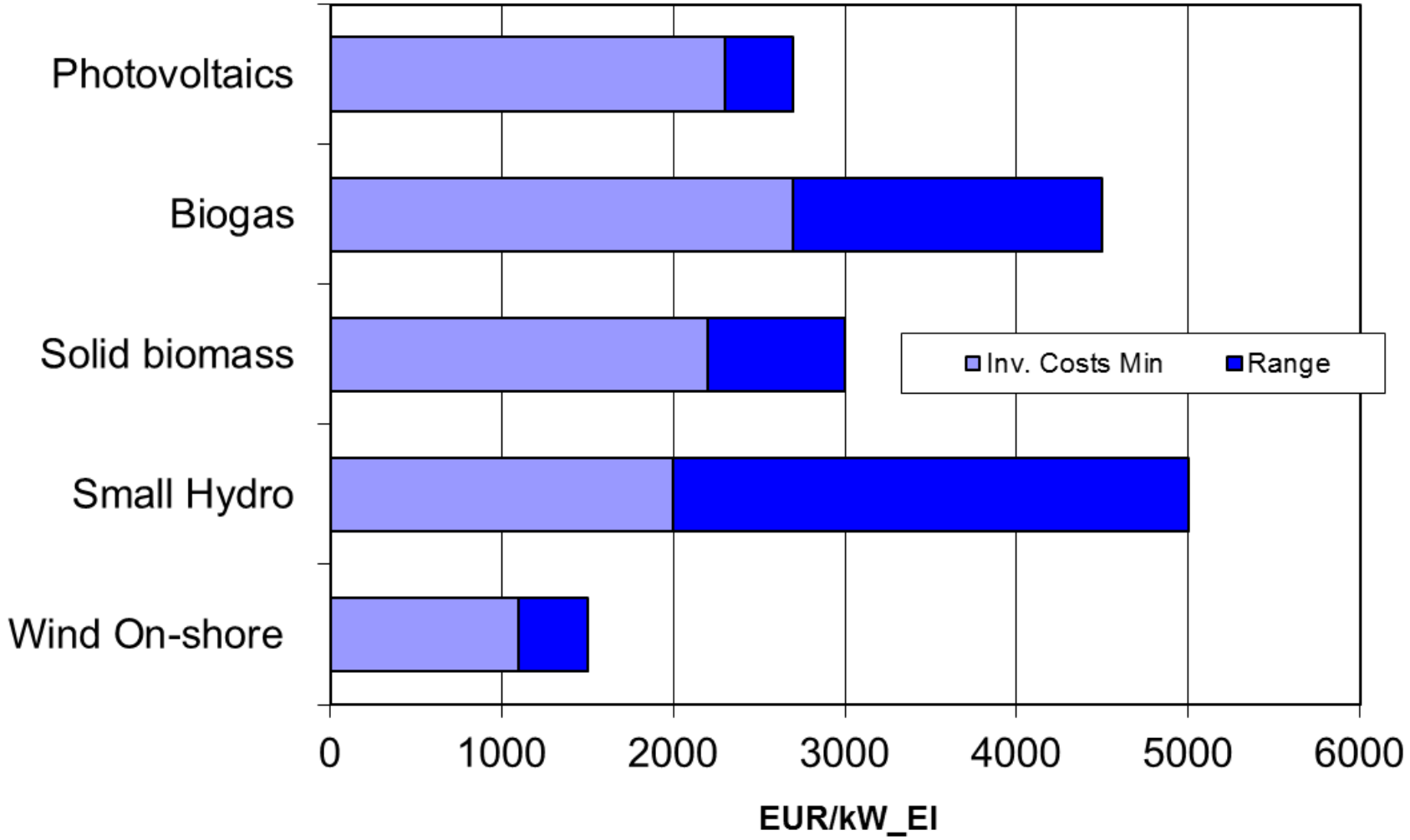
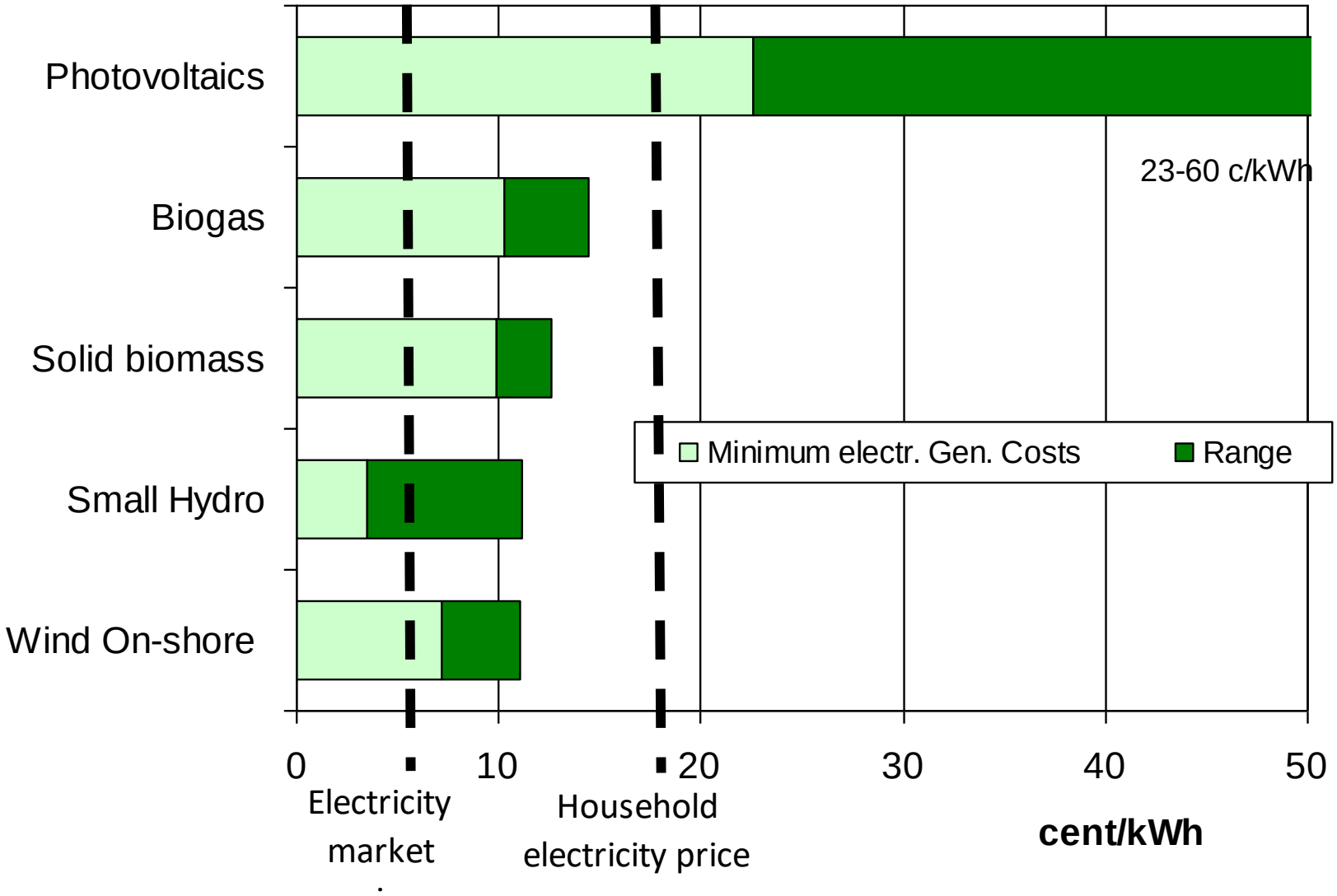


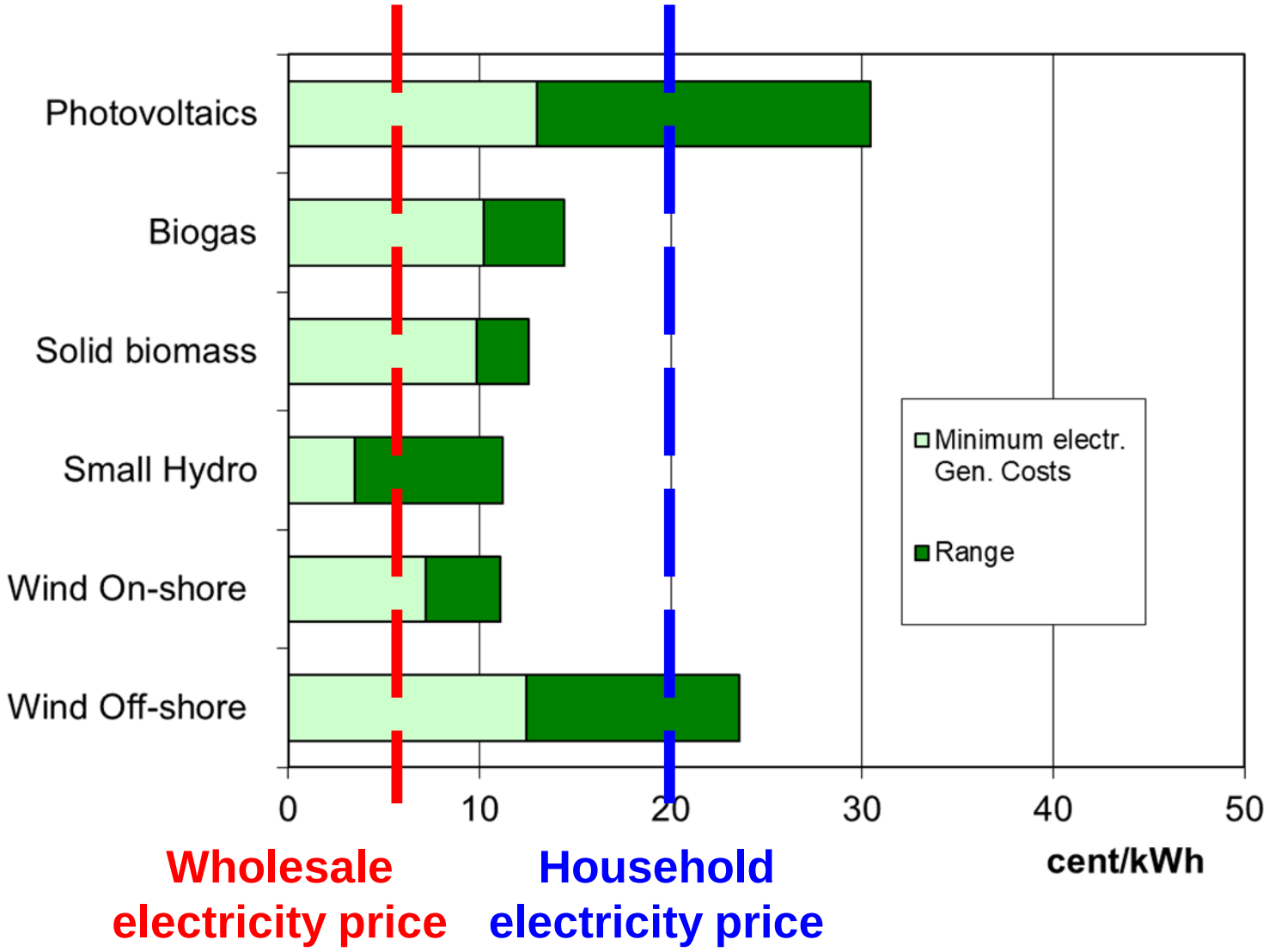
Generation costs

Electricity from new renewables 2010



Generation costs

Electricity from new renewables 2020



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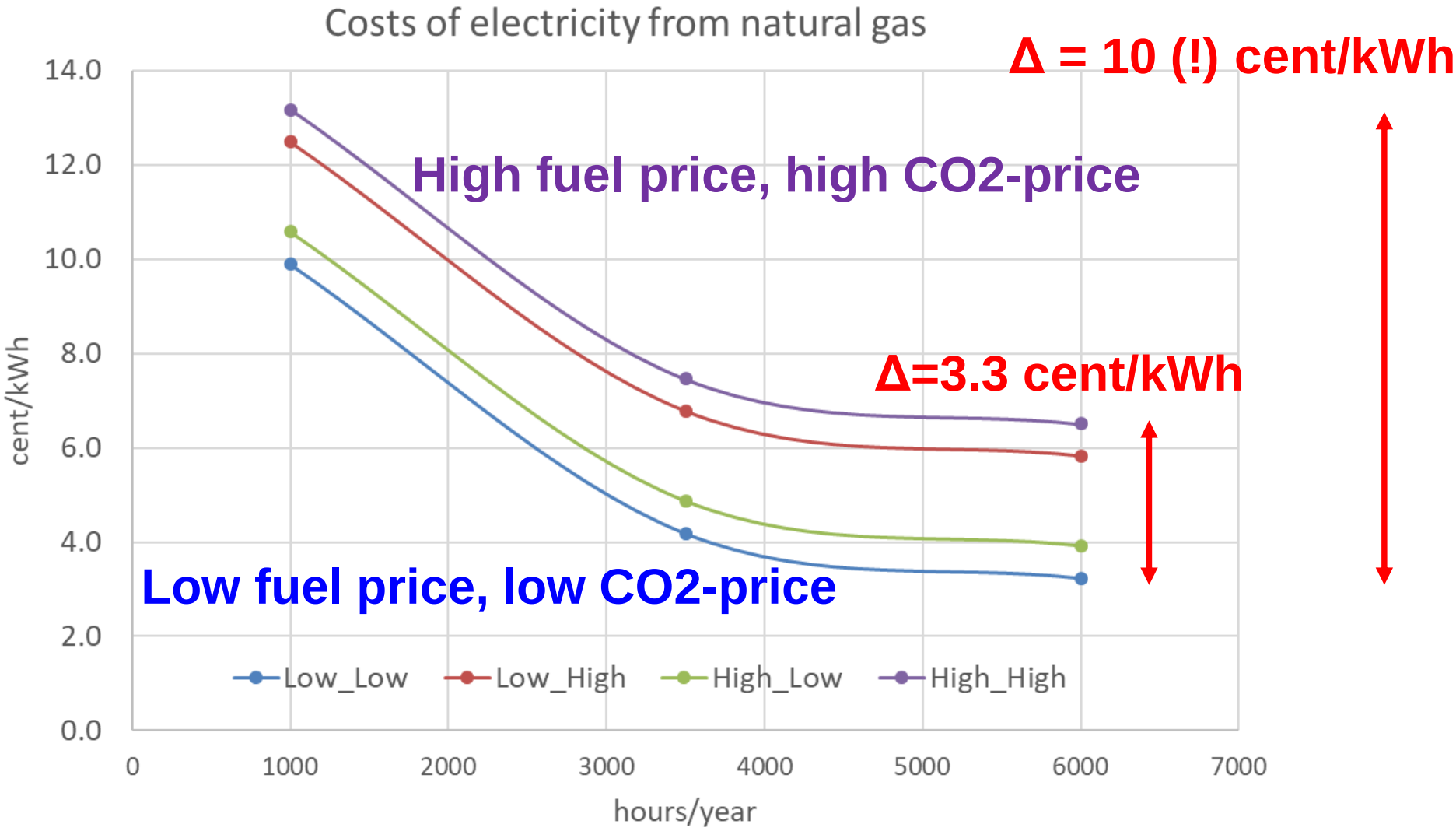


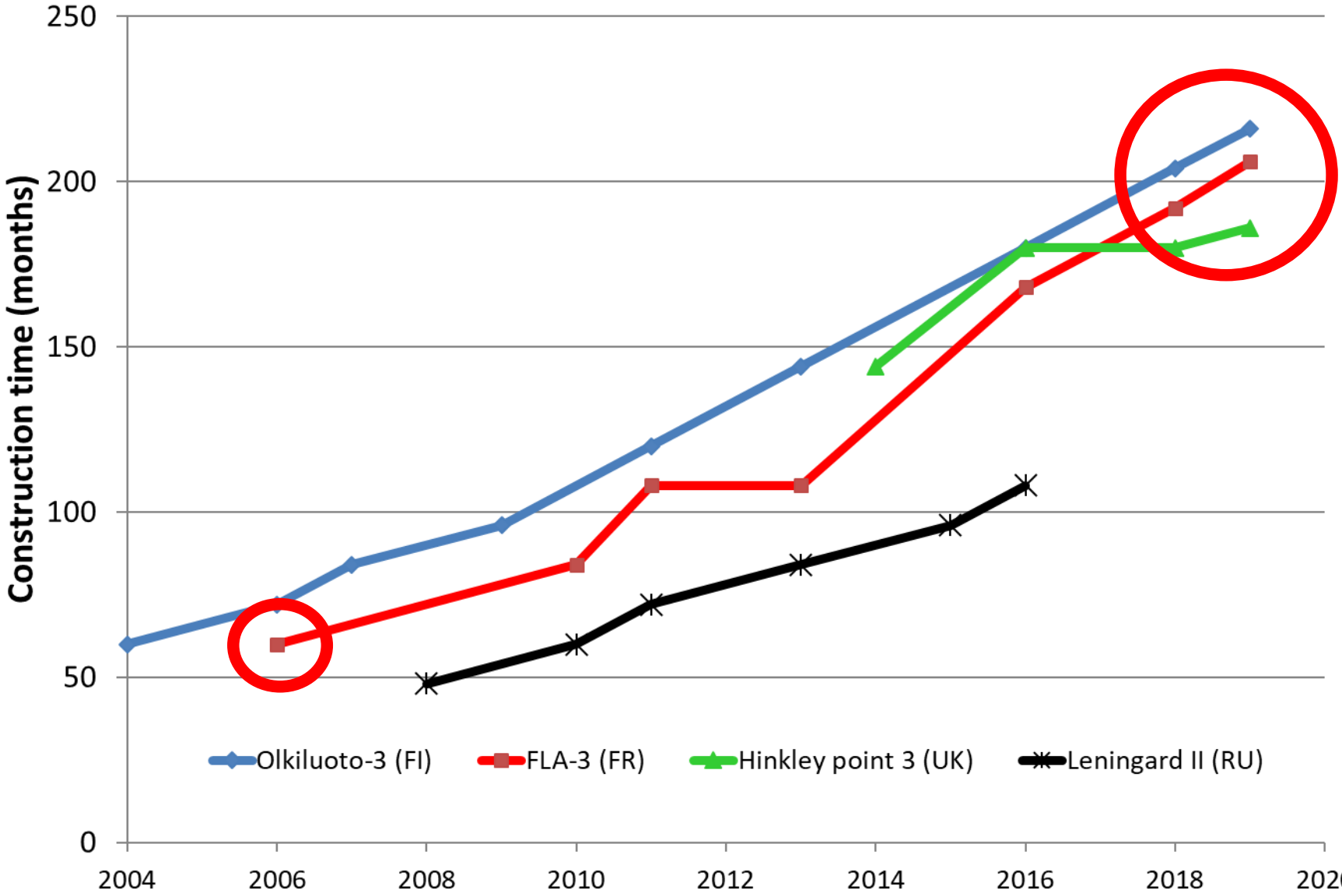
6. RECENT DEVELOPMENT OF NUCLEAR COSTS

- Olkiluoto-3 (Finland): Construction started in 2004, now expected to be completed 2019 (originally: 2009); 1600 MW

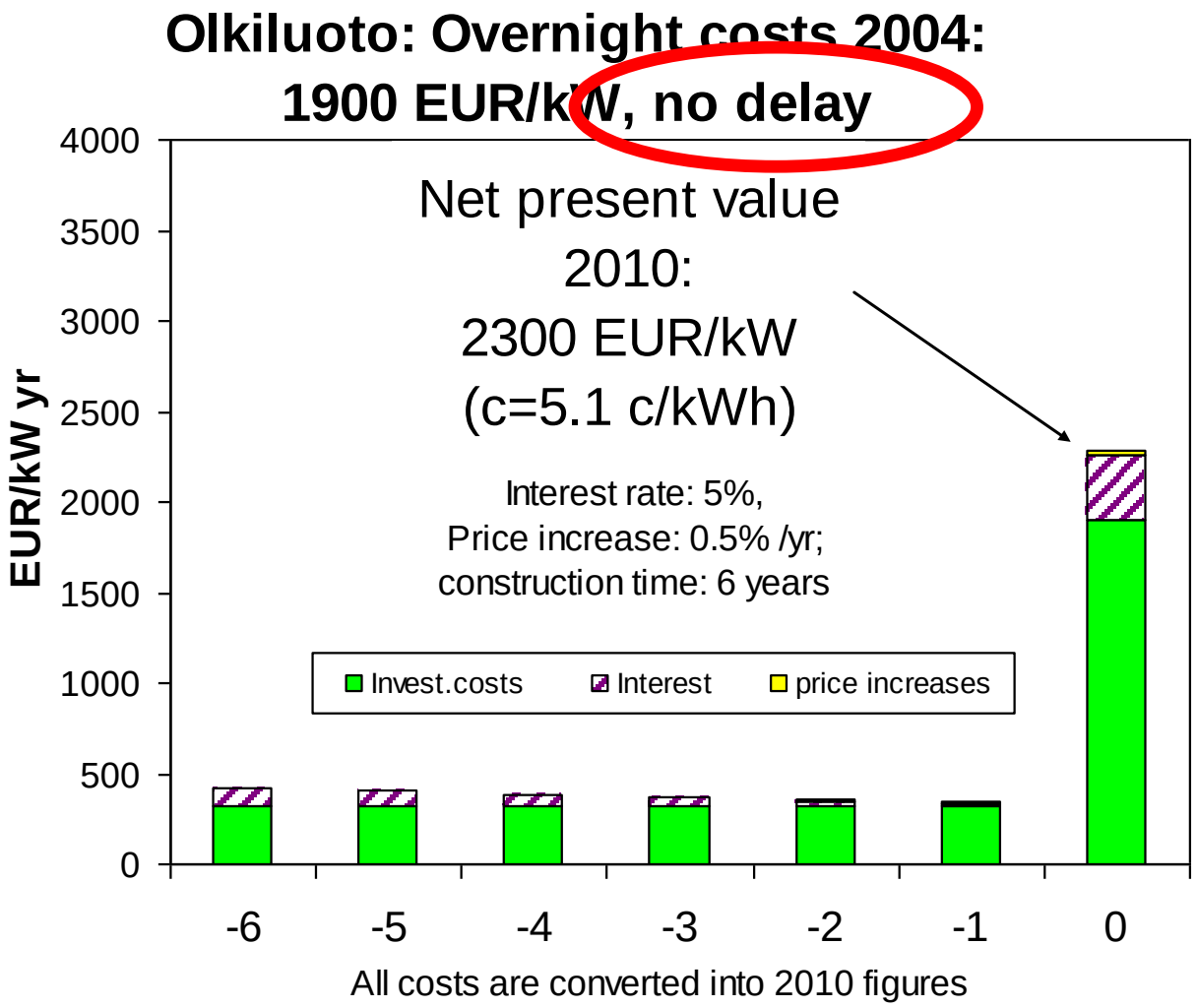
- Flamanville-3 (France): Construction started in 2006, now expected to be completed 2019 (originally: 2011); 1600 MW

- Hinkley point (UK): Construction start expected in 2022, 1600 MW

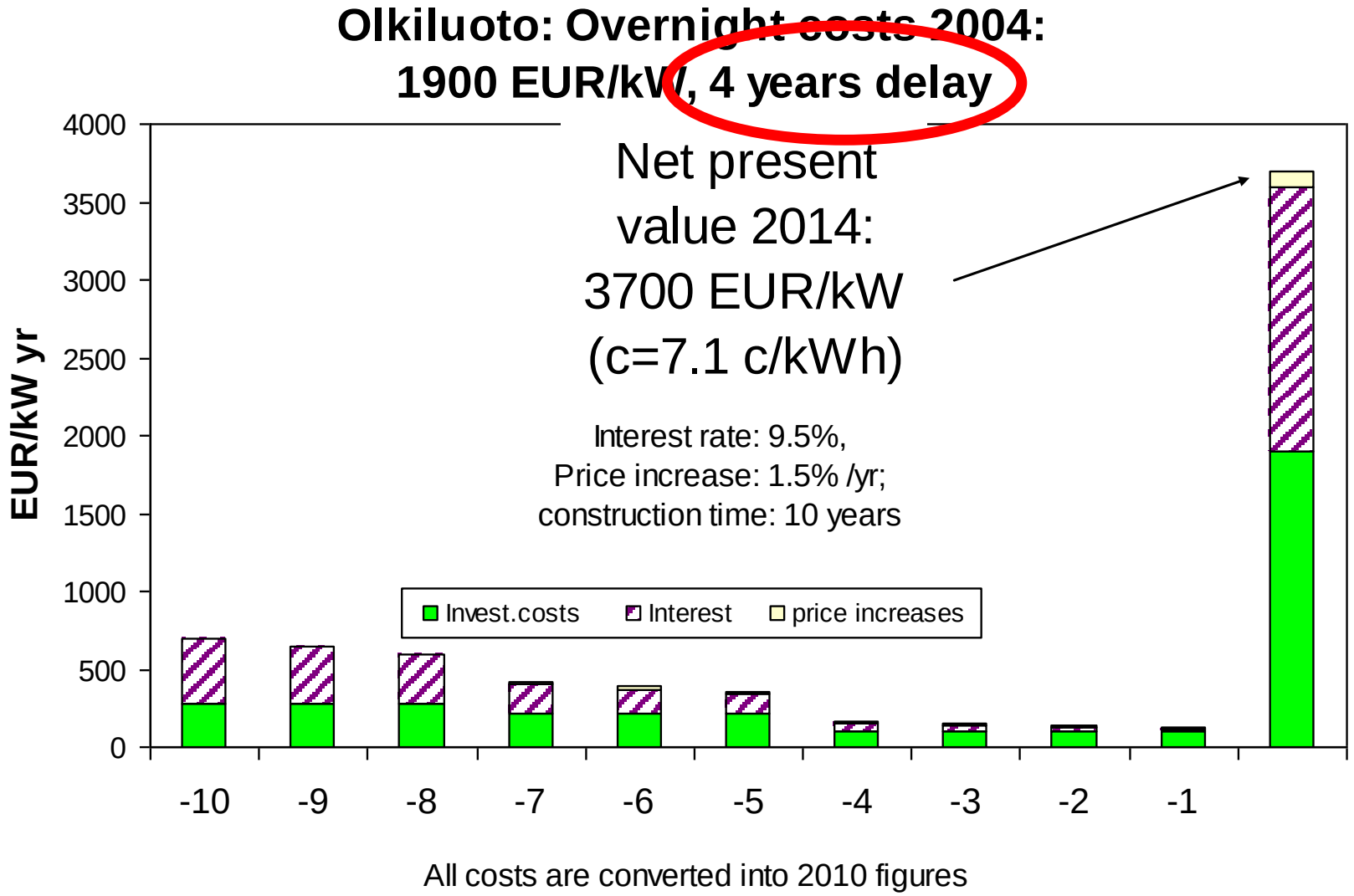
Construction times

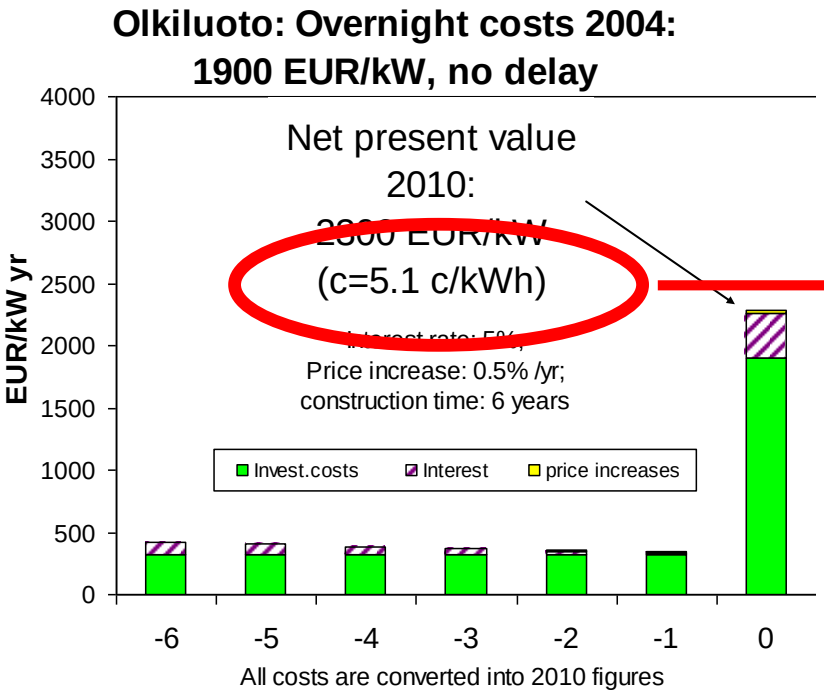


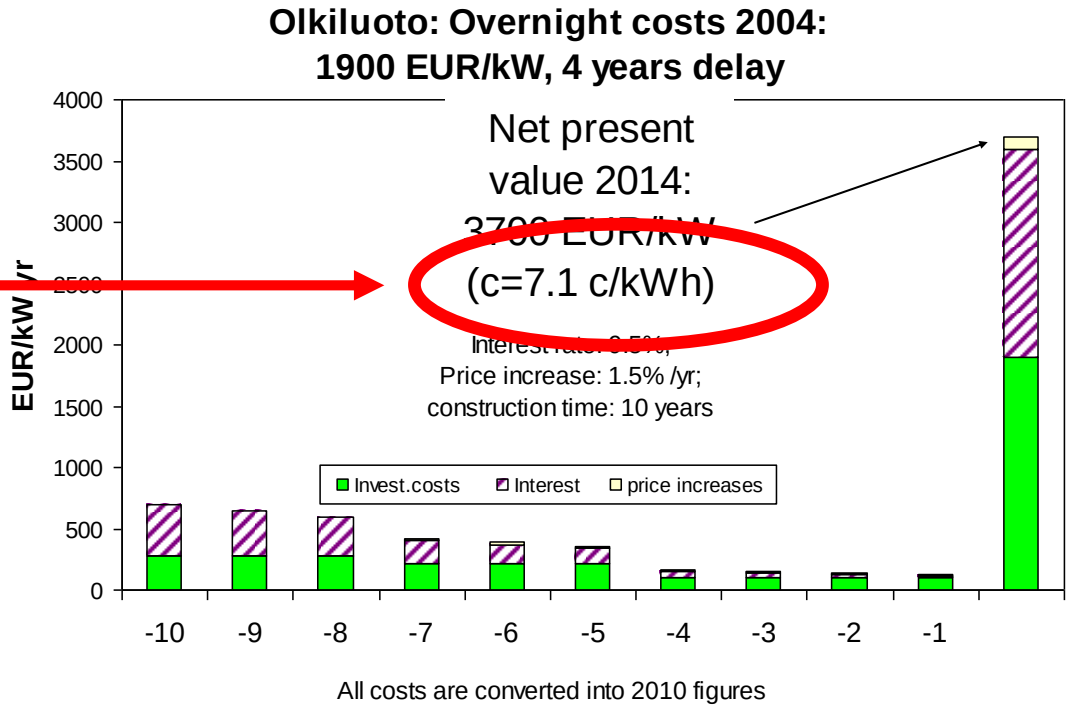
Impact of construction time on investment costs: Example Olkiluoto



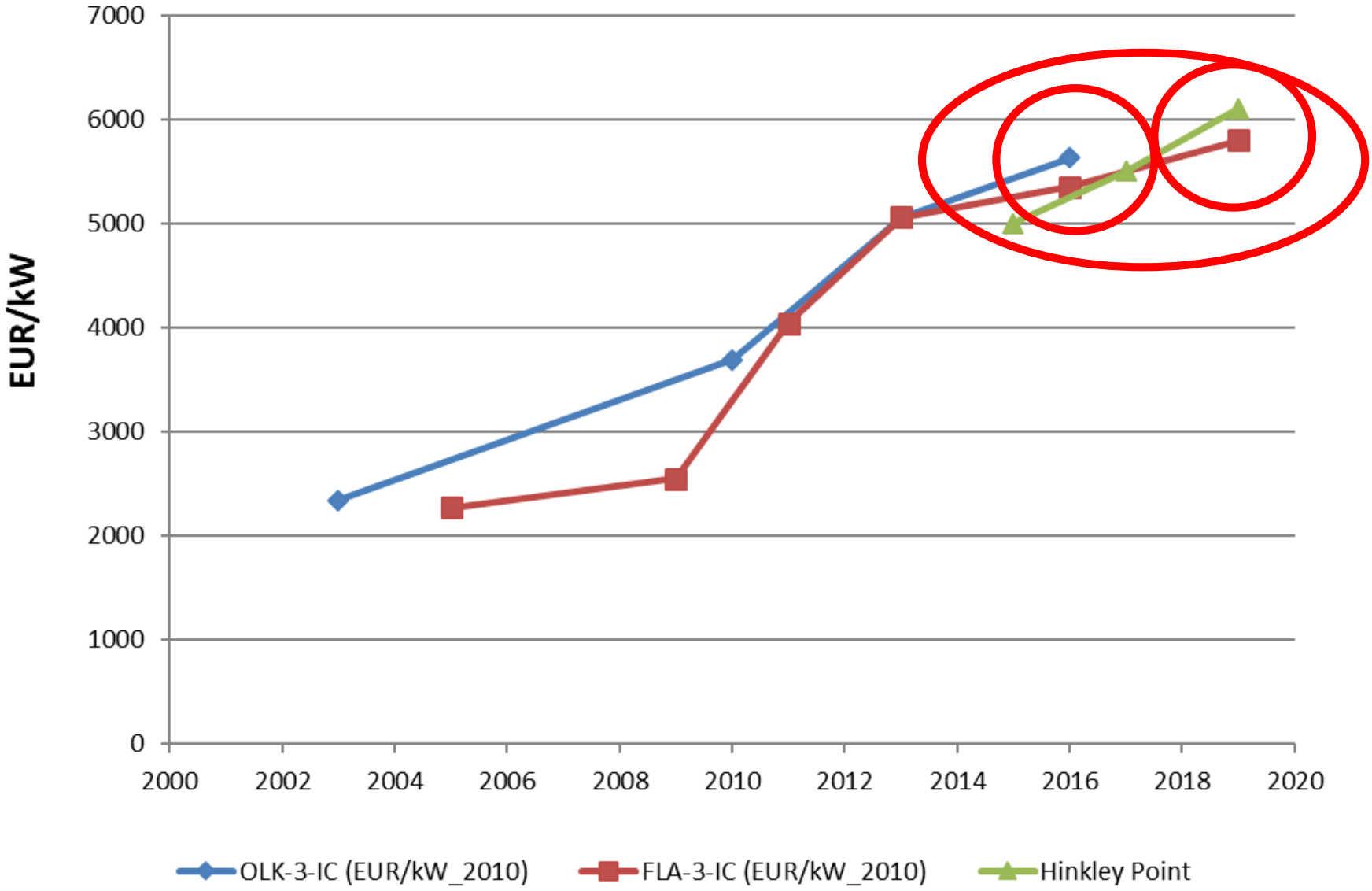
Impact of construction time on investment costs: Example Olkiluoto



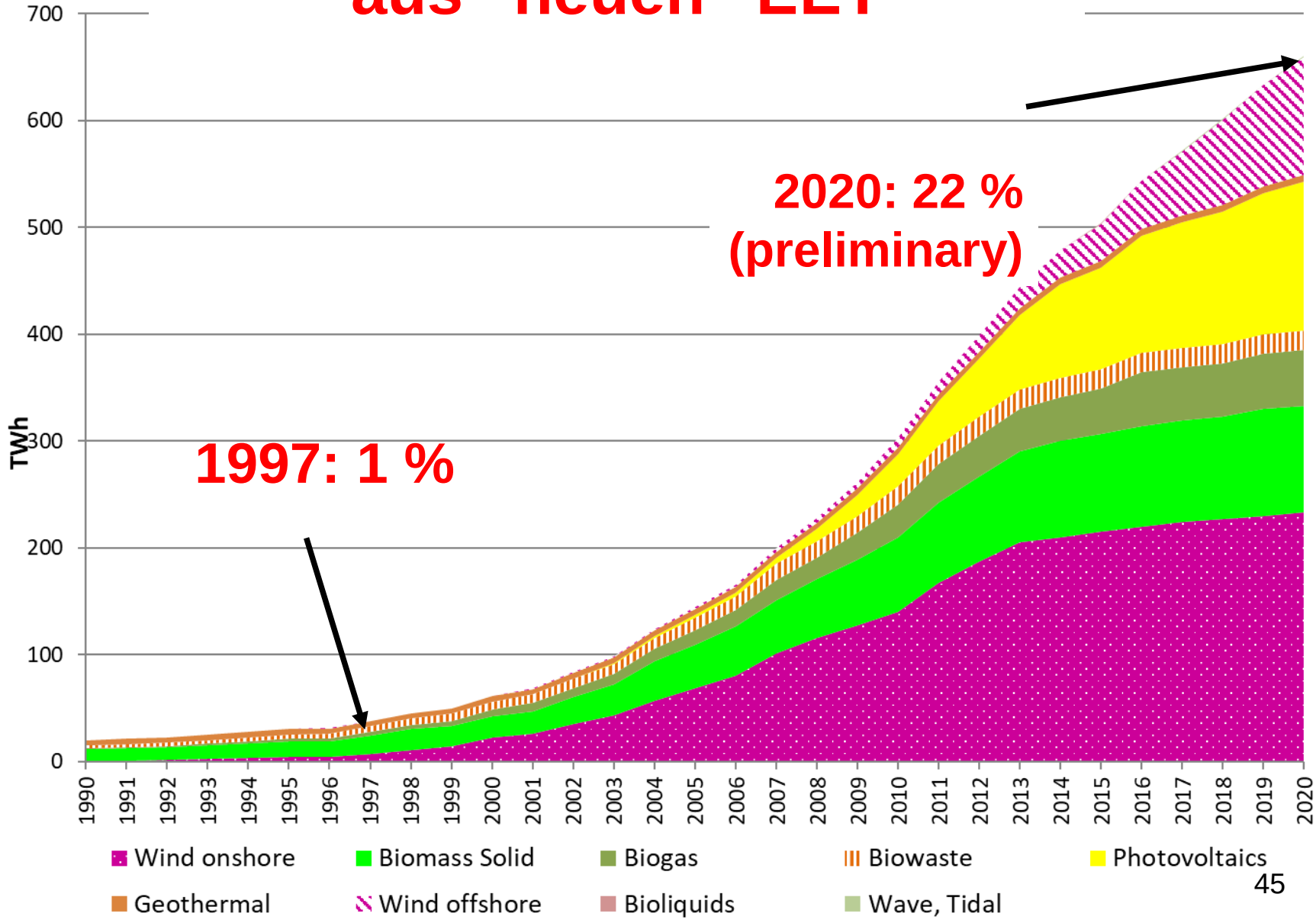

Olkiluoto: Overnight costs 2004:
1900 EUR/kW, no delay
Net present value 2010:
(c=5.1 c/kWh)
Price increase: 0.5% /yr;
construction time: 6 years
Invest.costs
Interest
price increases
EUR/kW yr
4000
3500
3000
2500
2000
1500
1000
500
0
-6
-5
-4
-3
-2
-1
0
All costs are converted into 2010 figures


Olkiluoto: Overnight costs 2004:
1900 EUR/kW, 4 years delay
Net present value 2014:
(c=7.1 c/kWh)
Price increase: 1.5% /yr;
construction time: 10 years
Invest.costs
Interest
price increases
EUR/kW yr
4000
3500
3000
2500
2000
1500
1000
500
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
All costs are converted into 2010 figures

Investment cost development Olkiluoto 3 vs Flamanville 3 vs HP

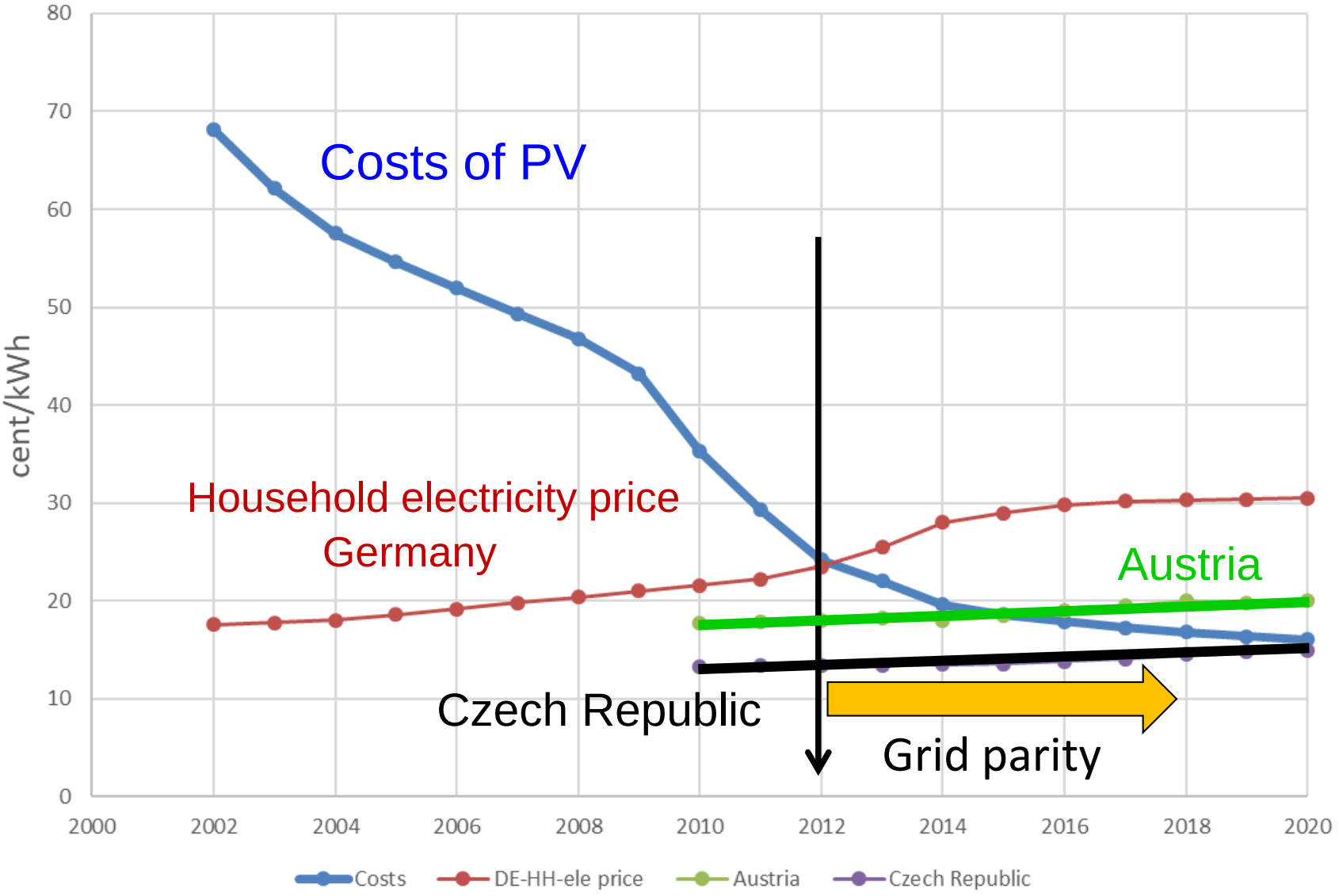


7. EU-28: Stromerzeugung aus “neuen” EET

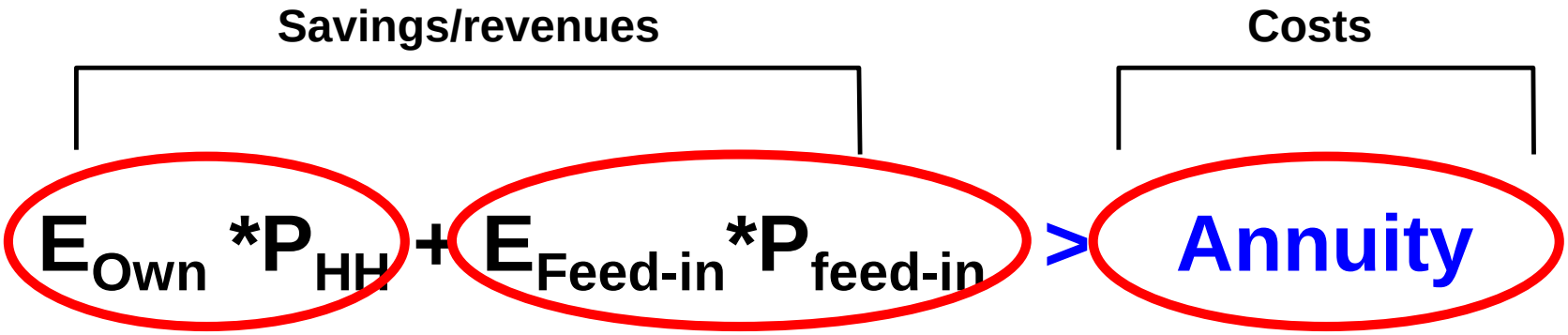


Source: EUROSTAT, own estimations

Grid parity: PV-costs and household electricity prices



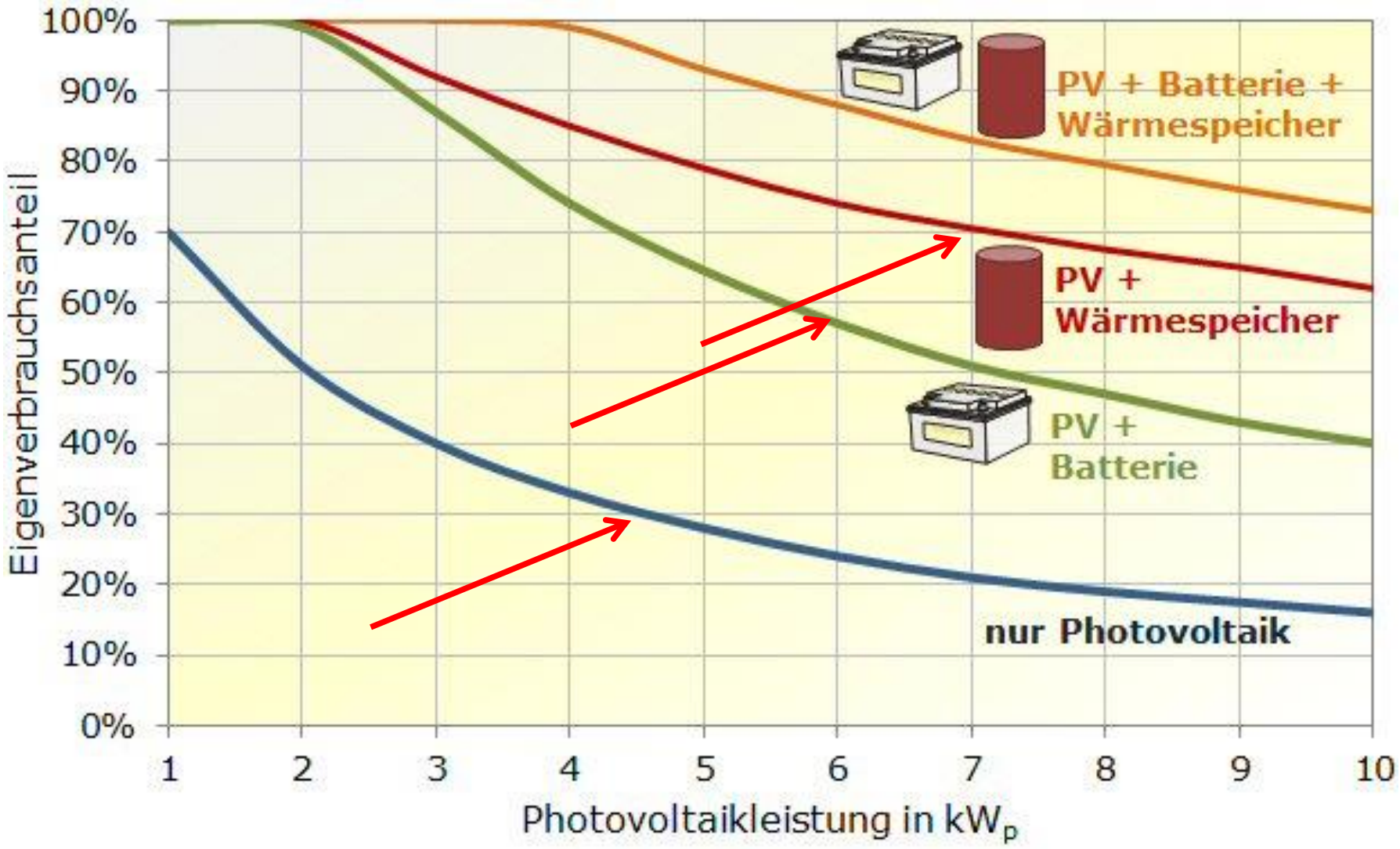
Assessment of Grid Parity



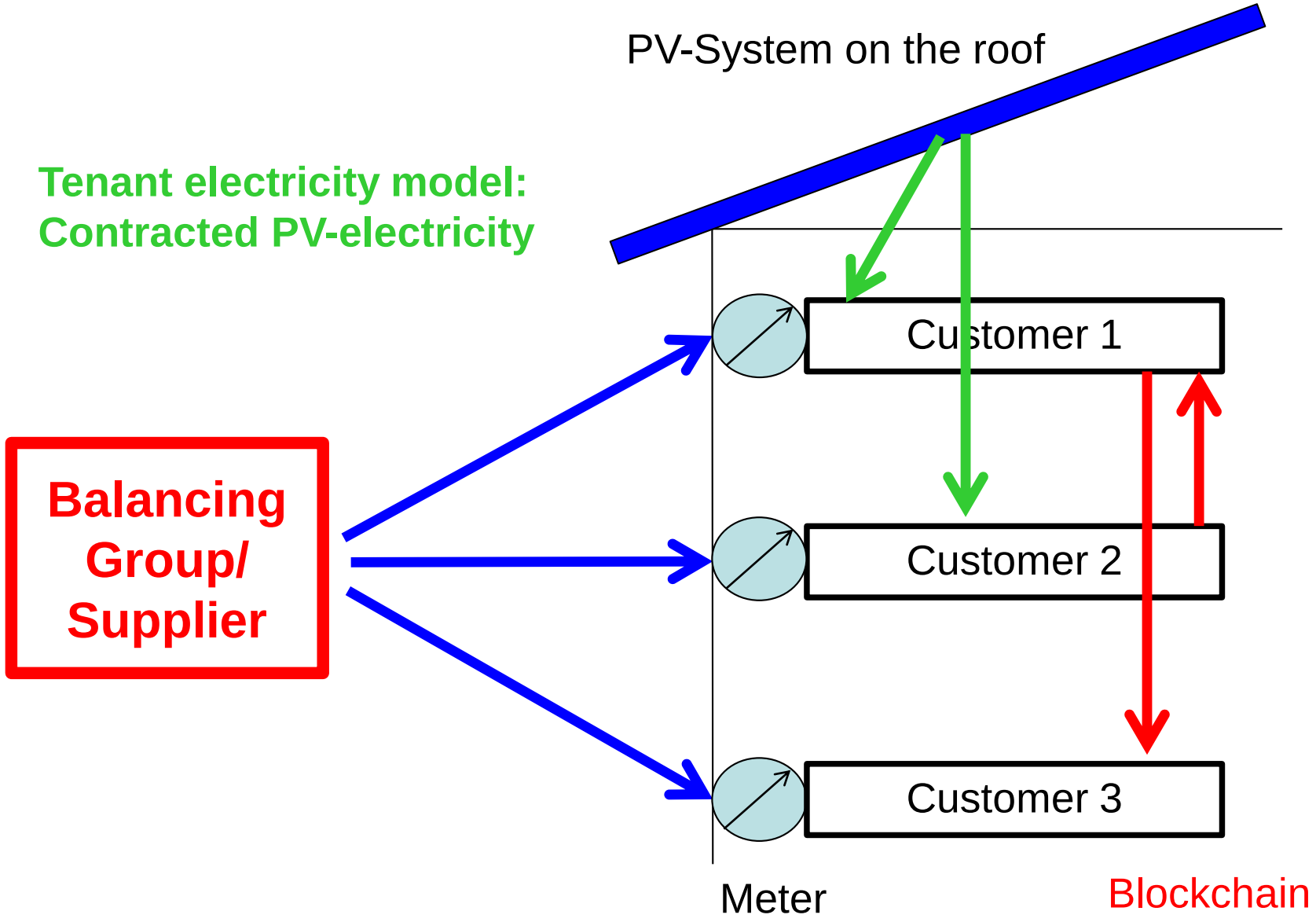
Grid parity term

Subsidy still necessary?

Share of own consumption



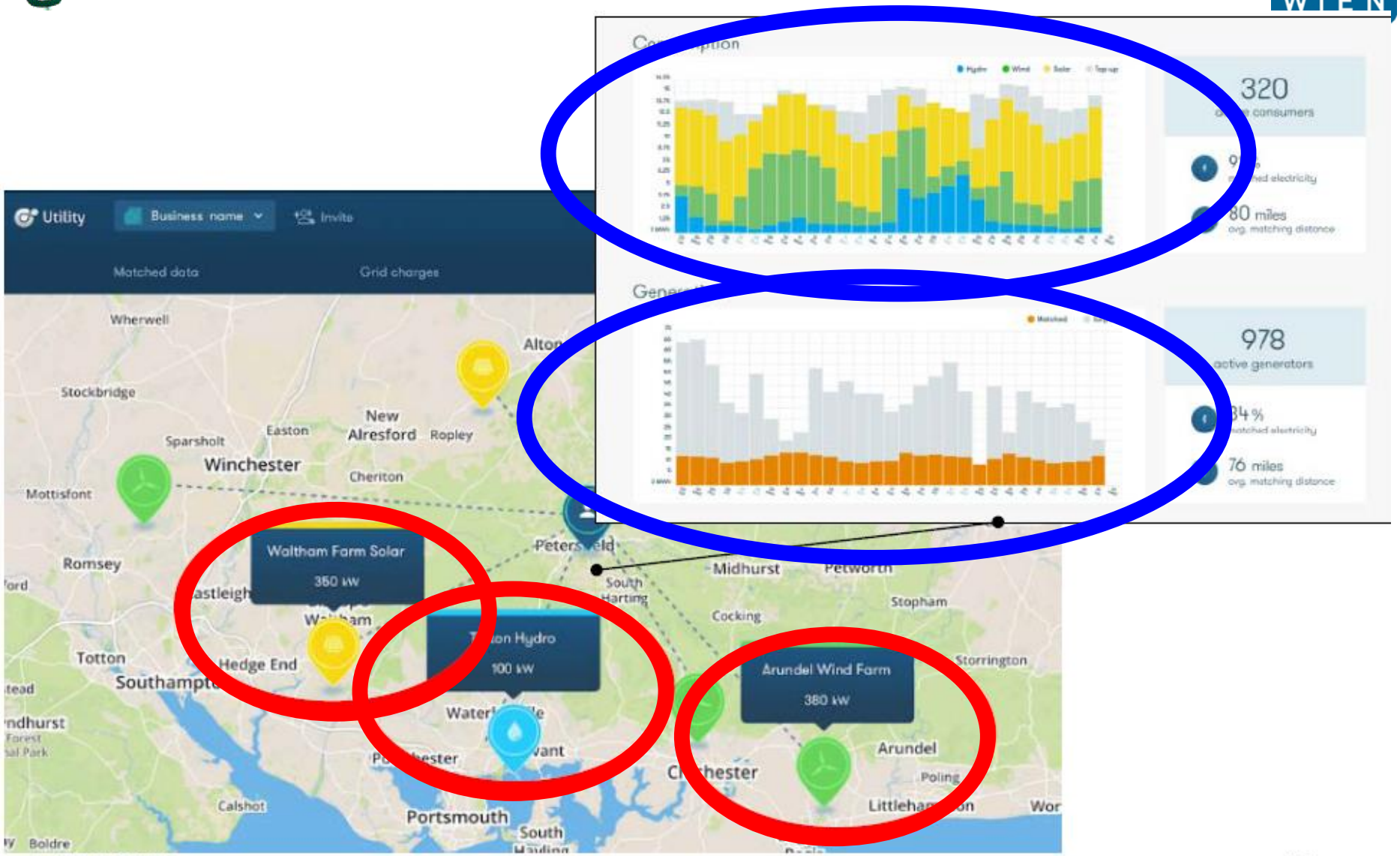
Tenant electricity model and Blockchain



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%

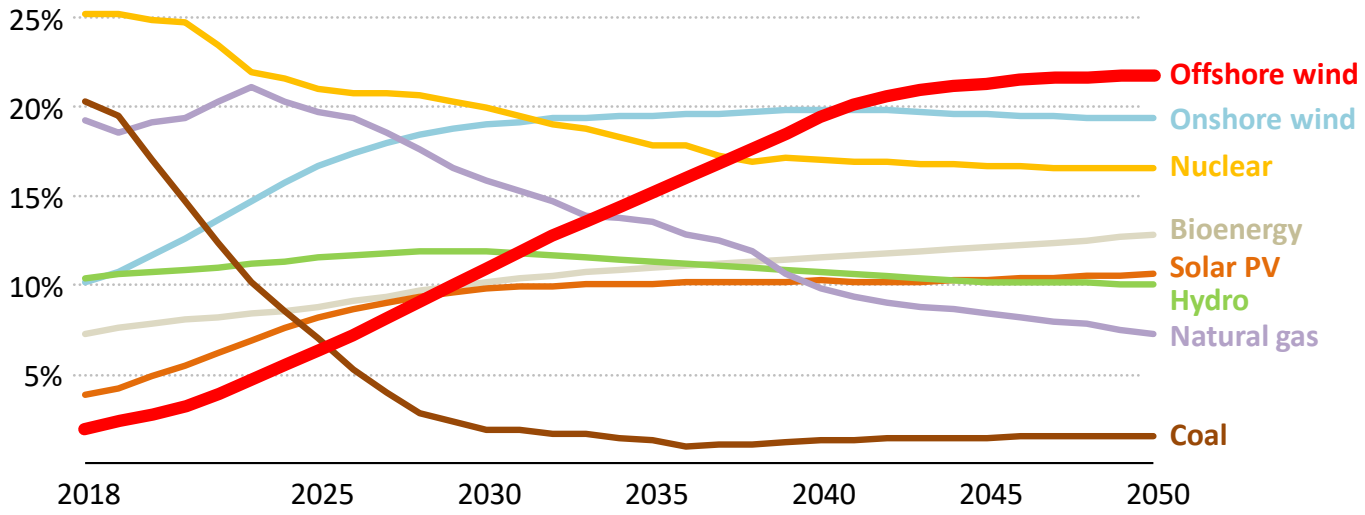
Peer-to-peer



Source: piclo.co.uk

A carbon neutral Europe puts offshore wind in front

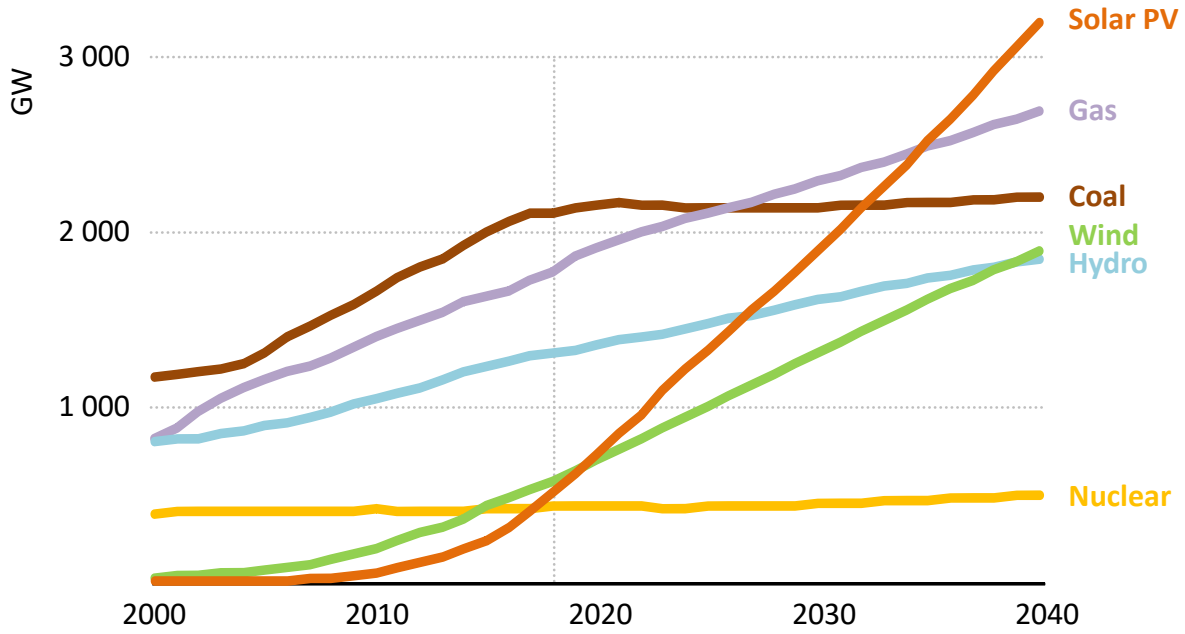
Shares of electricity generation by technology in the European Union, Sustainable Development Scenario



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

New solar PV projects are taking off

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 & CO2-price:

C = 1.0 + 0.33 + 1.72 +0.17 = 3.22 cent/kWh

High fuel & CO2-price:

C = 1.0 + 0.33 + 4.31 +0.86 = 6.50 cent/kWh

1000 h/yr:

Low fuel & CO2-price:

C = 6.0 + 2.0 + 1.72 +0.17 = 9.89 cent/kWh

High fuel & CO2-price:

C = 6.0 + 2.0 + 4.31 +0.86 = 13.17 cent/kWh