


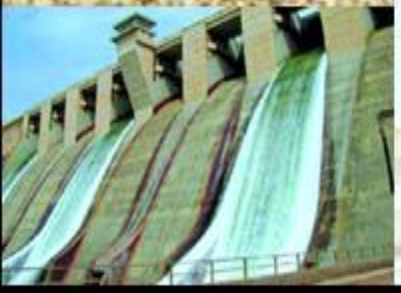

ELECTRICITY MARKETS, AND THE ROLE OF RENEWABLES & NUCLEAR

Reinhard Haas

Energy Economics Group,
Vienna University of Technology

PRAGUE 2.2.2016

SURVEY

1. Introduction: Historical background
2. How prices come about (theory)
3. Environmental issues: CO2-prices
4. How prices developed in Europe
5. Electricity generation costs
6. Recent developments of nuclear
7. The role of Renewables
8. Conclusions

Energy Economics Group

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OUR LIFE: PERMANENTLY UNDER

ELECTRICITY

Electricity – THE universal technology for providing energy services

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 energy system?

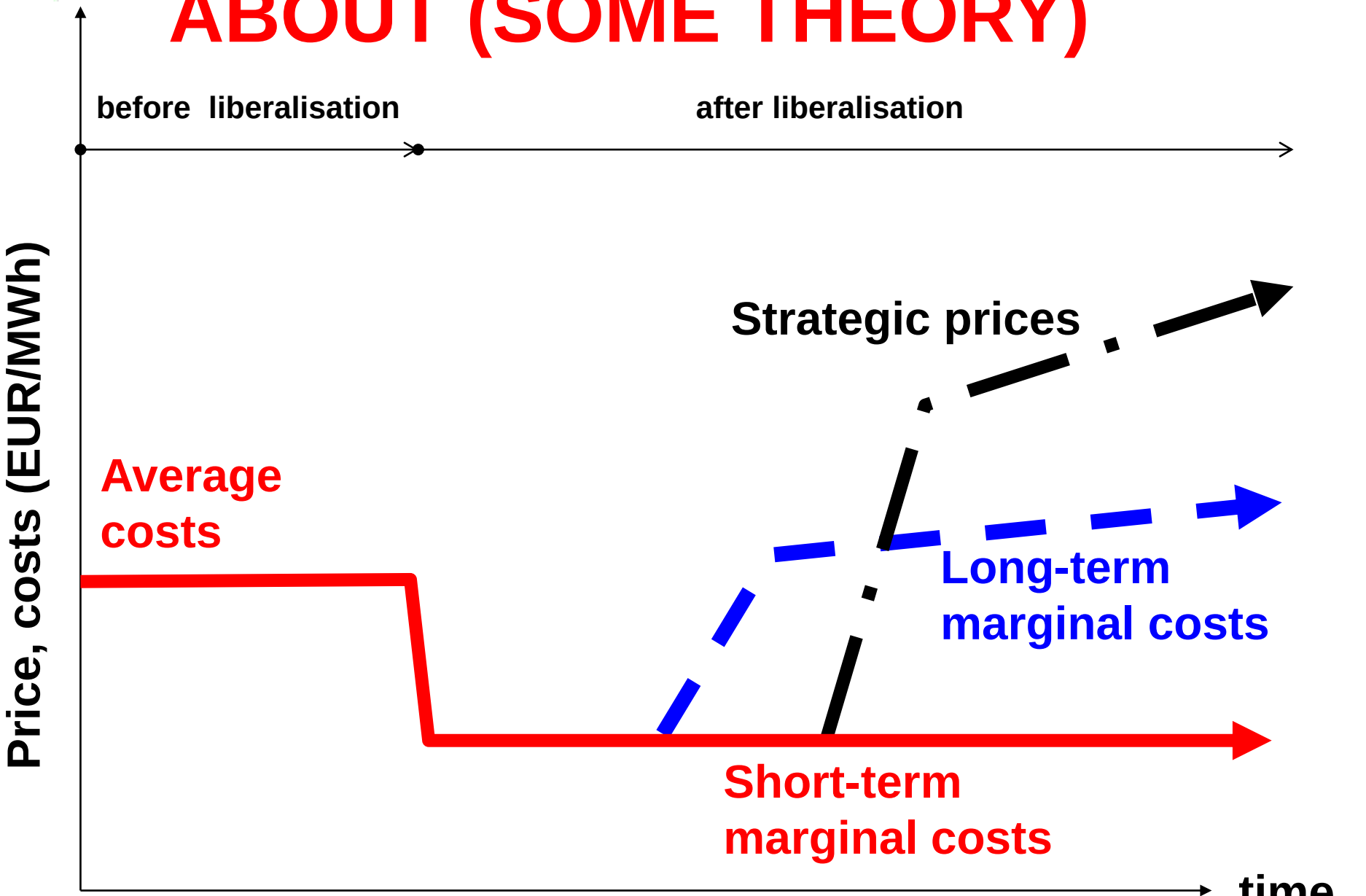
THE EU-DIRECTIVE(S) 1

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"

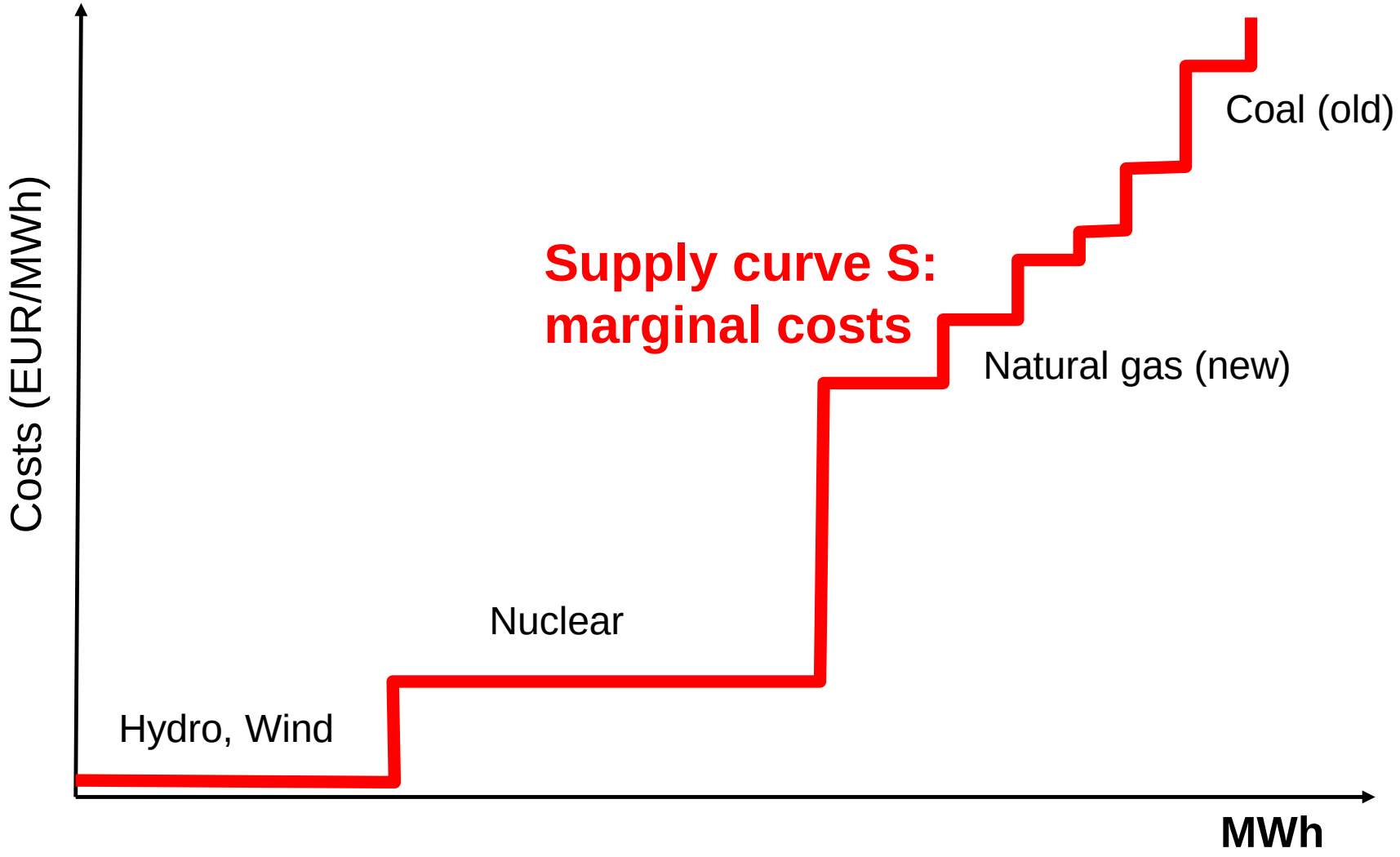
- **Intentions of the EC directive:**
  - → **Competitive markets**
    - → **lower electricity prices**
      - → **more environmentally benign**

2 HOW PRICES COME ABOUT (SOME THEORY)

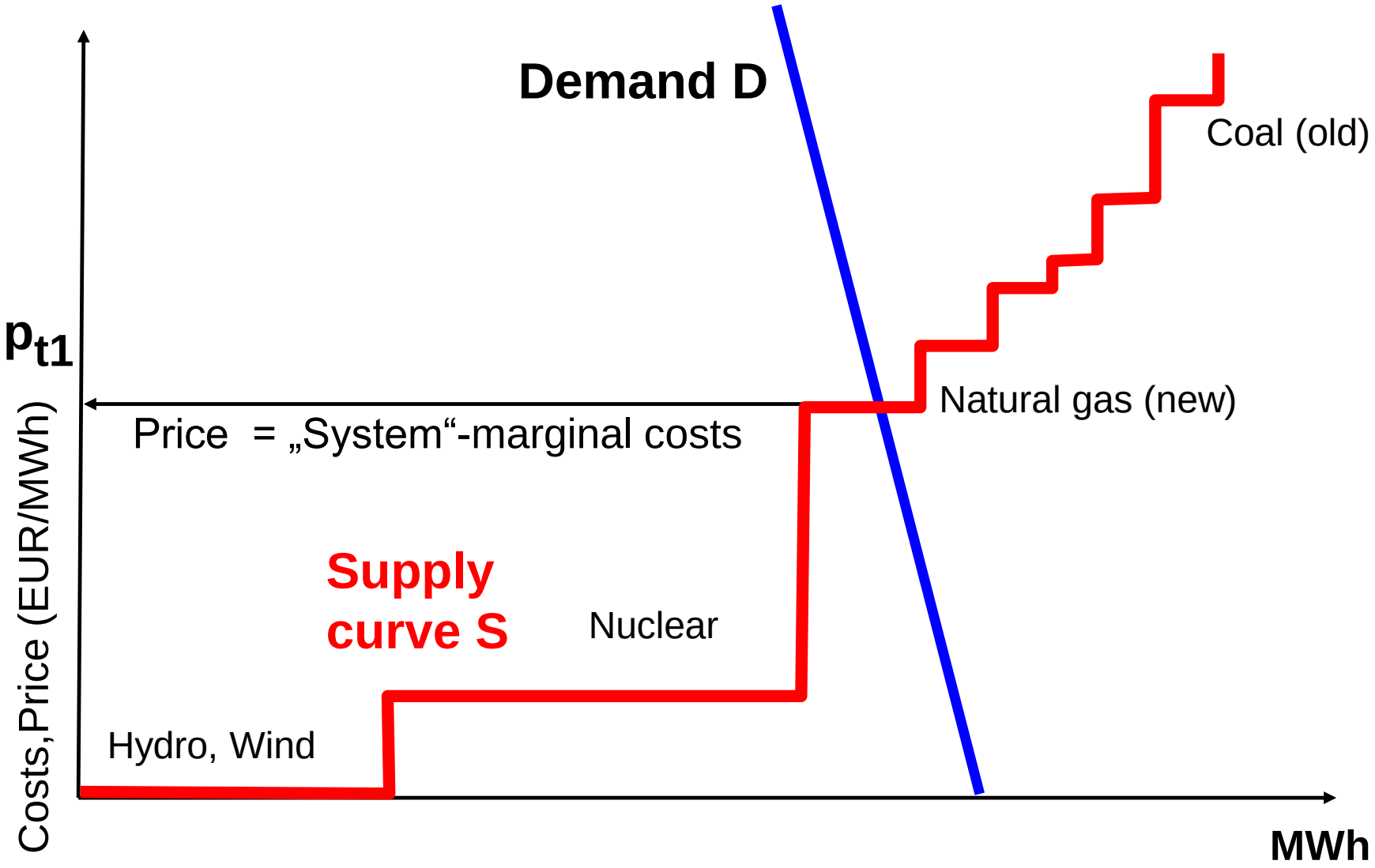


THE *MERIT-ORDER* CURVE OF SUPPLY

based on short-term marginal costs (MC)



BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



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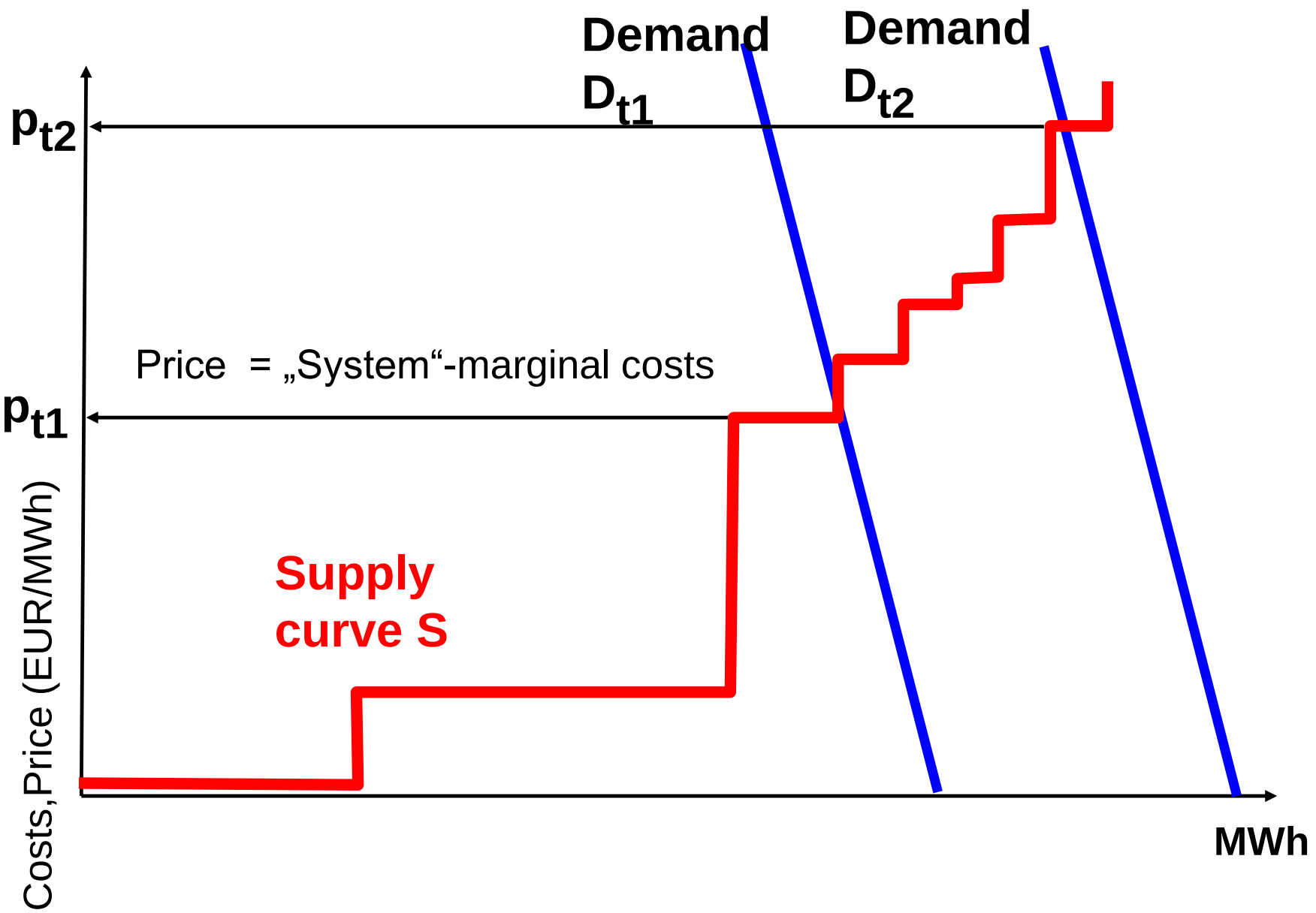


LONG-TERM
VS
SHORT-TERM
MARGINAL COSTS

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):

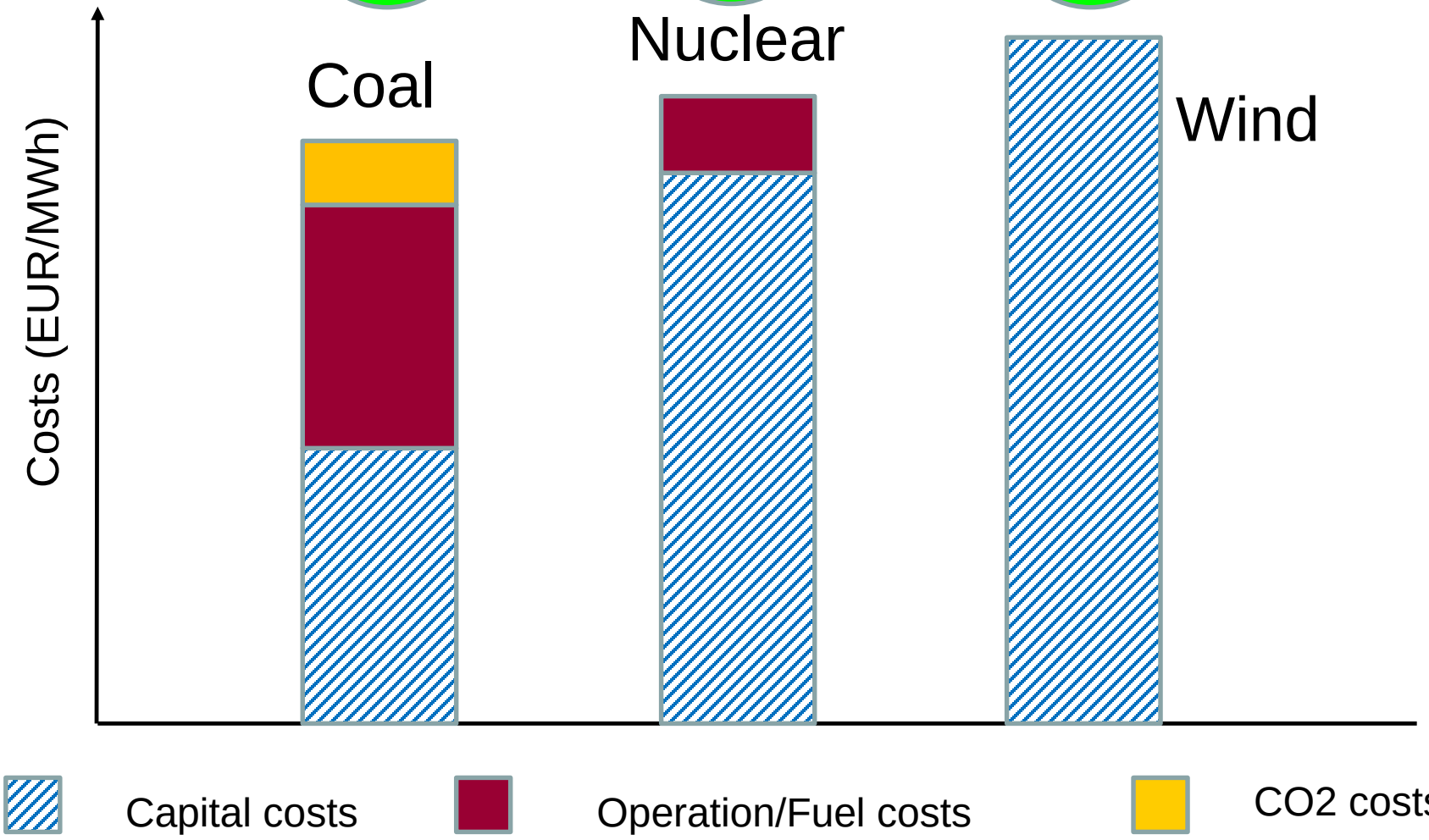
STMC= Fuel costs + CO2 costs

Long-term marginal costs (LTMC):

LTMC= STMC + Capital costs + O&M costs

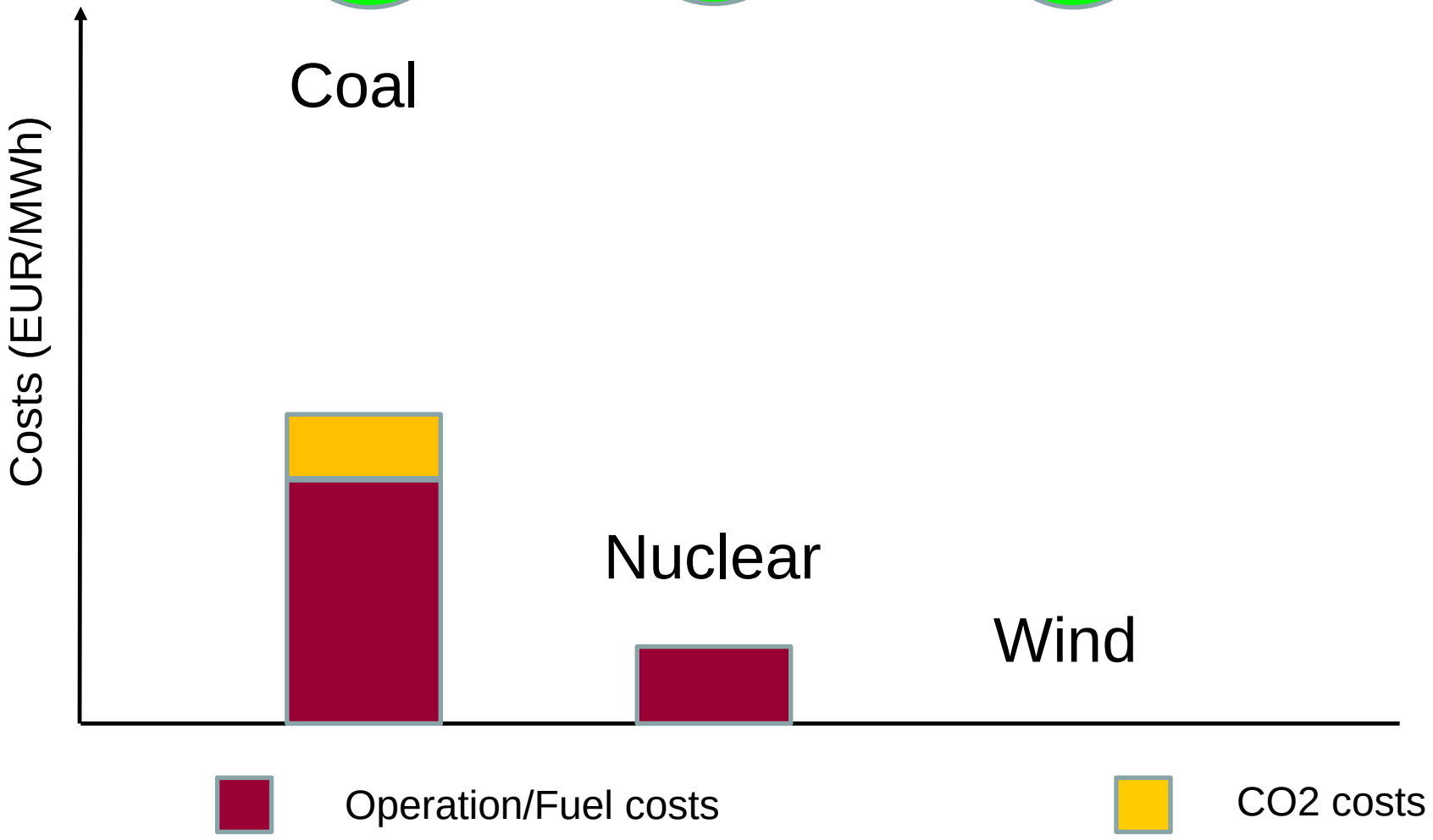
LONG-TERM MARGINAL COSTS

Cheapest: 1. 2. 3.

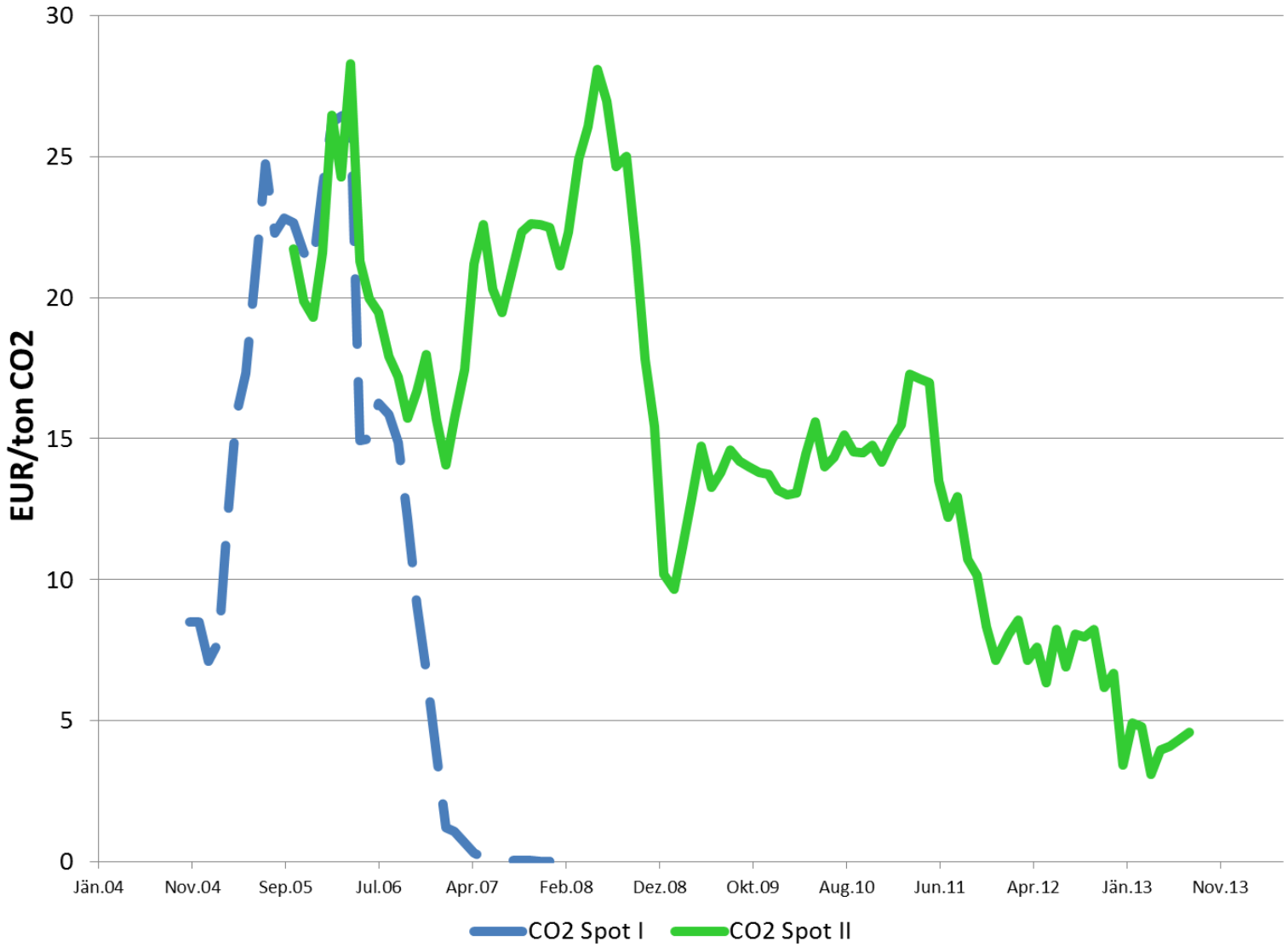


SHORT-TERM MARGINAL COSTS

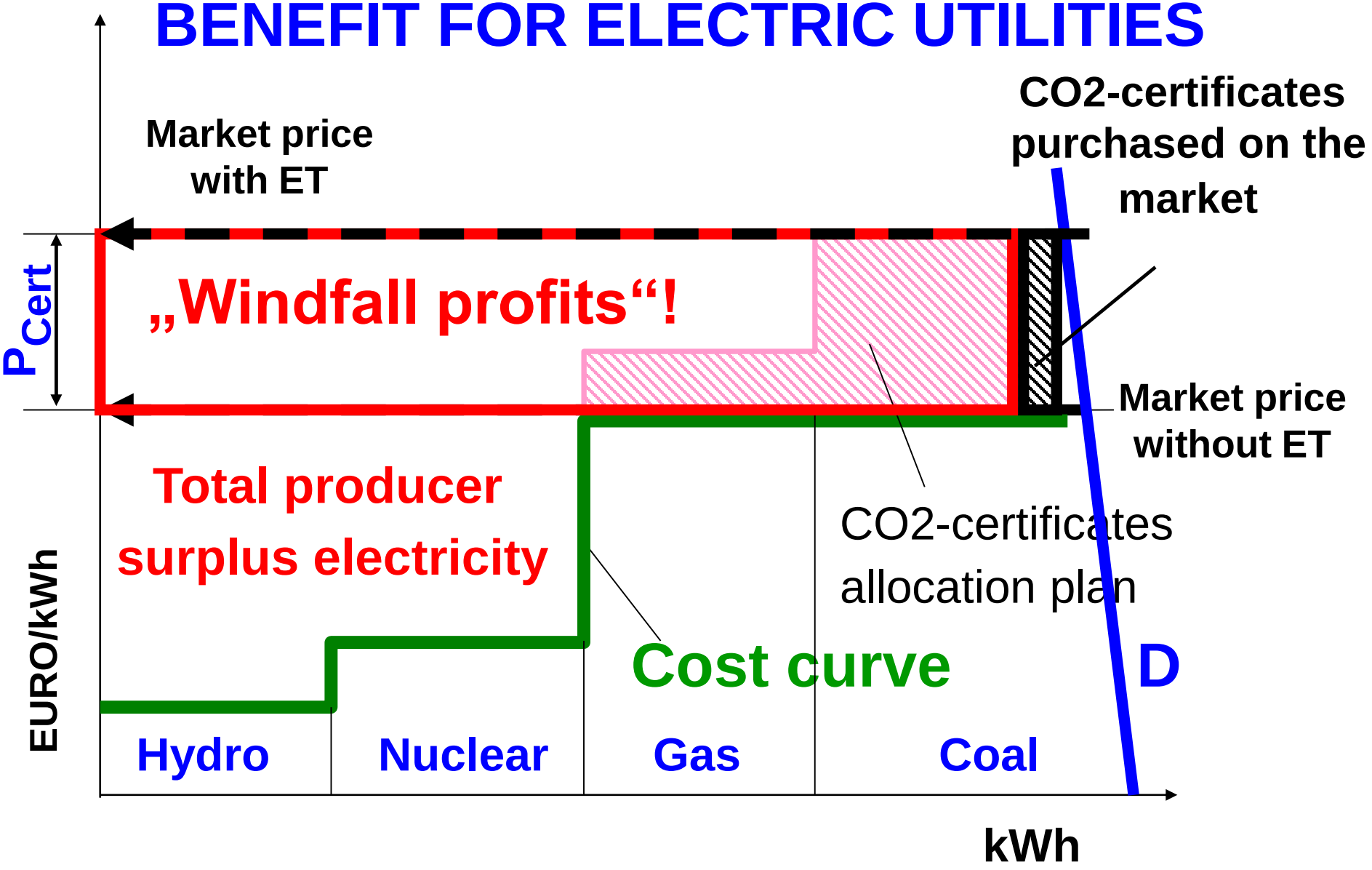
Cheapest: 3. 2. 1.



3 ENVIRONMENTAL ASPECTS – THE CO2-PRICE

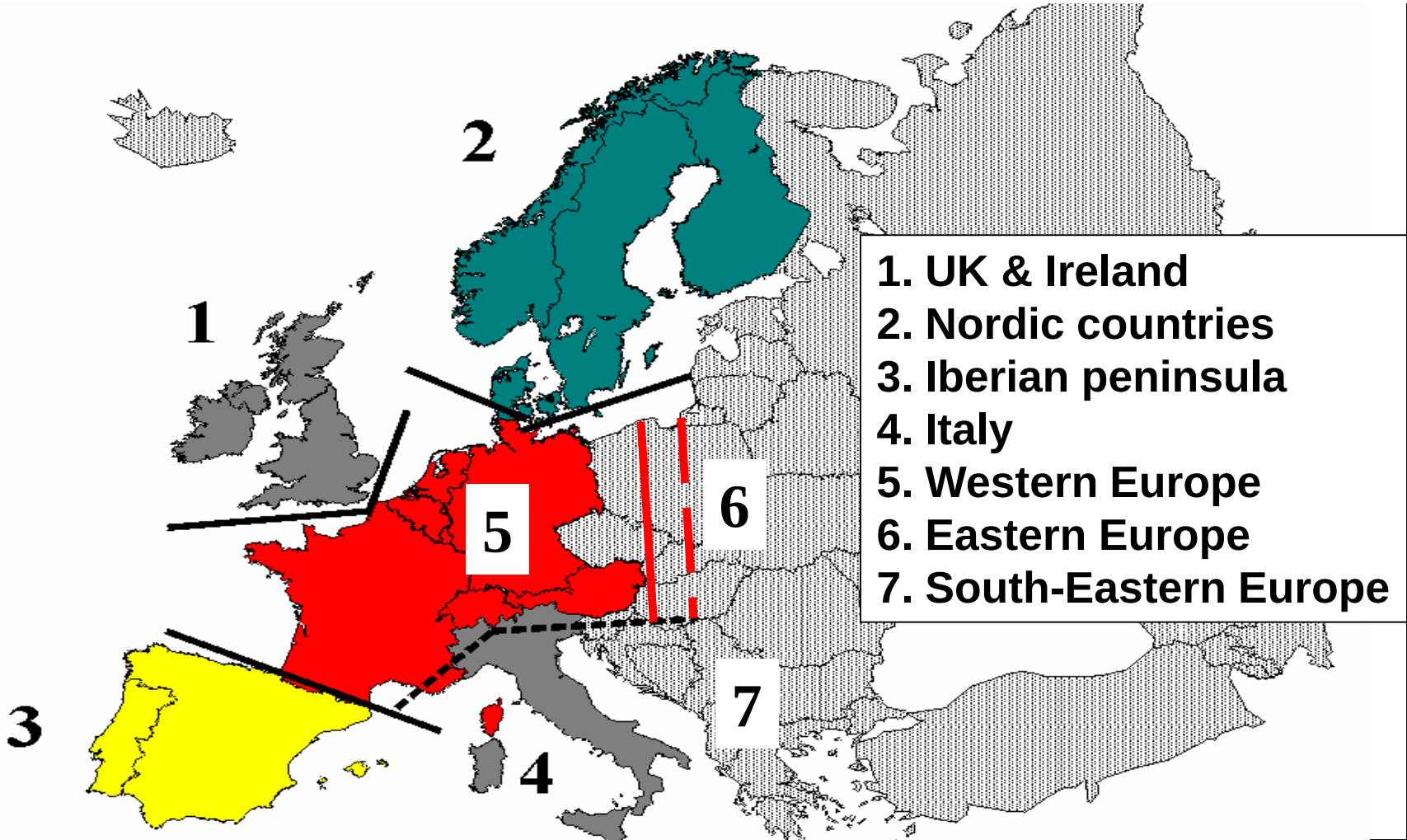


EMISSION TRADING'S BENEFIT FOR ELECTRIC UTILITIES

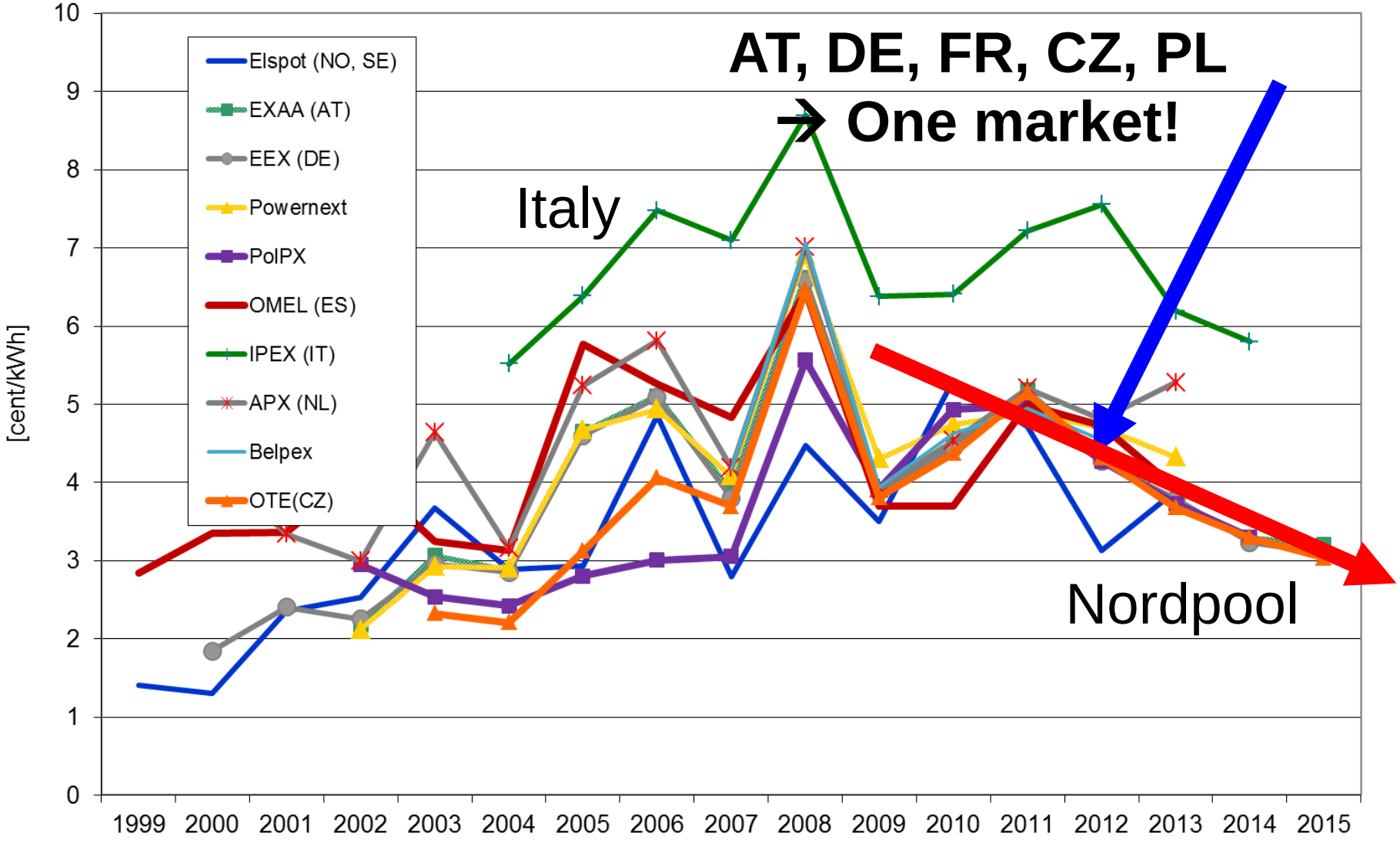


4 HOW PRICES DEVELOPED IN EUROPE

EUROPEAN ELECTRICITY SUB-MARKETS

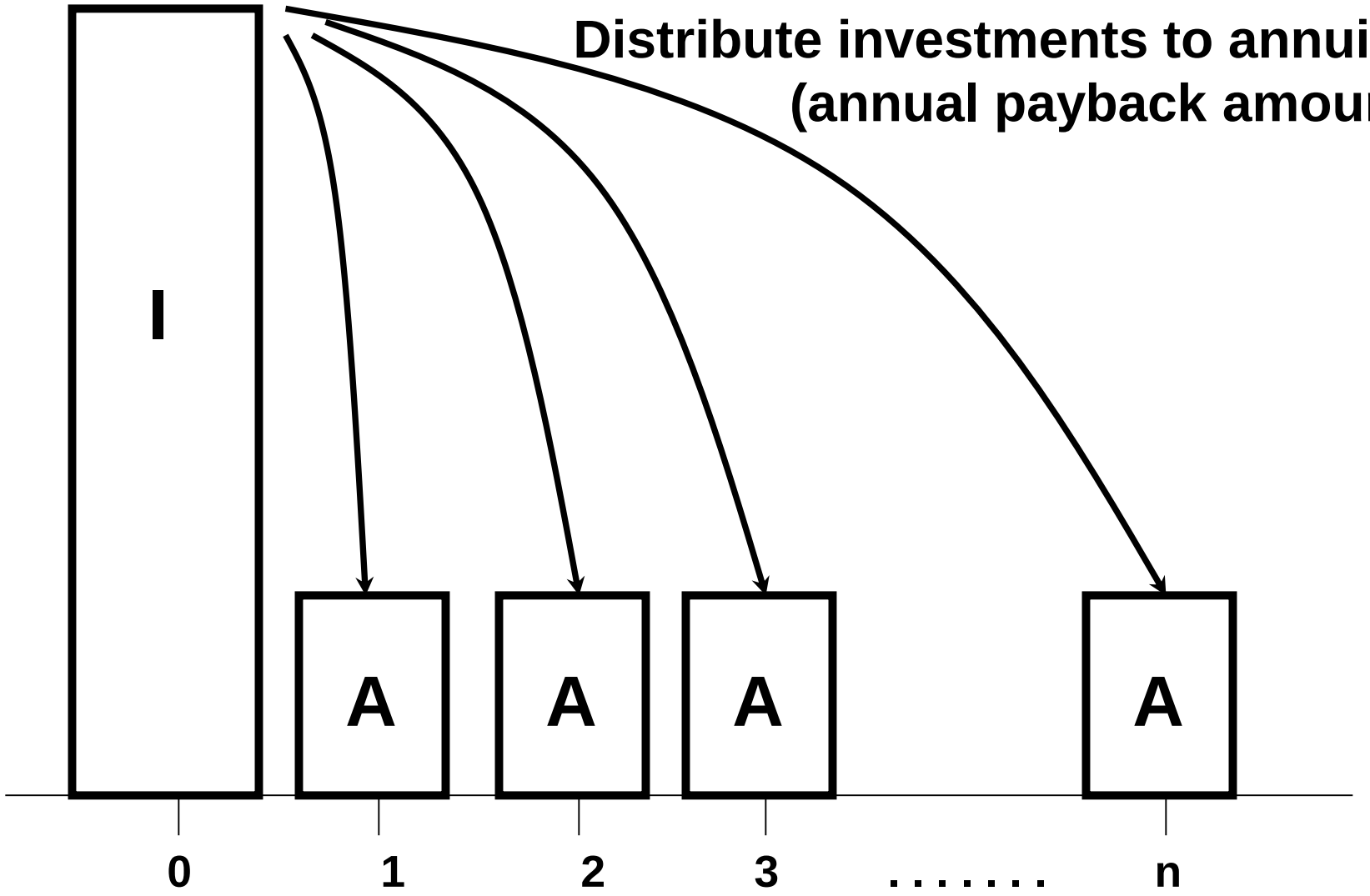


Development of day-ahead electricity prices in Europe per year



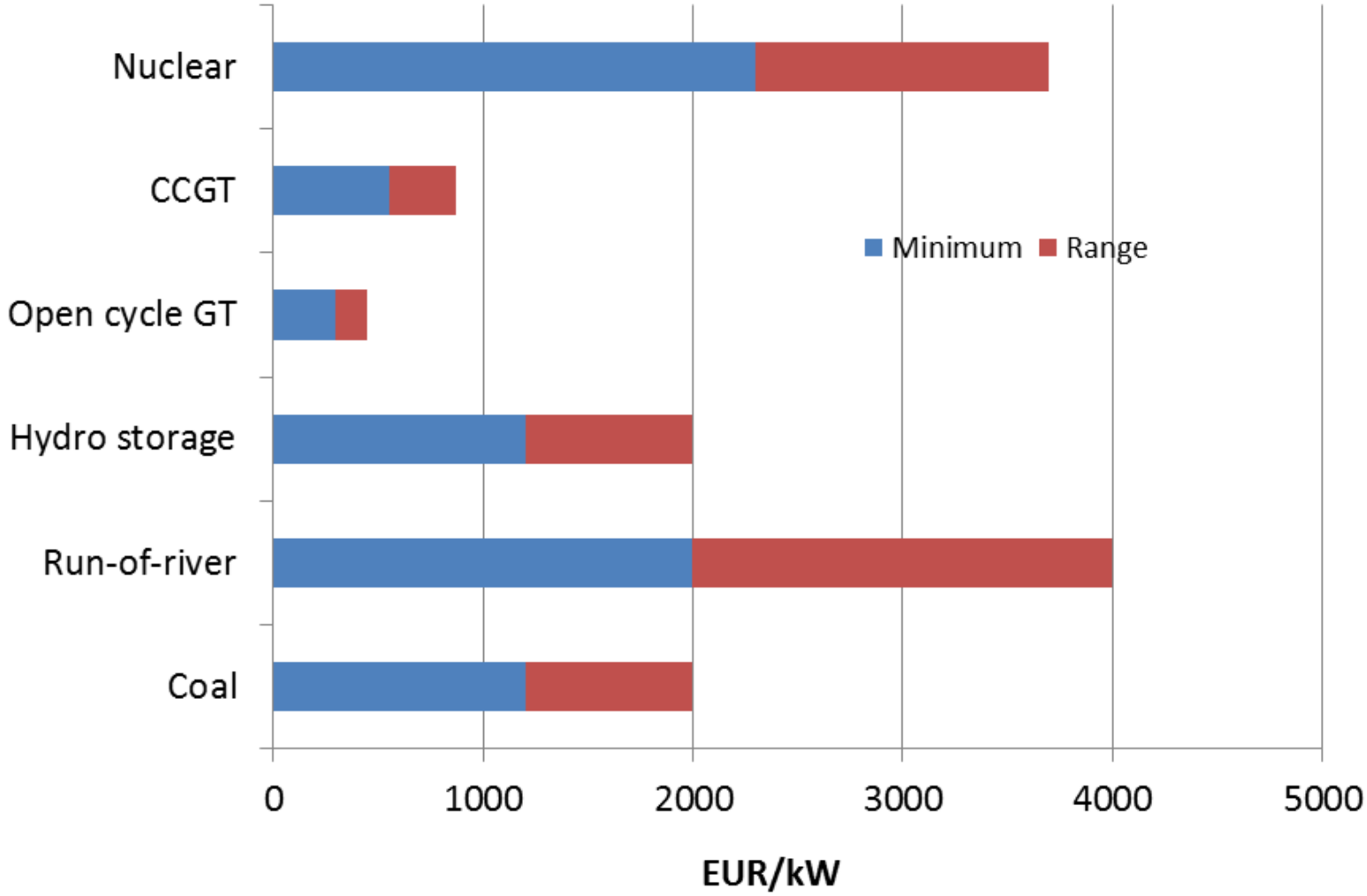
5 ELECTRICITY GENERATION COSTS

ANNUITY METHOD

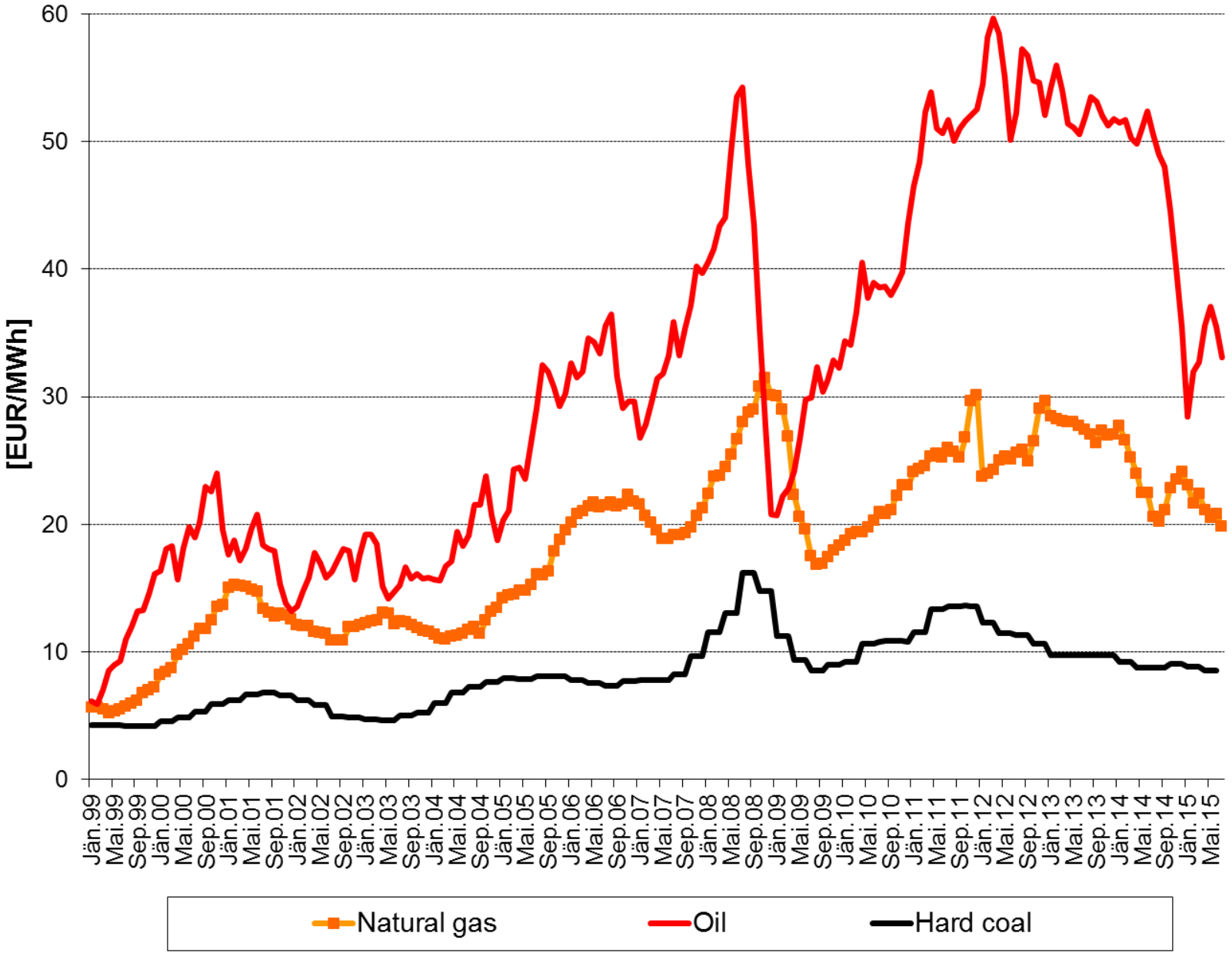


Investment costs

Electricity generation Conventional 2015



Fossil fuel prices 1999-2015



Costs of electricity generation

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

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. 5 EUR/ton Carbon)

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

Example: Costs of electricity generation from CCGT

I ….Investment costs = 600 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. 25 cents/m³ natural gas)

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

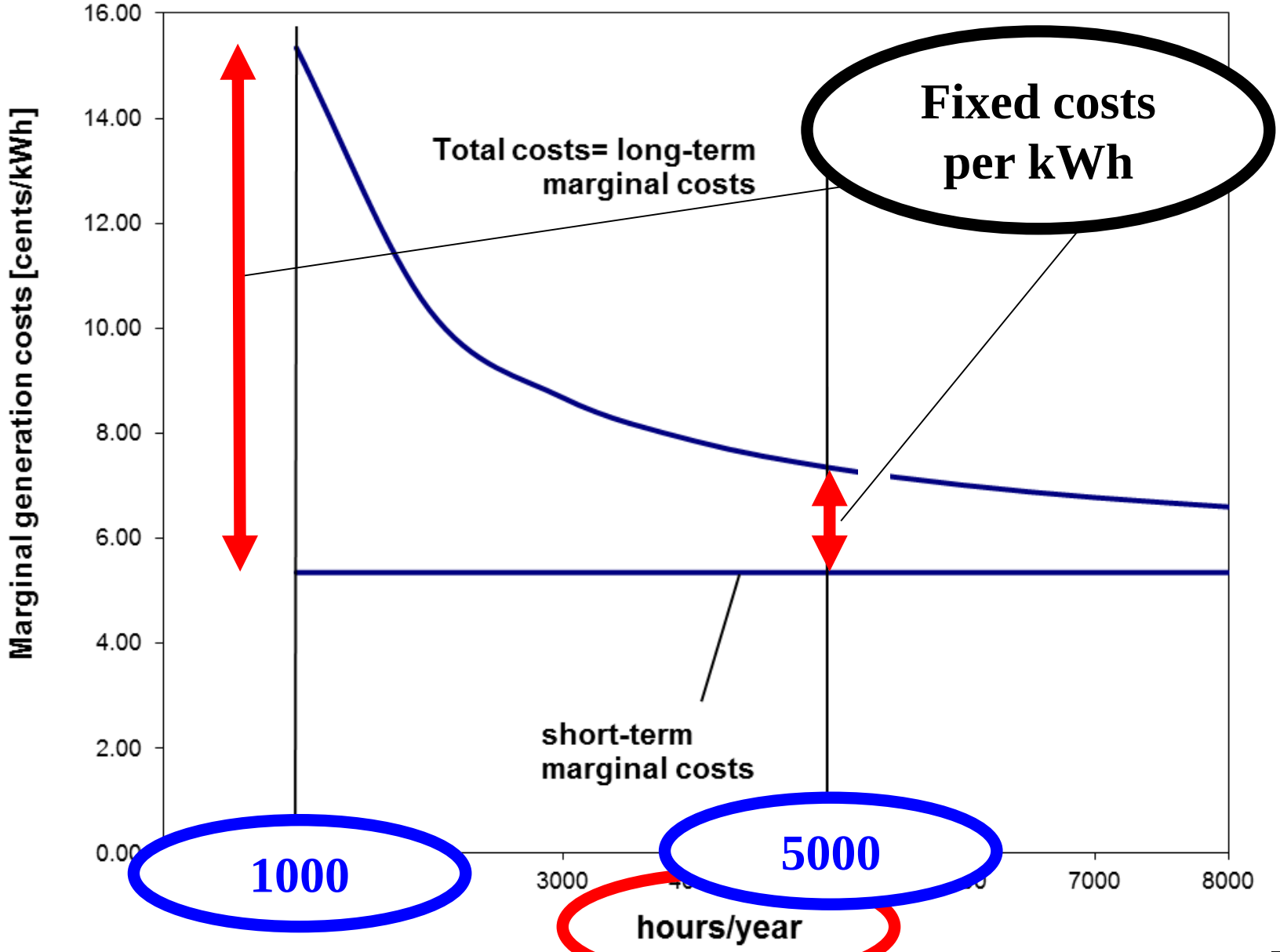
η …Efficiency of CCGT plant = 0.58

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

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

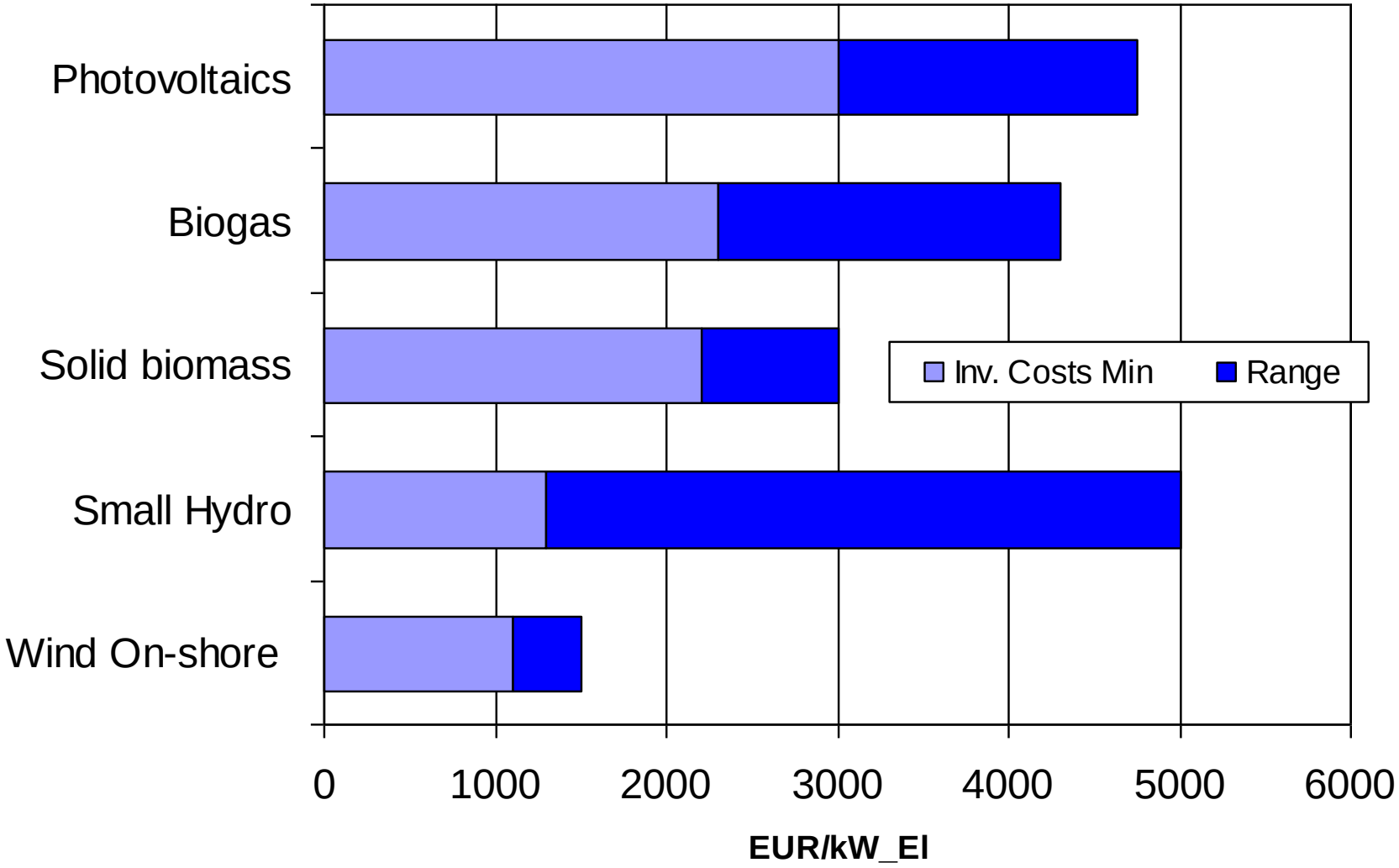
Example: Costs of electricity generation from CCGT

Generation costs CCGT



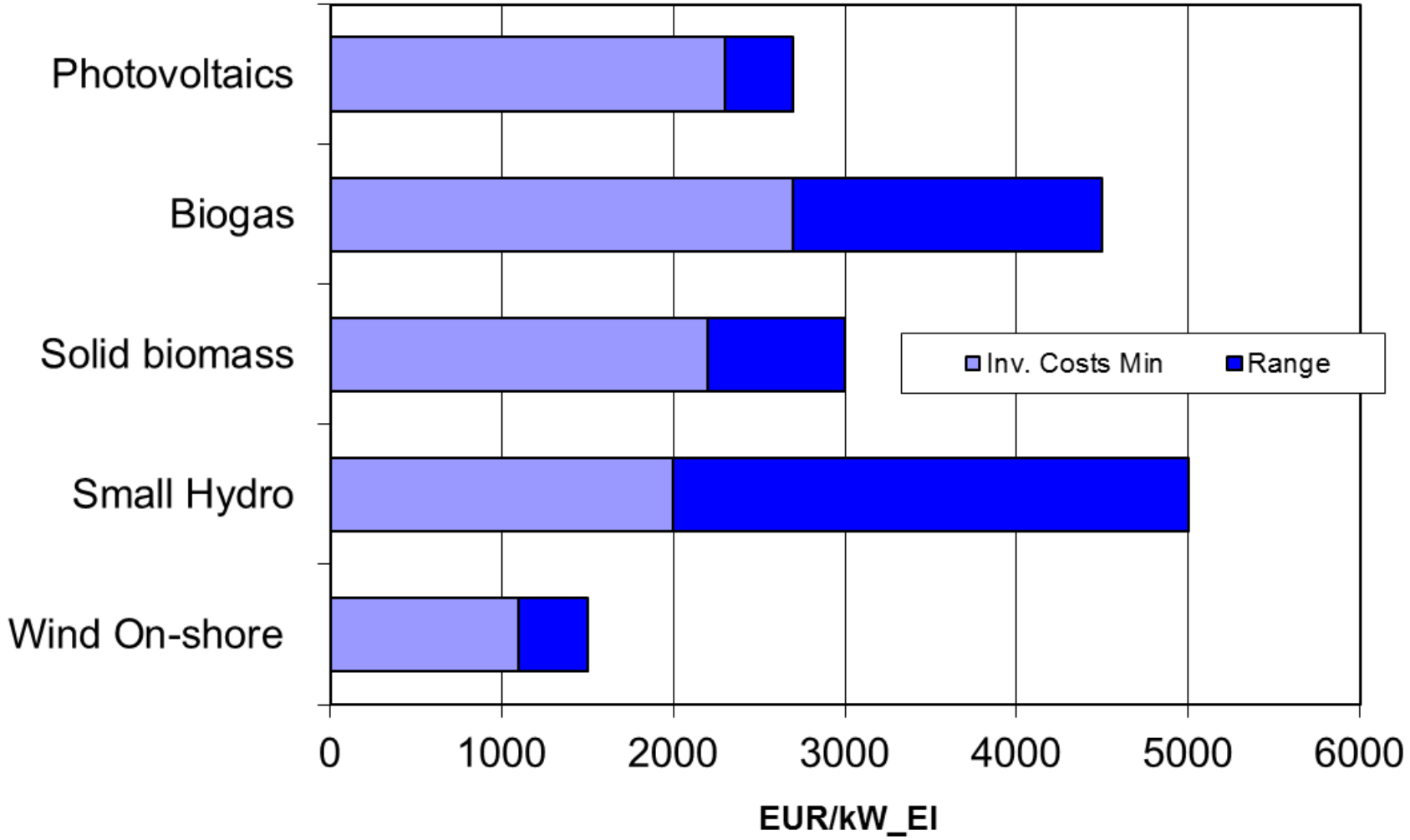
Investment costs

Electricity from new renewables 2010



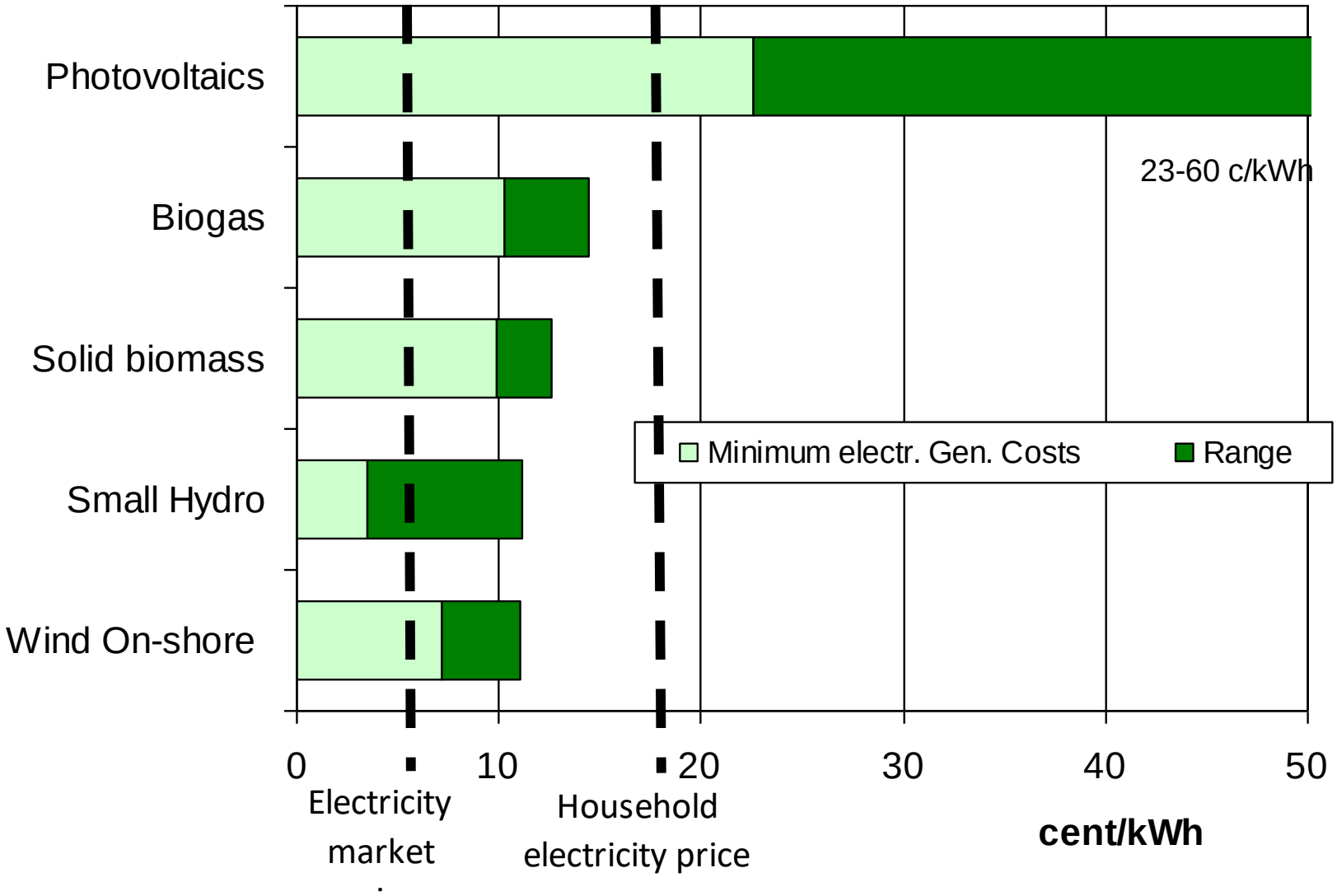
Investment costs

Electricity from new renewables 2015



Generation costs

Electricity from new renewables 2010



Generation costs

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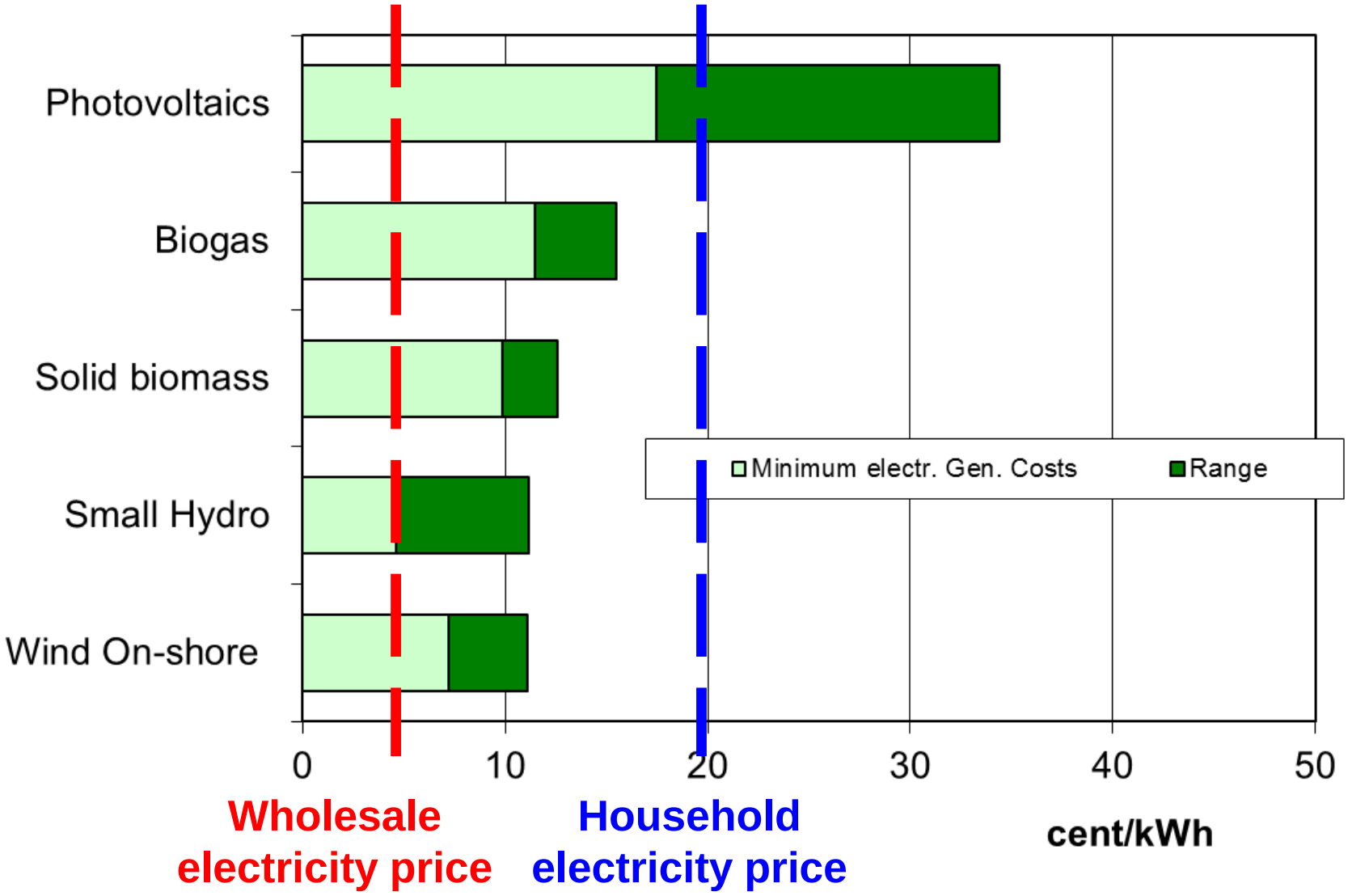
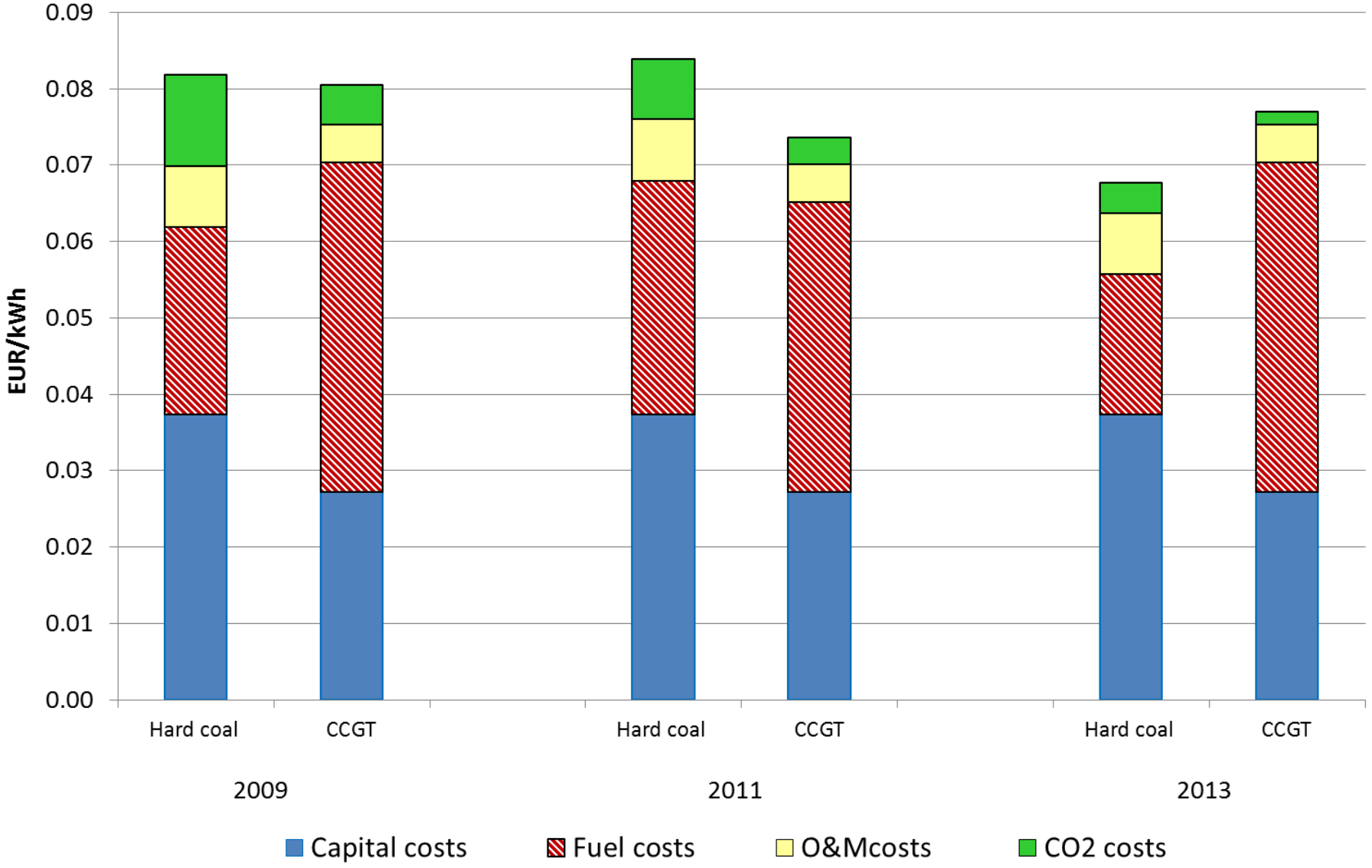
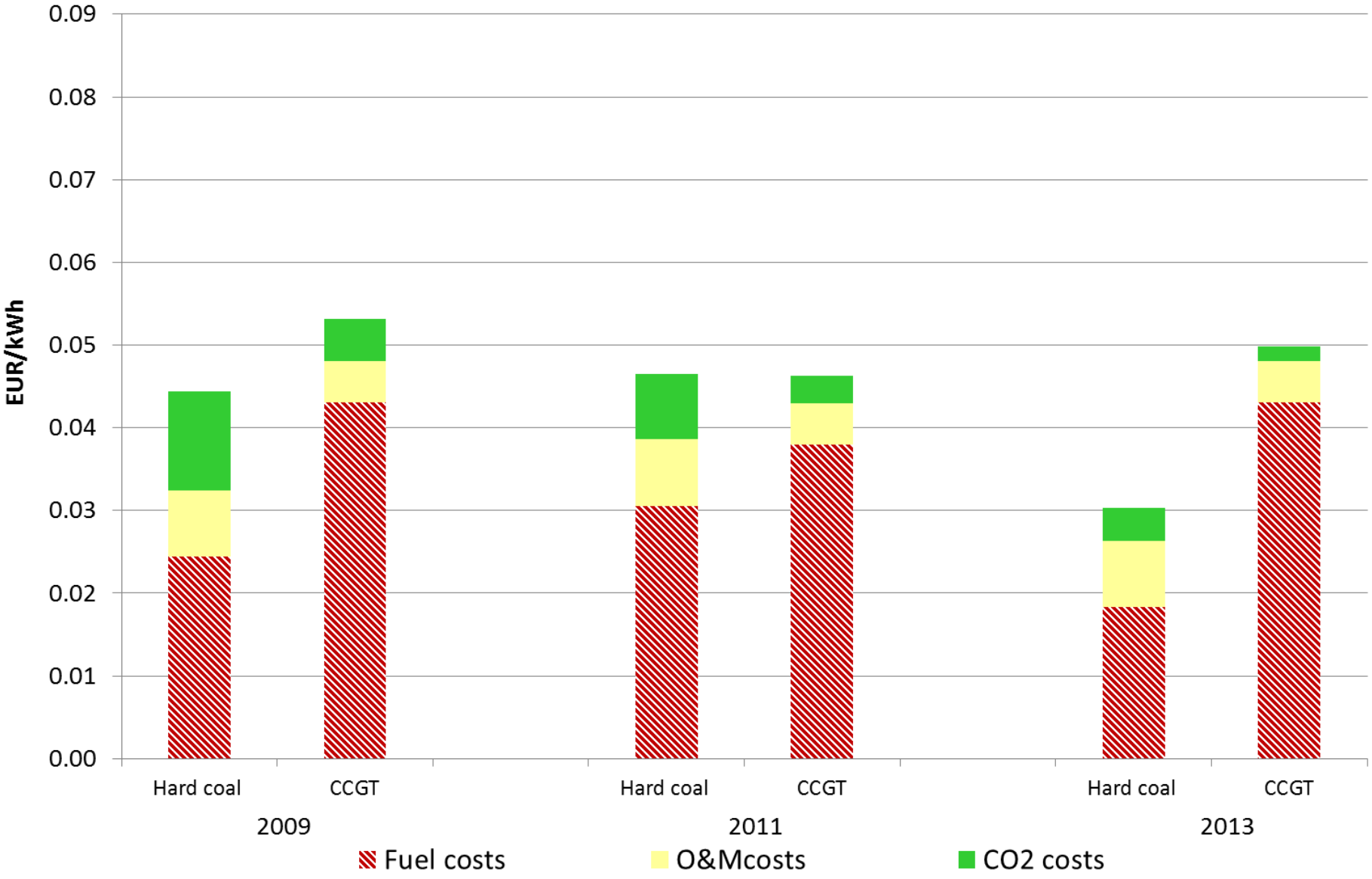


Total electricity generation costs 2009-2013



Variable electricity generation costs 2009-2013

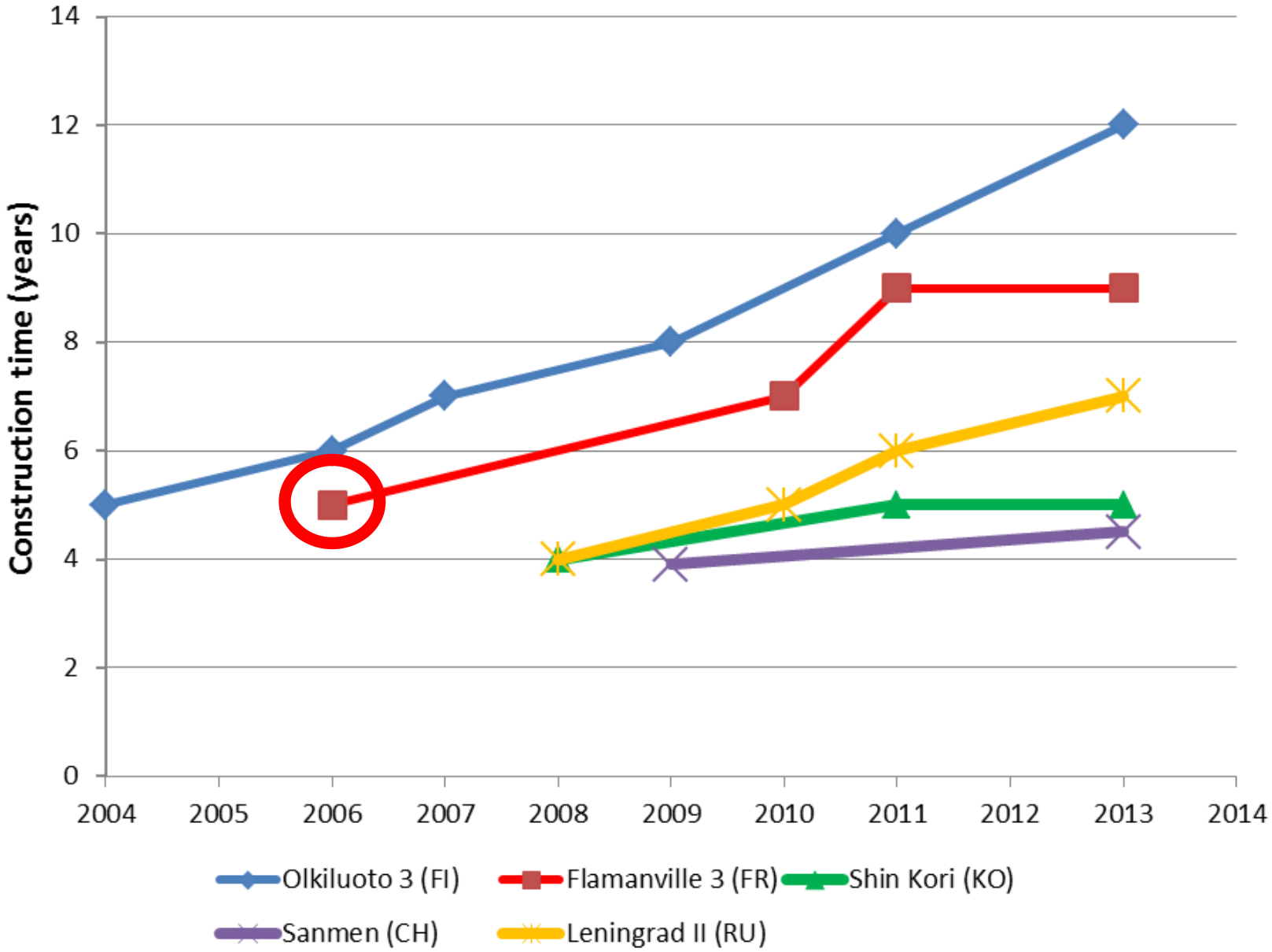


6. RECENT DEVELOPMENT OF NUCLEAR COSTS

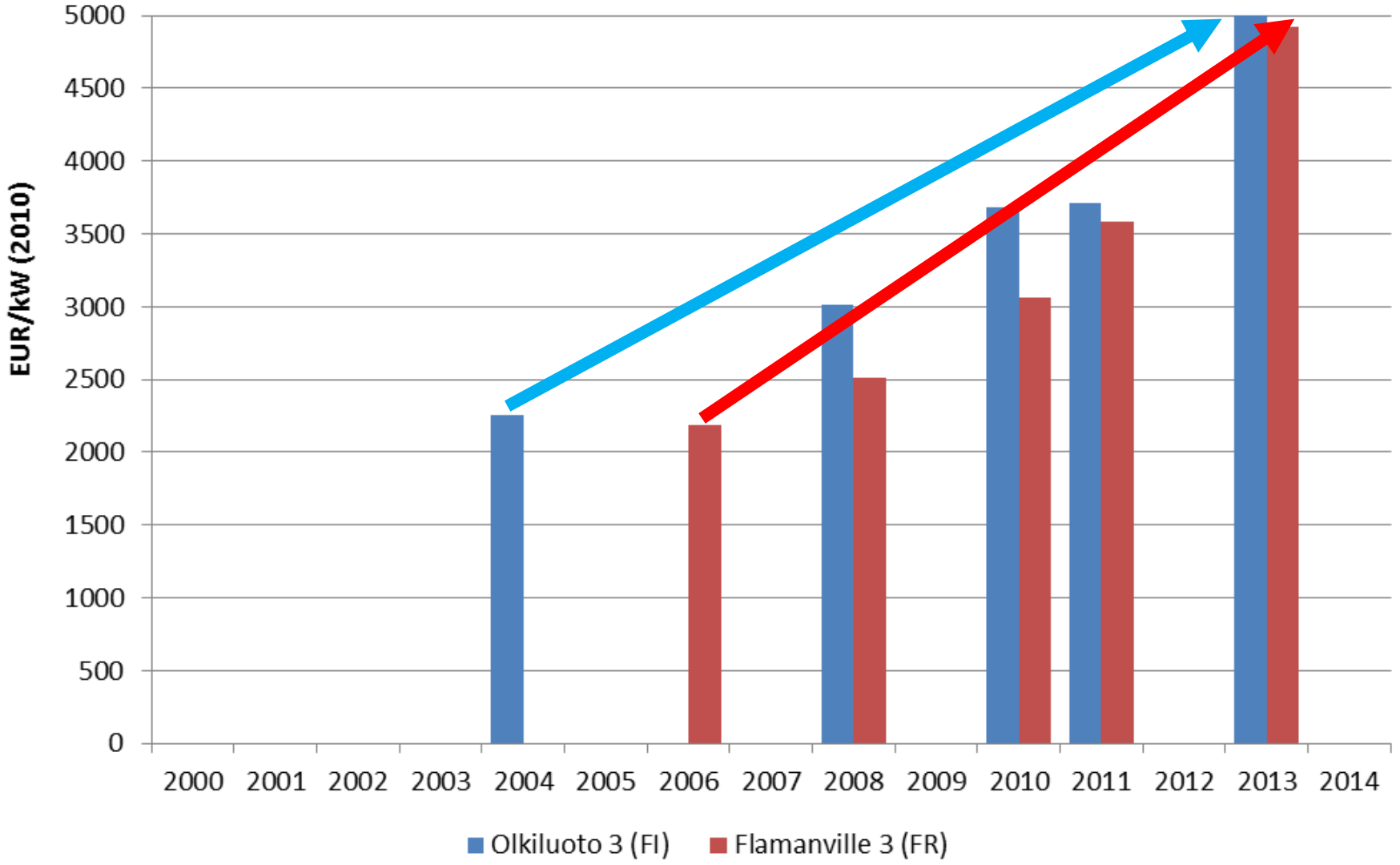
- **Olkiluoto-3 (Finland): Construction started in 2004, now expected to be completed 2017 (originally: 2009); 1600 MW**

- **Flamanville-3 (France): Construction started in 2006, now expected to be completed 2017 (originally: 2011); 1600 MW**

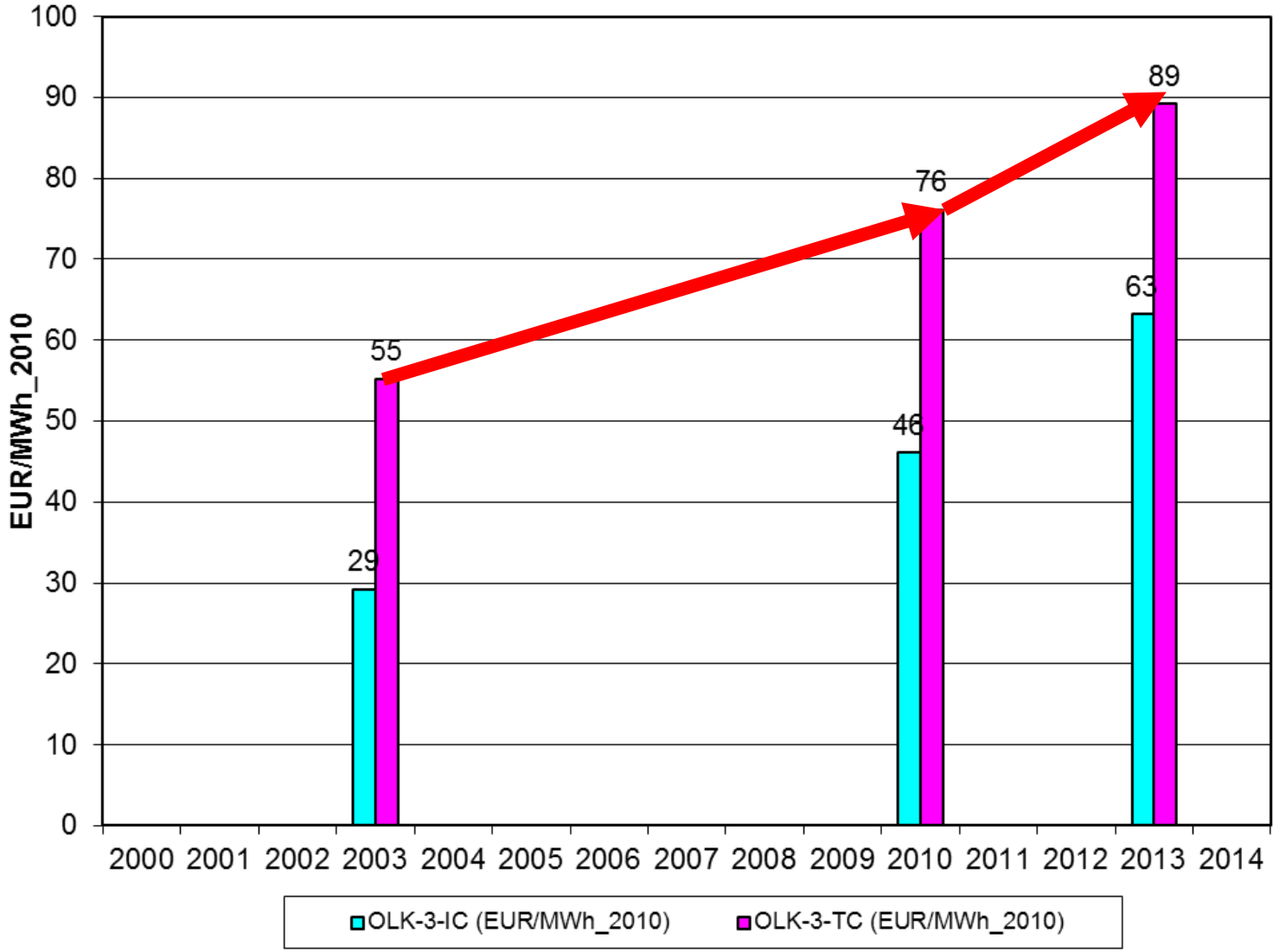
Construction times



Investment cost development Olkiluoto 3 vs Flamanville 3

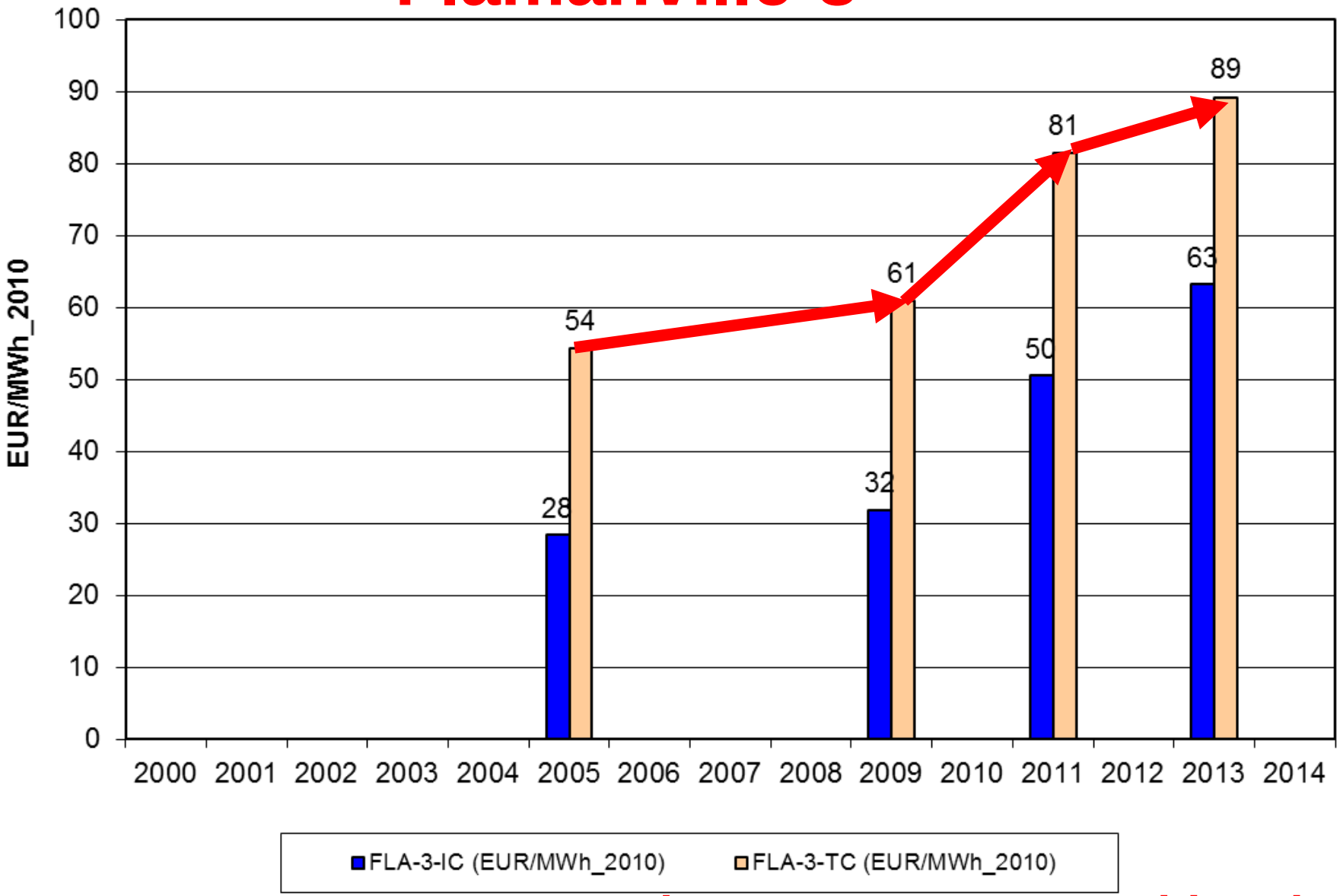


„Total“ Cost development Olkiluoto



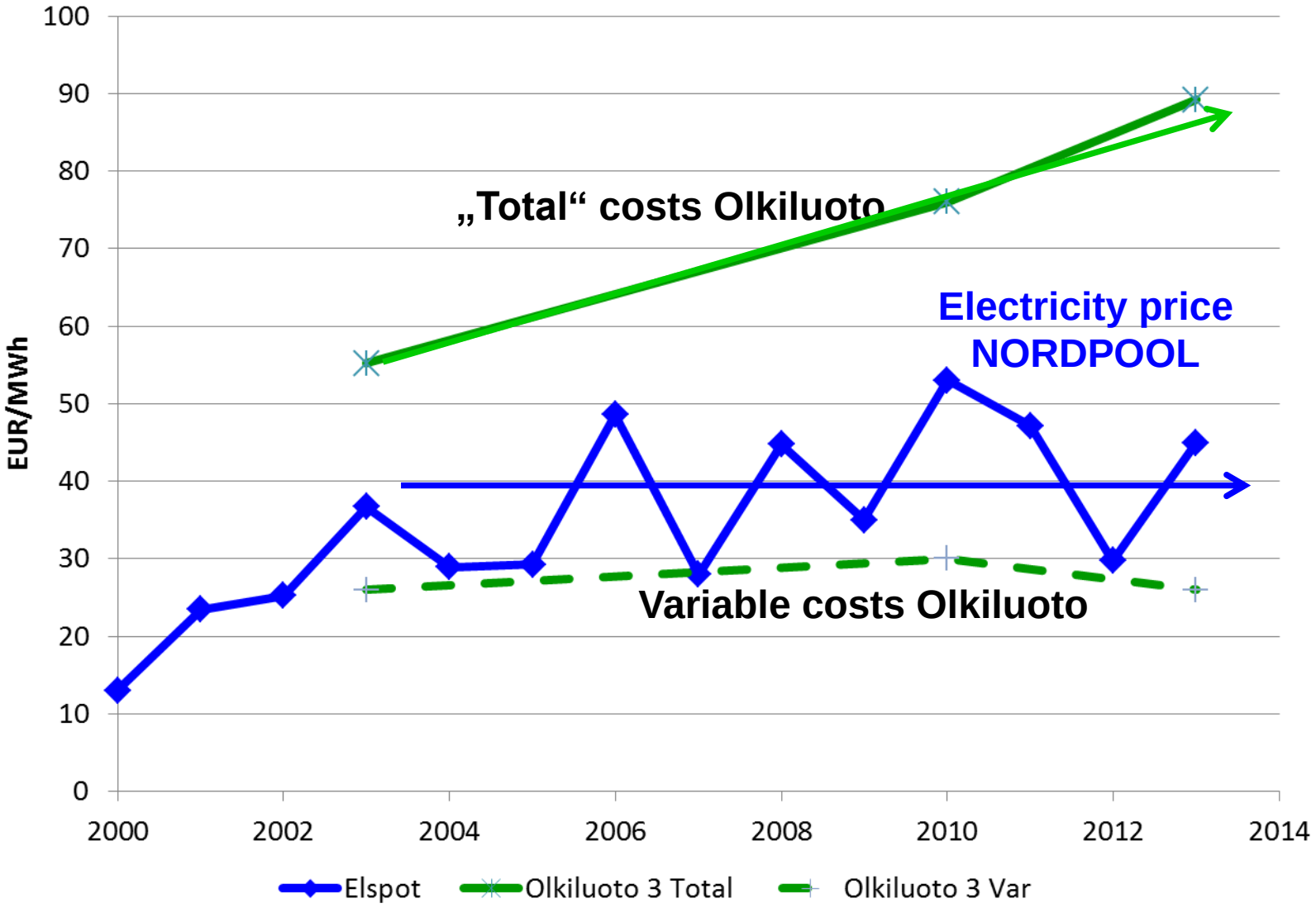
No insurance costs considered!

„Total“ Cost development Flamanville-3

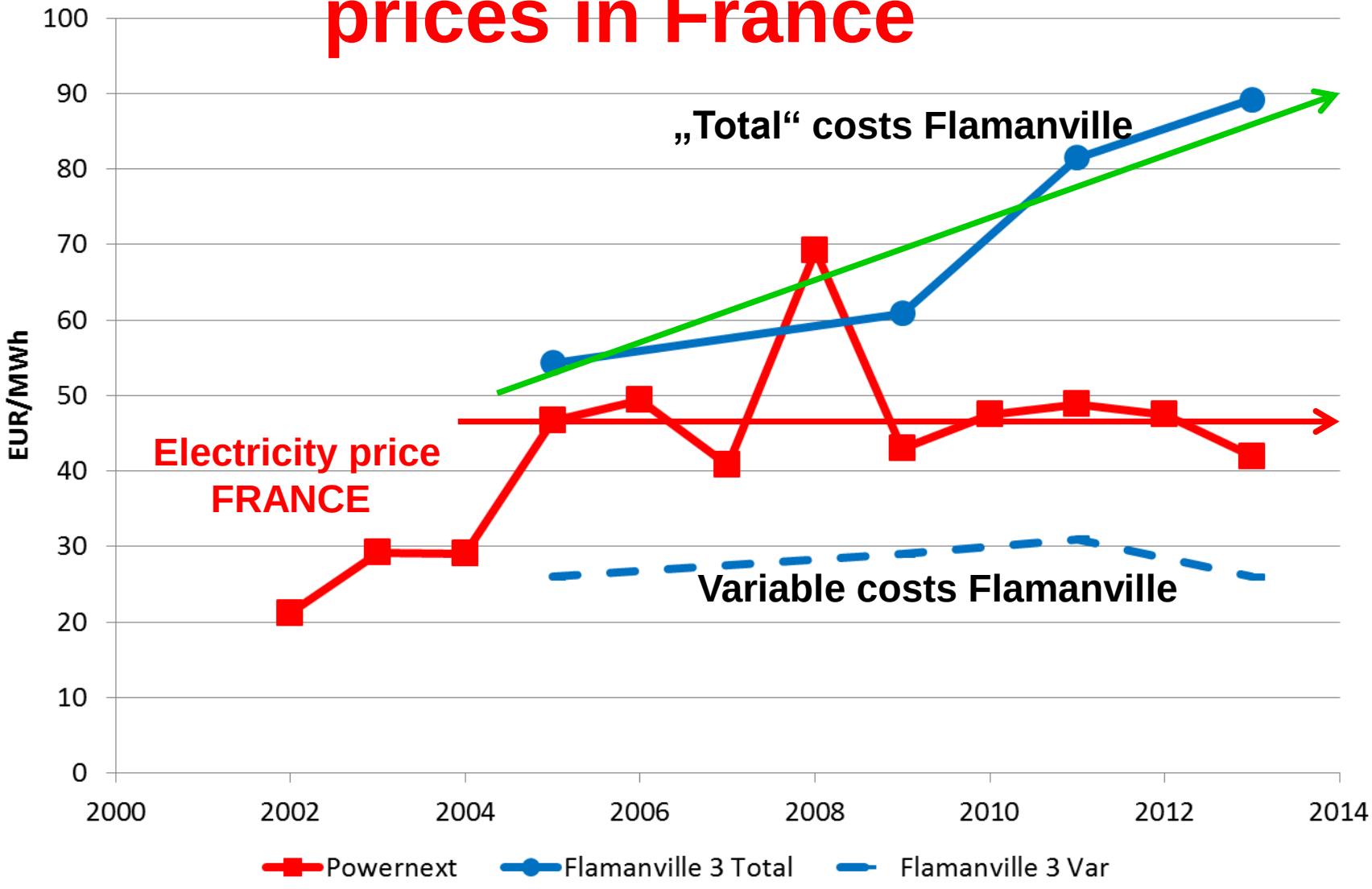


No insurance costs considered!

Costs vs market prices in Nordic countries



Costs vs market prices in France



7. THE ROLE OF RENEWABLES

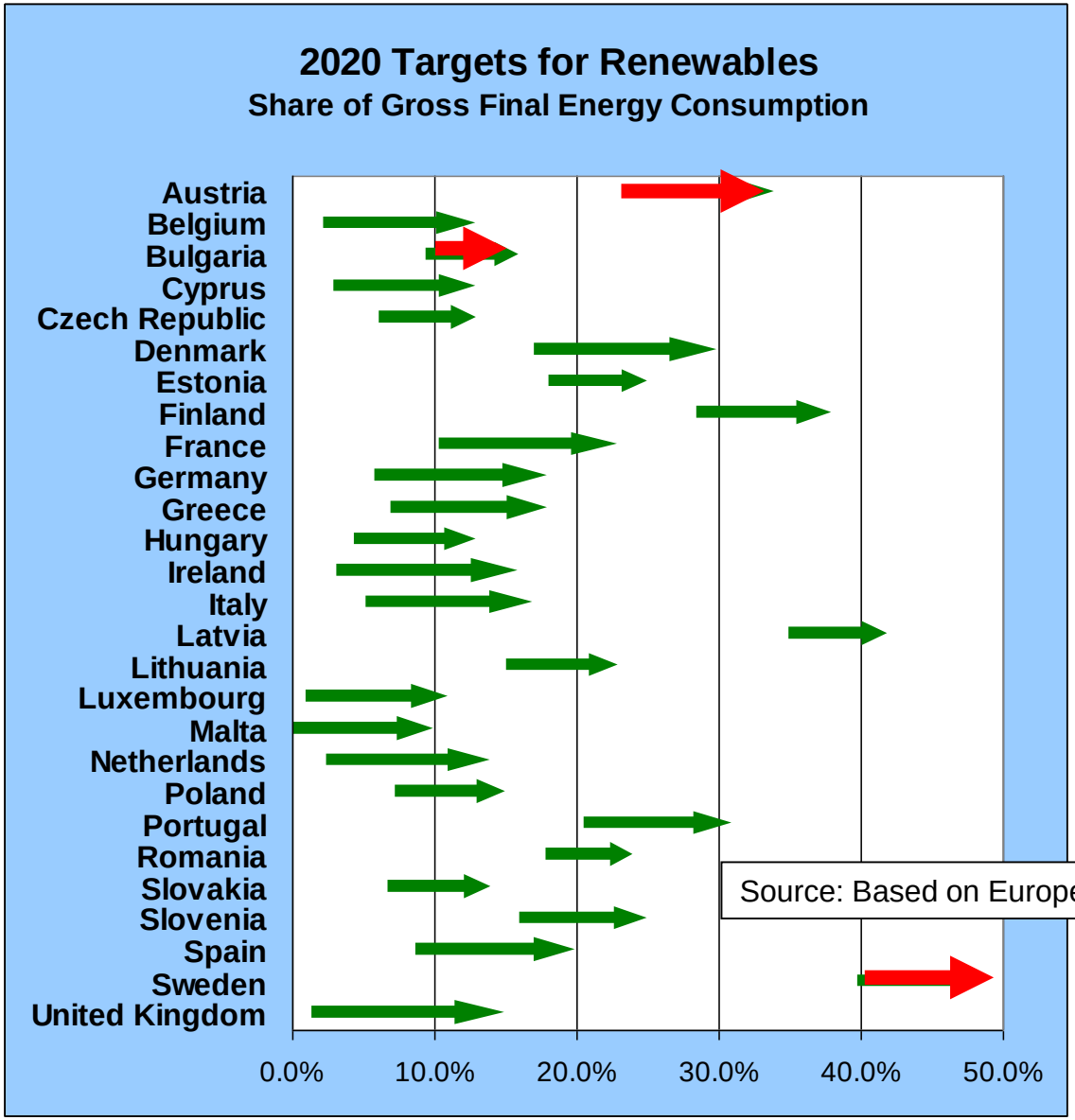
CORE MOTIVATION:

Policy targets for an INCREASE of RES-E!

e.g. 2020/20/20/20 targets

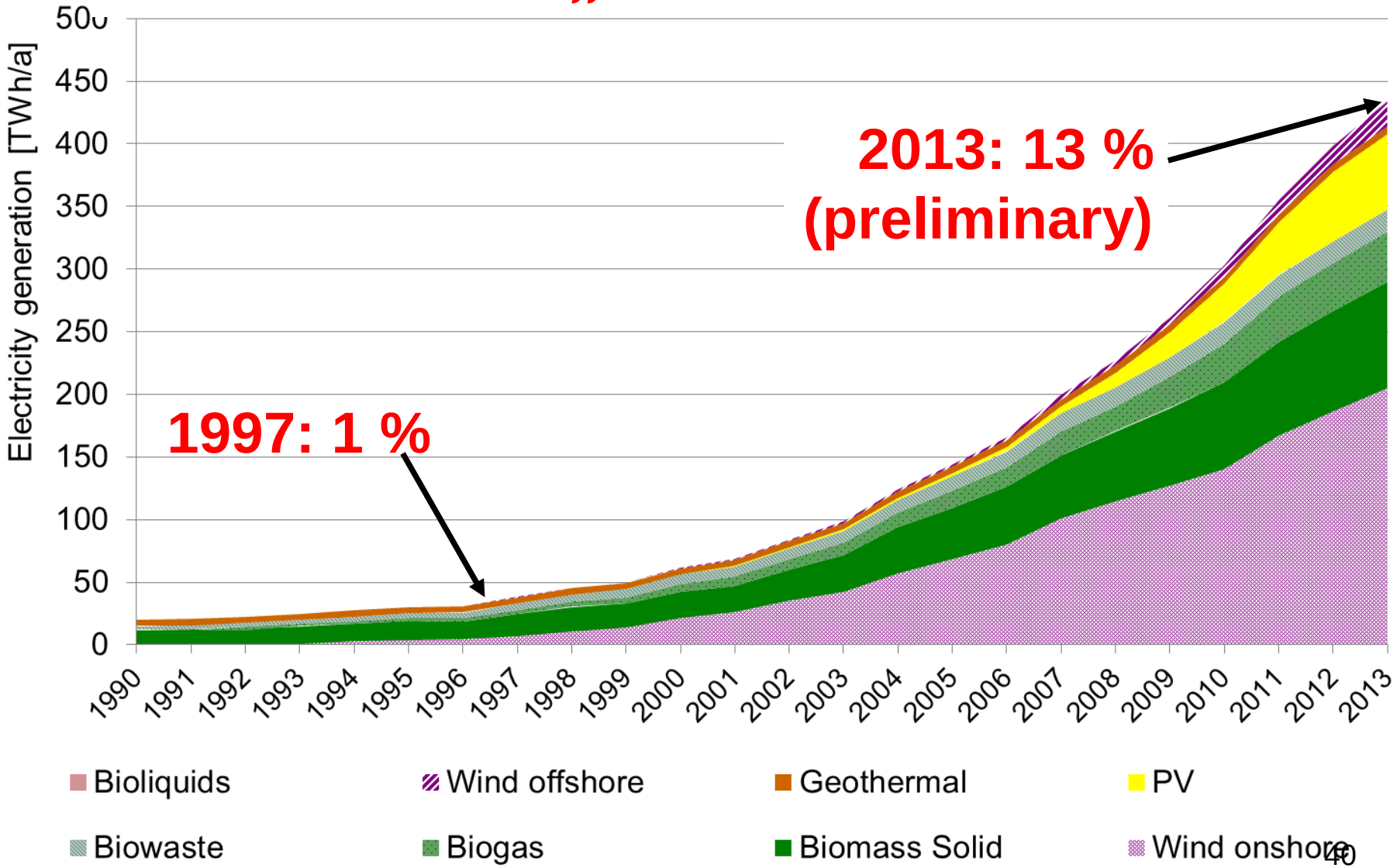
RES-E directive: increase share of RES-E from 12% 1997 to 22% in 2010)

RES targets for 2020:



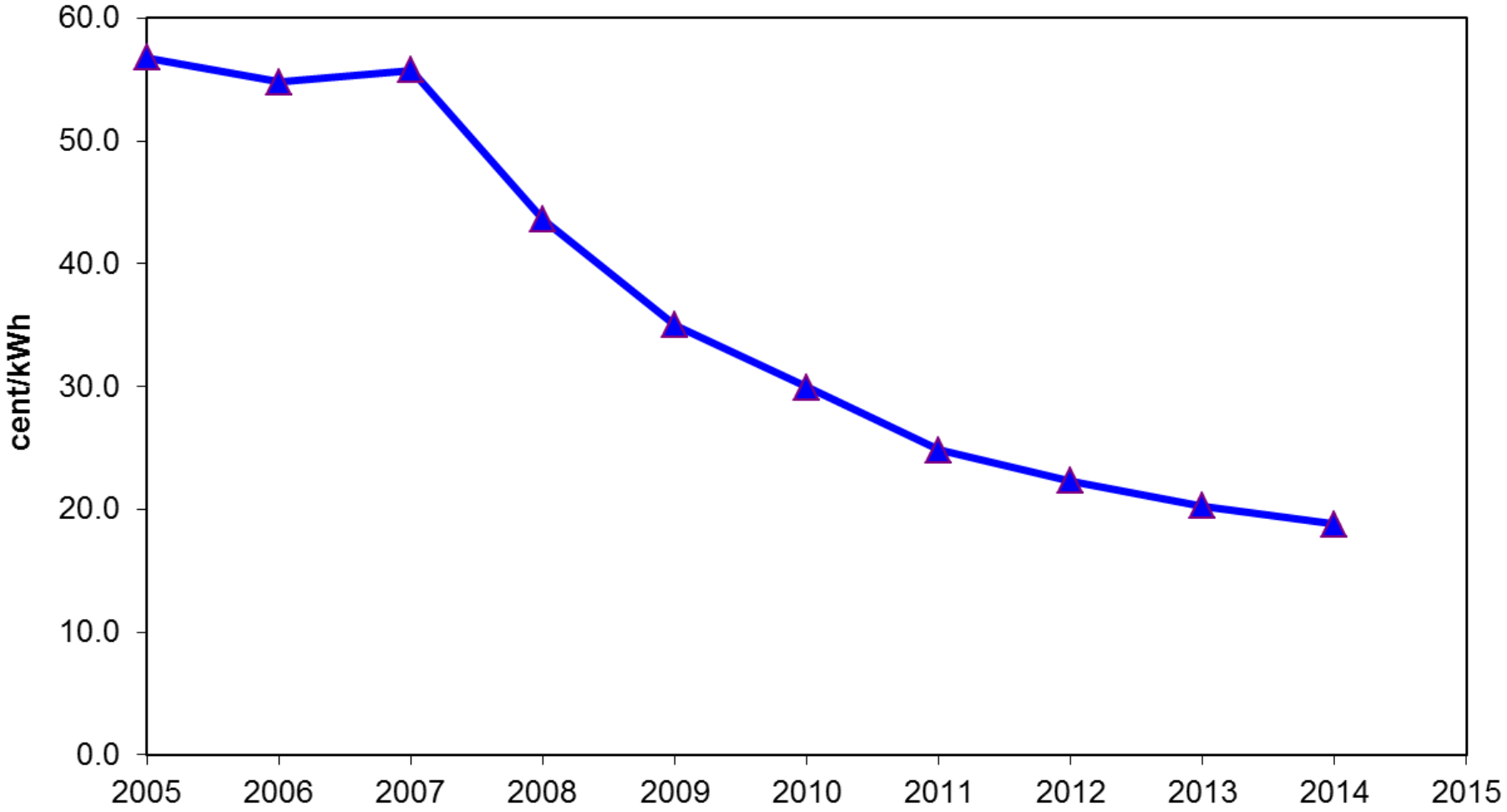
Source: Based on European Commission (COM(2008) 19)

EU-27: Electricity generation from „new“ RES

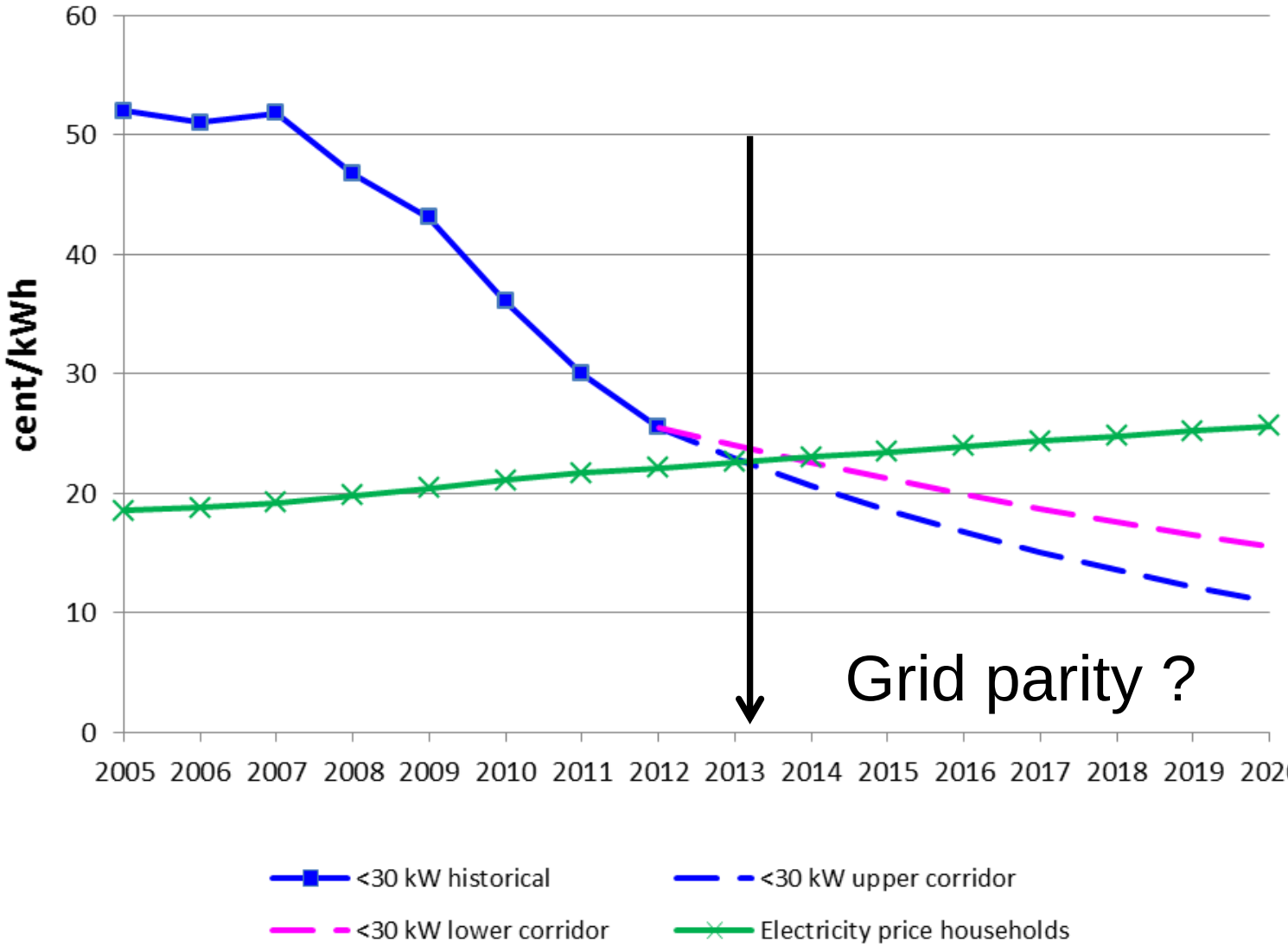


Source: EUROSTAT, own estimations

Development of PV generation costs



Development of PV generation costs vs household electricity prices



8. CONCLUSIONS:

- Markets are in a period of transition towards volatility;
- Nuclear: long lead time, uncertain costs → high promises, low fullfilments;
- Renewables: next very interesting phase: after PV-Grid parity!
- More details: Summer school

Example: Costs of electricity generation from CCGT

5000 h/yr:

C = 1.20 + 0.40 + 4.31 +0.17 = 6.08 cent/kWh

1000 h/yr:

C = 6.0 + 2.0 + 4.31 +0.17 = 12.48 cent/kWh