ELECTRICITY MARKETS, AND THE ROLE OF RENEWABLES & NUCLEAR

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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

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

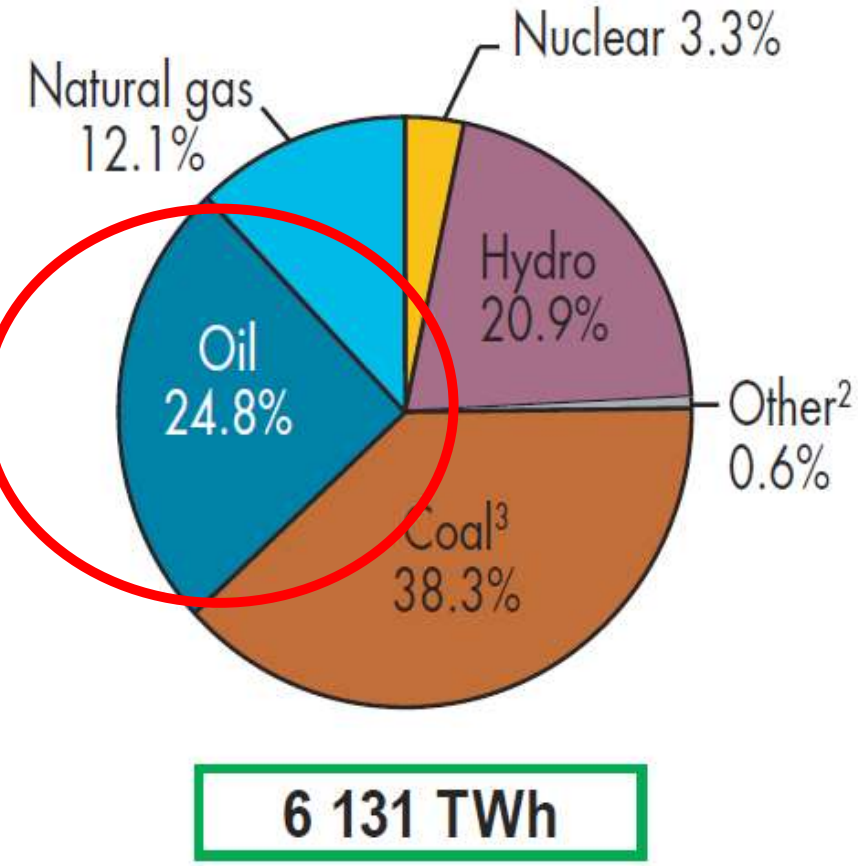
The European Commission's main expectation …. was the belief that

"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**

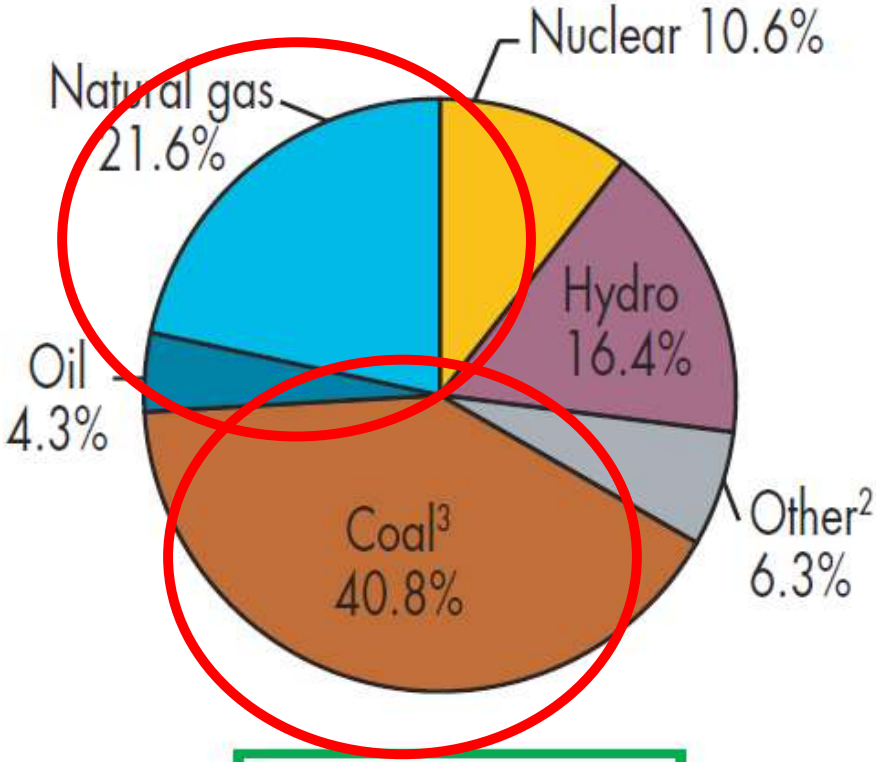
Global Electricity

1973



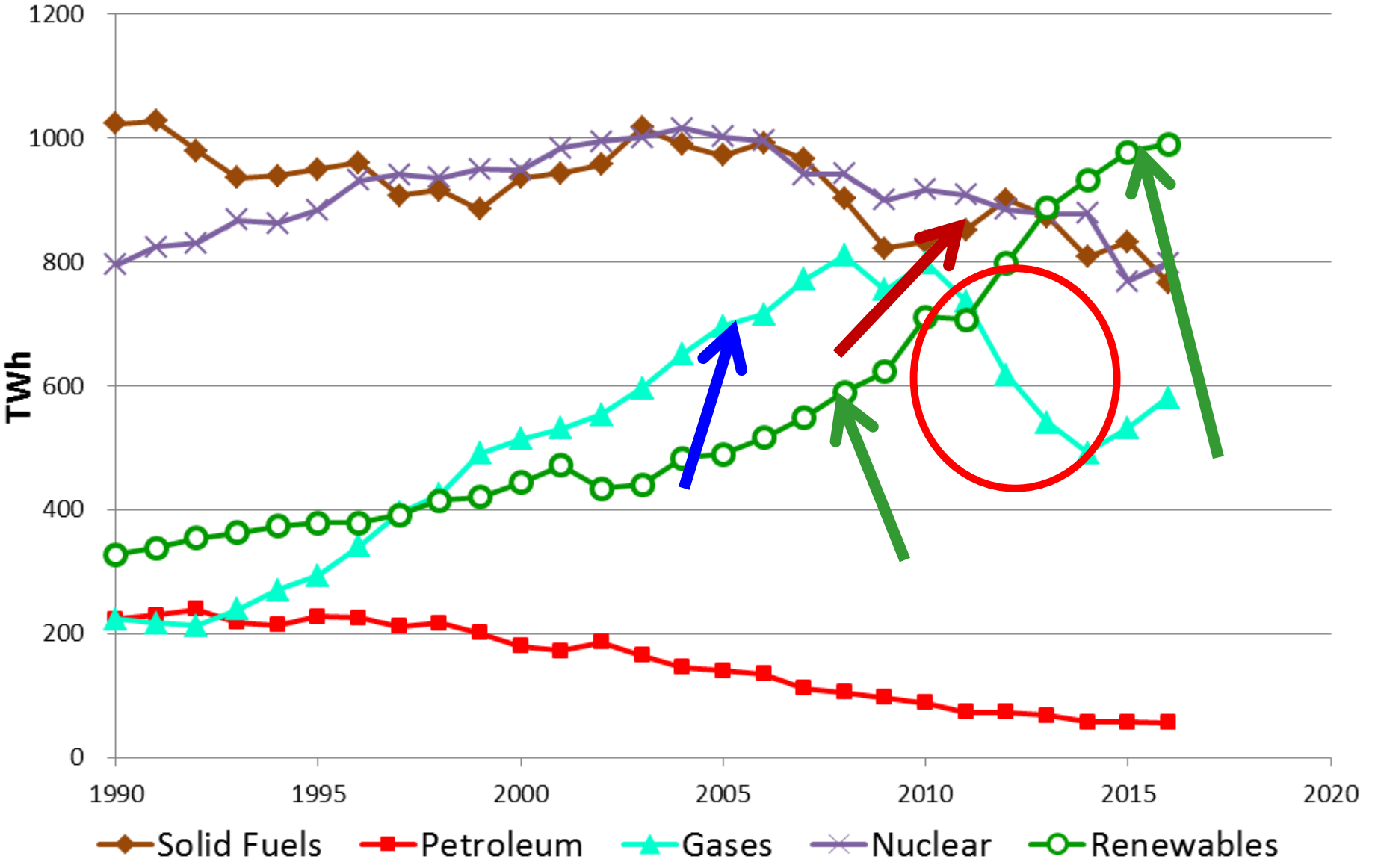
6 131 TWh

2016

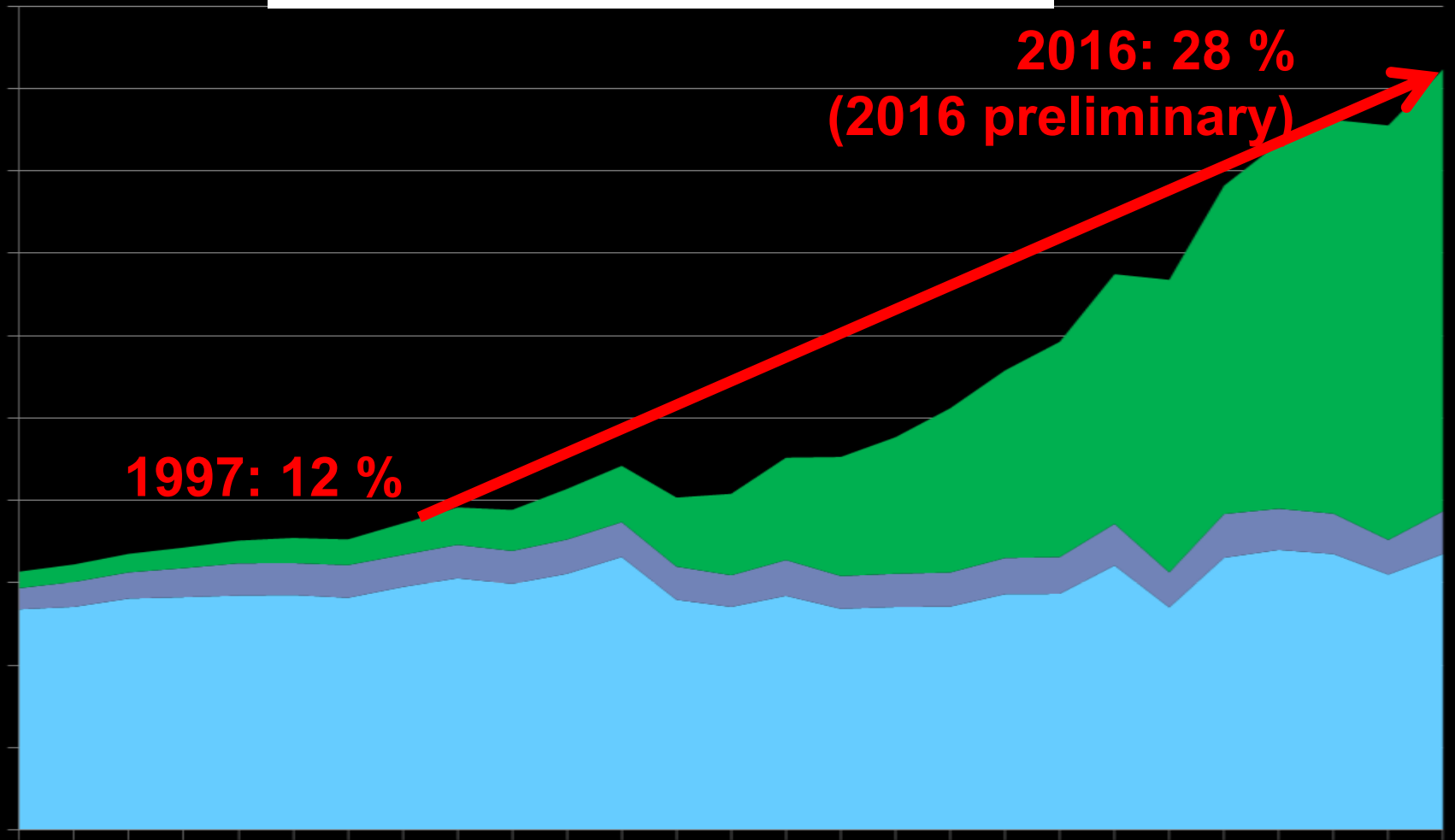


23 816 TWh

1. Introduction: Electricity generation EU-28

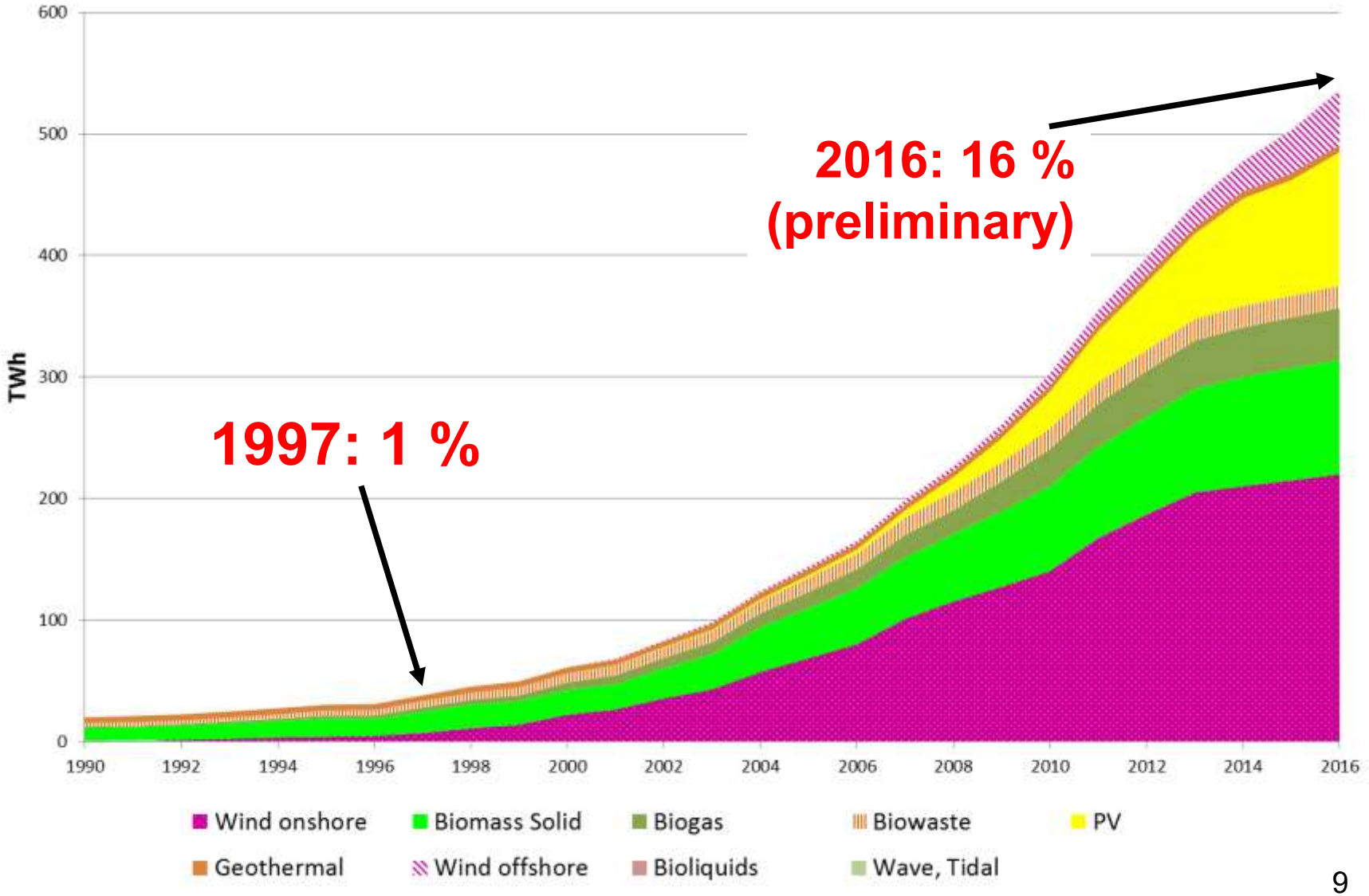


EU-28: Electricity generation from RES



Source: EUROSTAT, own estimations

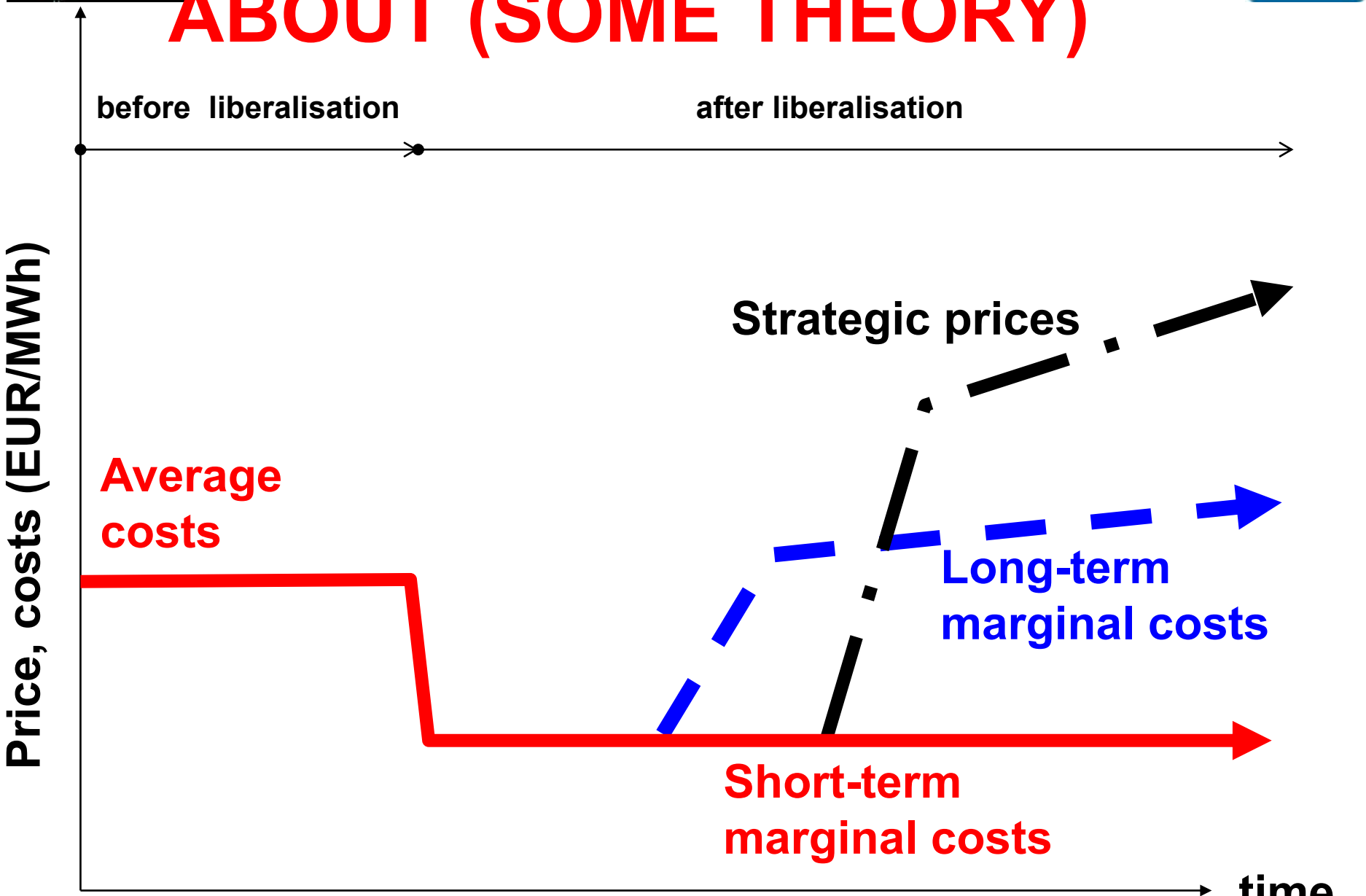
EU-28: Electricity generation from „new“ RES



Source: EUROSTAT, own estimations

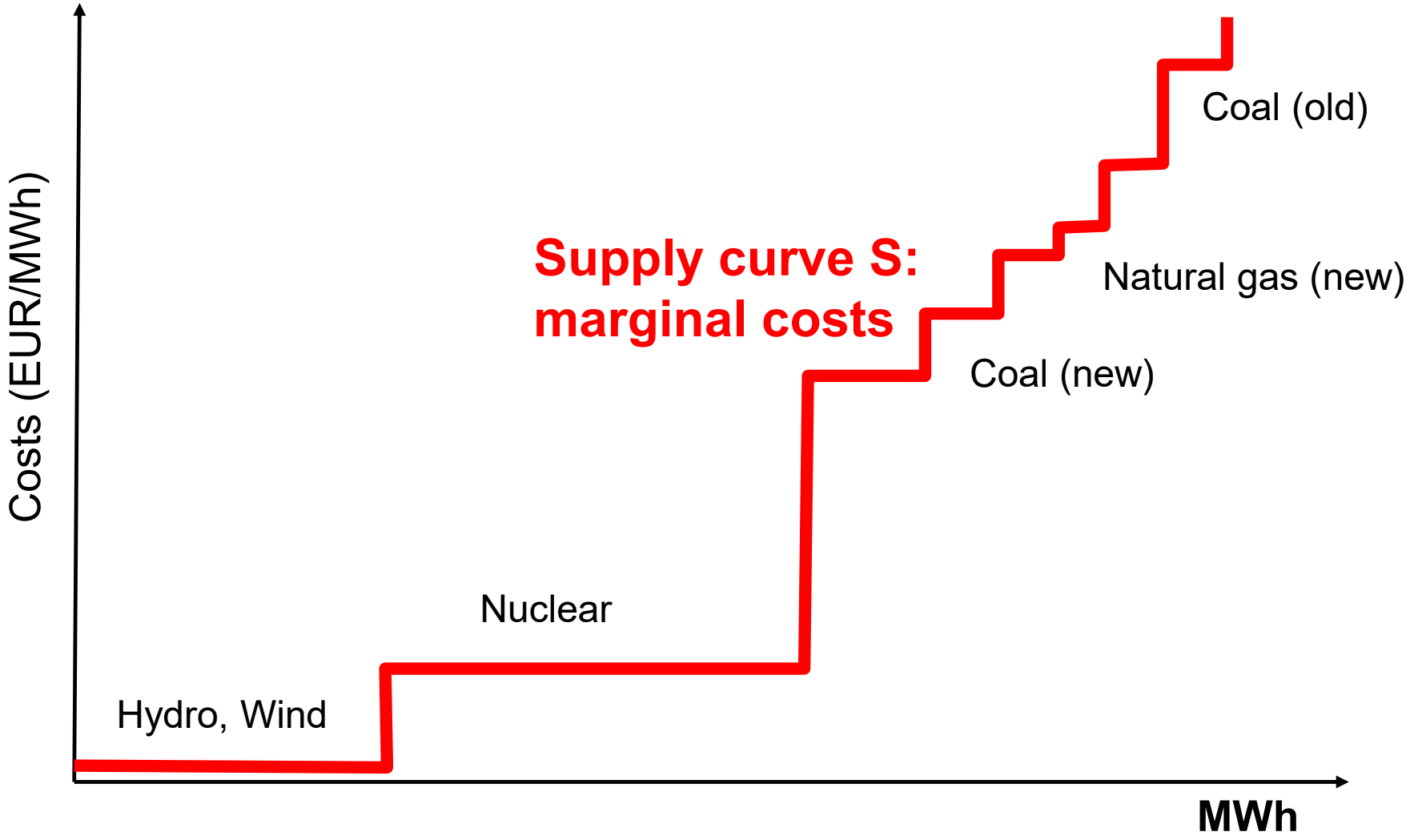
Discussion: PV vs Nuclear
What are the advantages and disadvantages for reducing GHG emissions and heading towards a sustainable energy system?

2 HOW PRICES COME ABOUT (SOME THEORY)

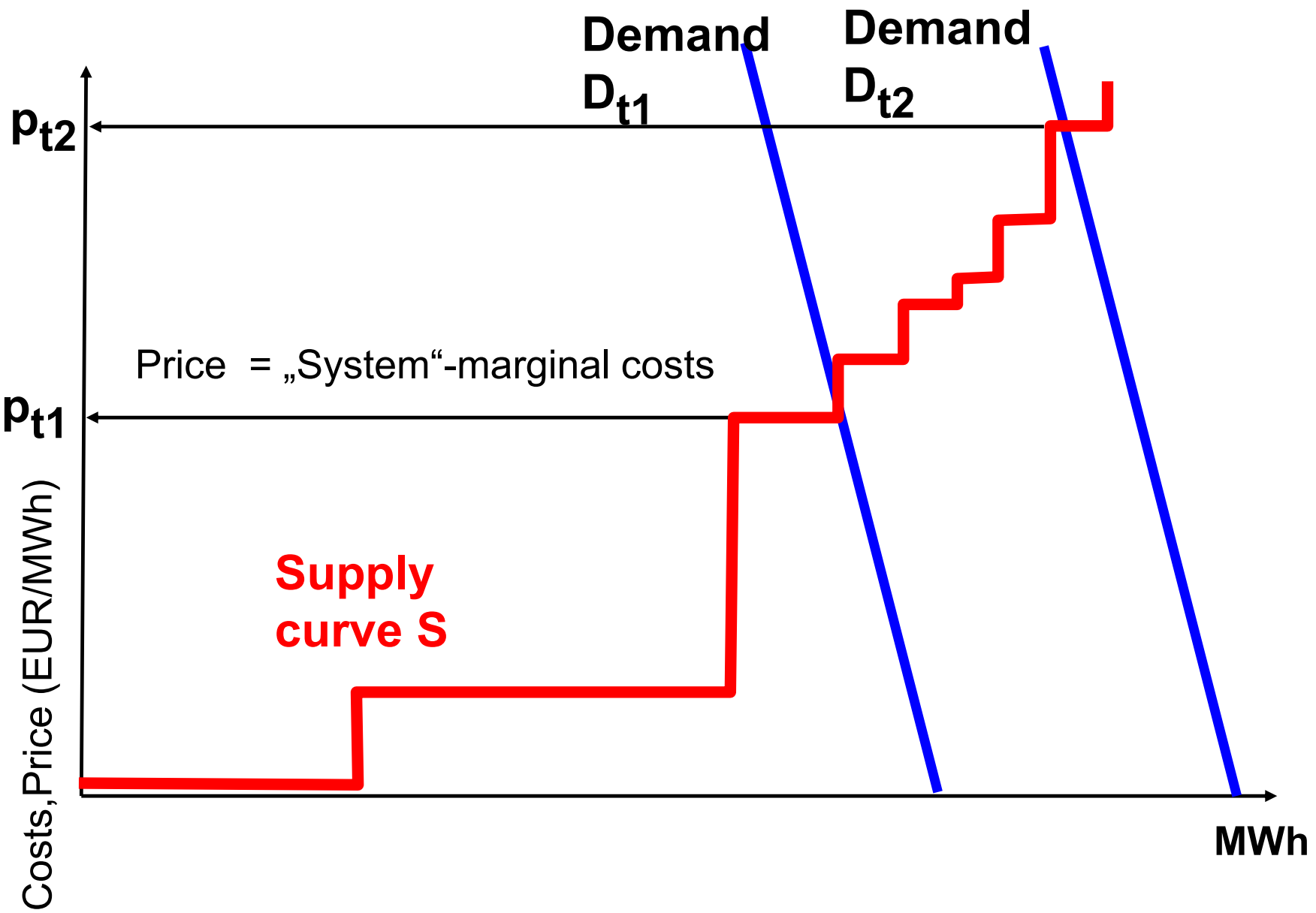


THE *MERIT-ORDER* CURVE OF SUPPLY

based on short-term marginal costs (MC)



BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



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

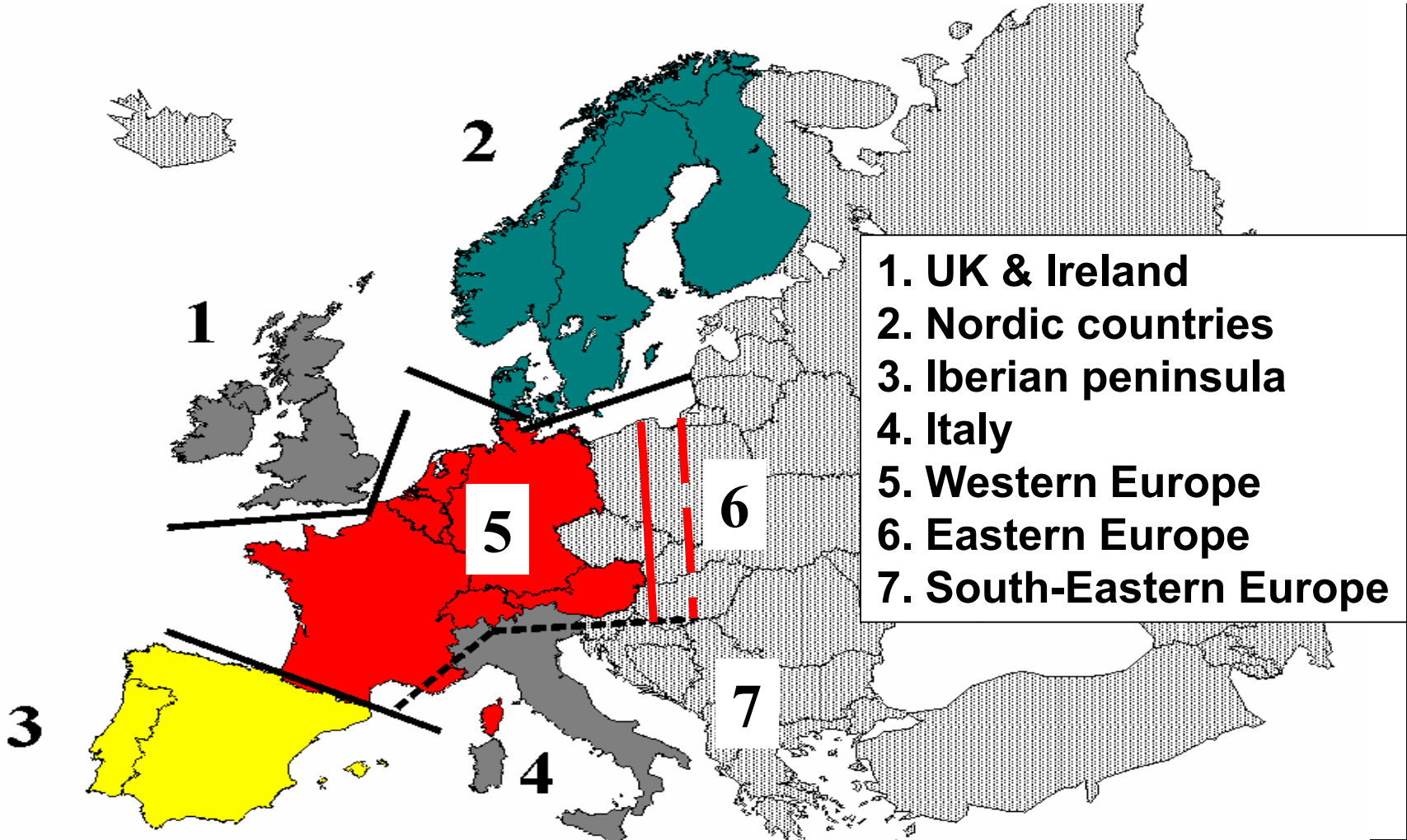
Long-term marginal costs (LTMC):

LTMC= STMC + Capital costs + O&M costs

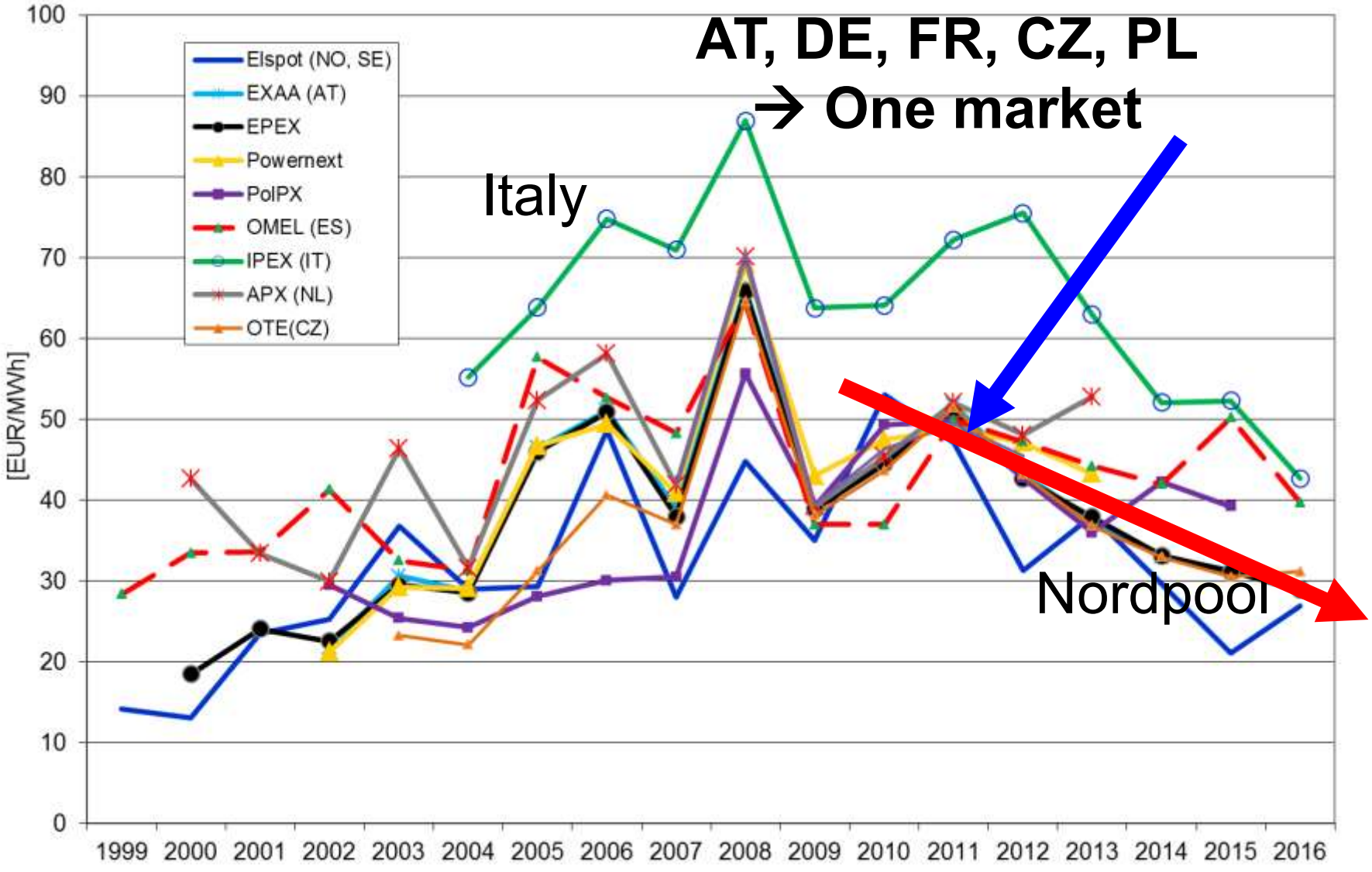
3 ENVIRONMENTAL ASPECTS – THE CO2-PRICE

4 HOW PRICES DEVELOPED IN EUROPE

EUROPEAN ELECTRICITY SUB-MARKETS

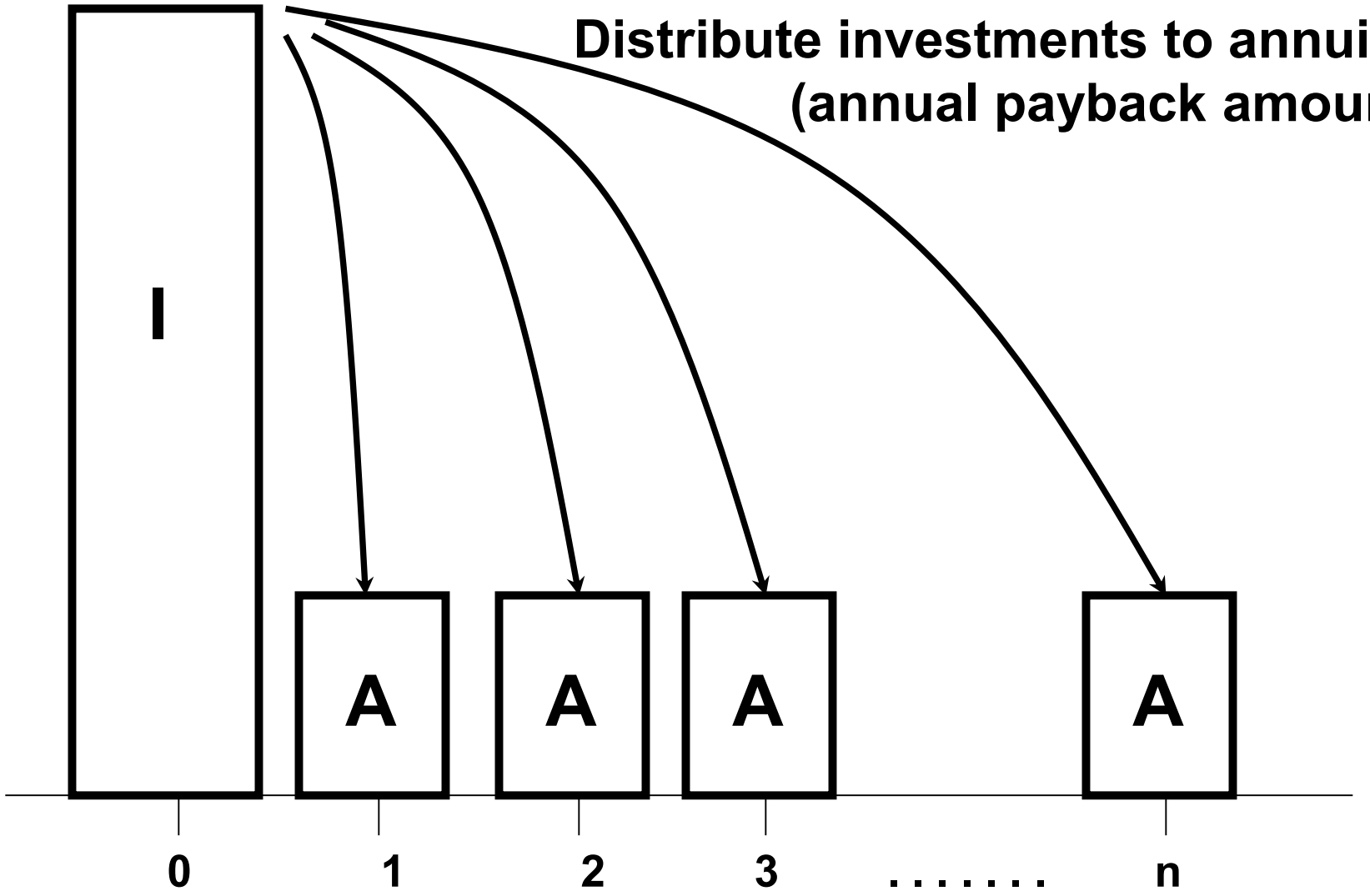


Development of day-ahead electricity prices in Europe per year



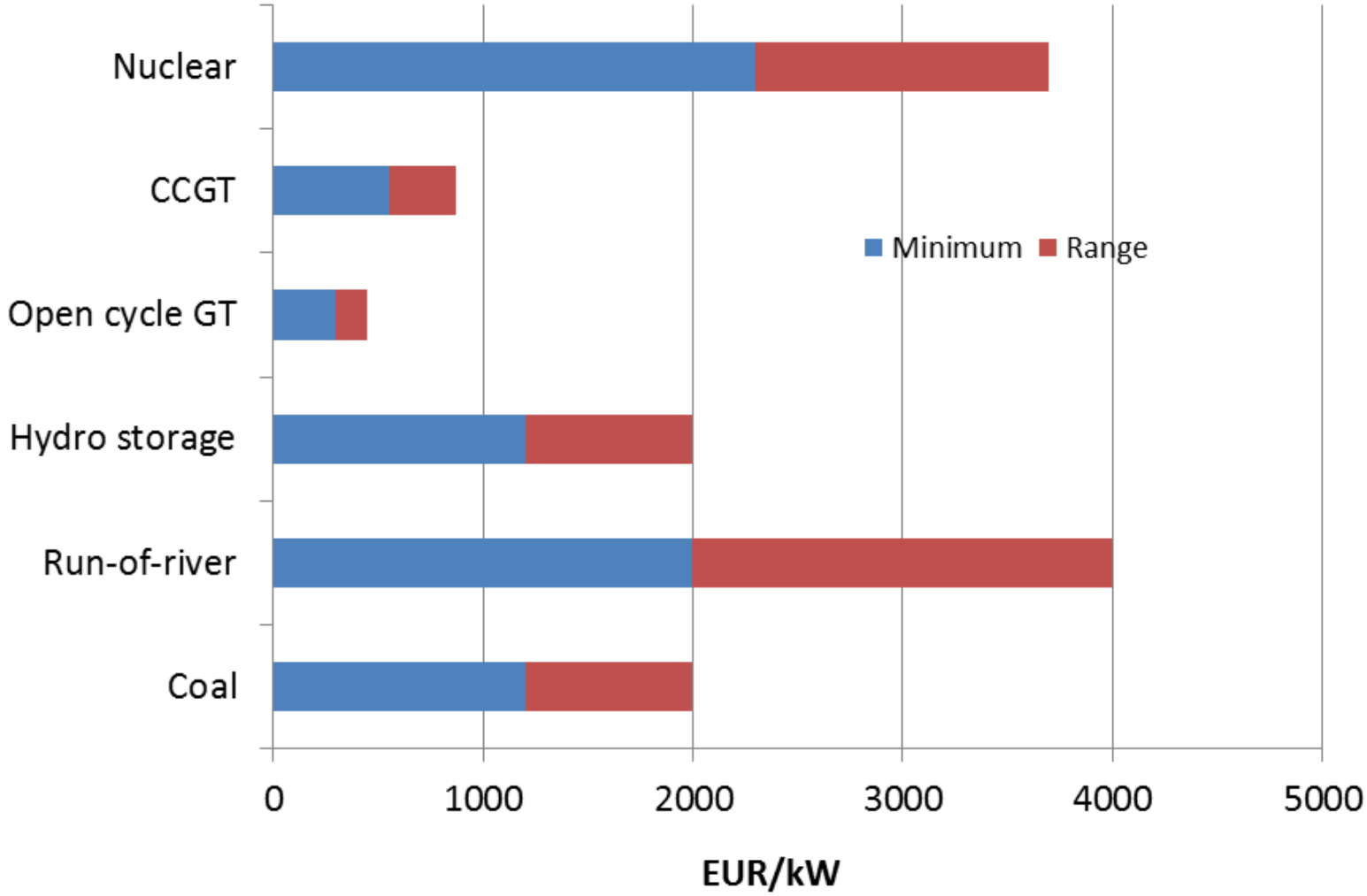
5 ELECTRICITY GENERATION COSTS

ANNUITY METHOD

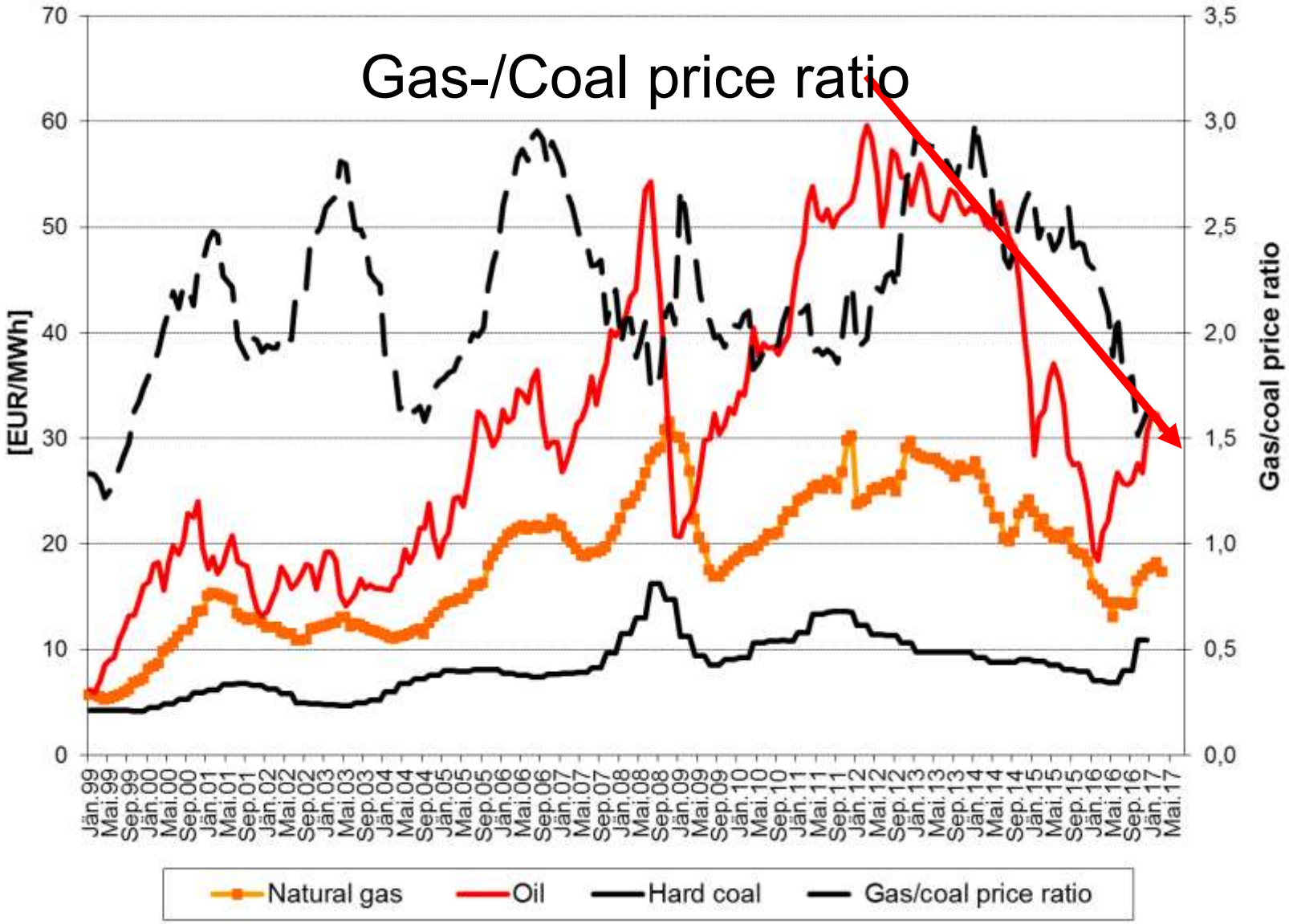


Investment costs

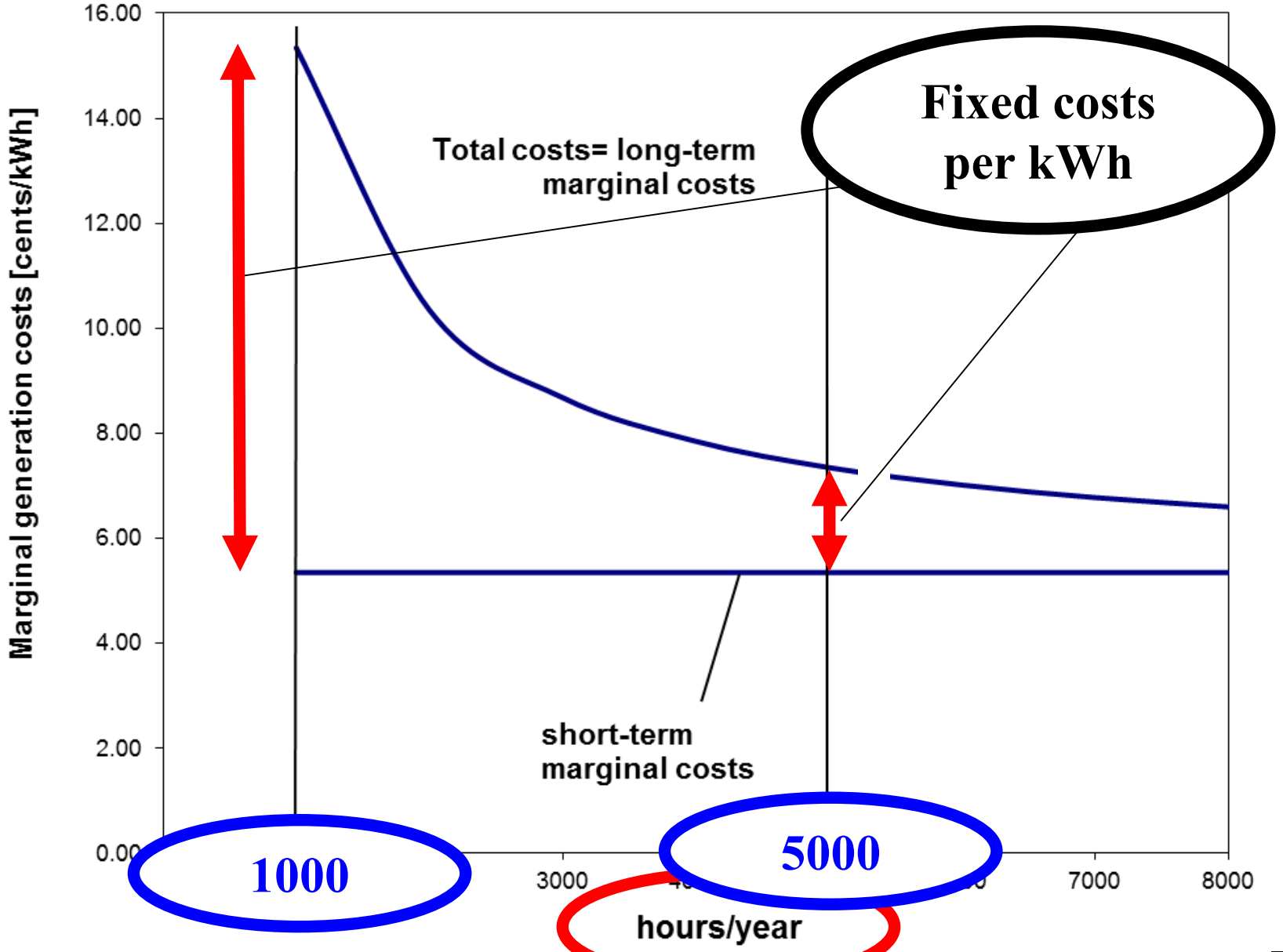
Electricity generation Conventional 2017



Fossil fuel prices 1999-2017



Generation costs CCGT



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. 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

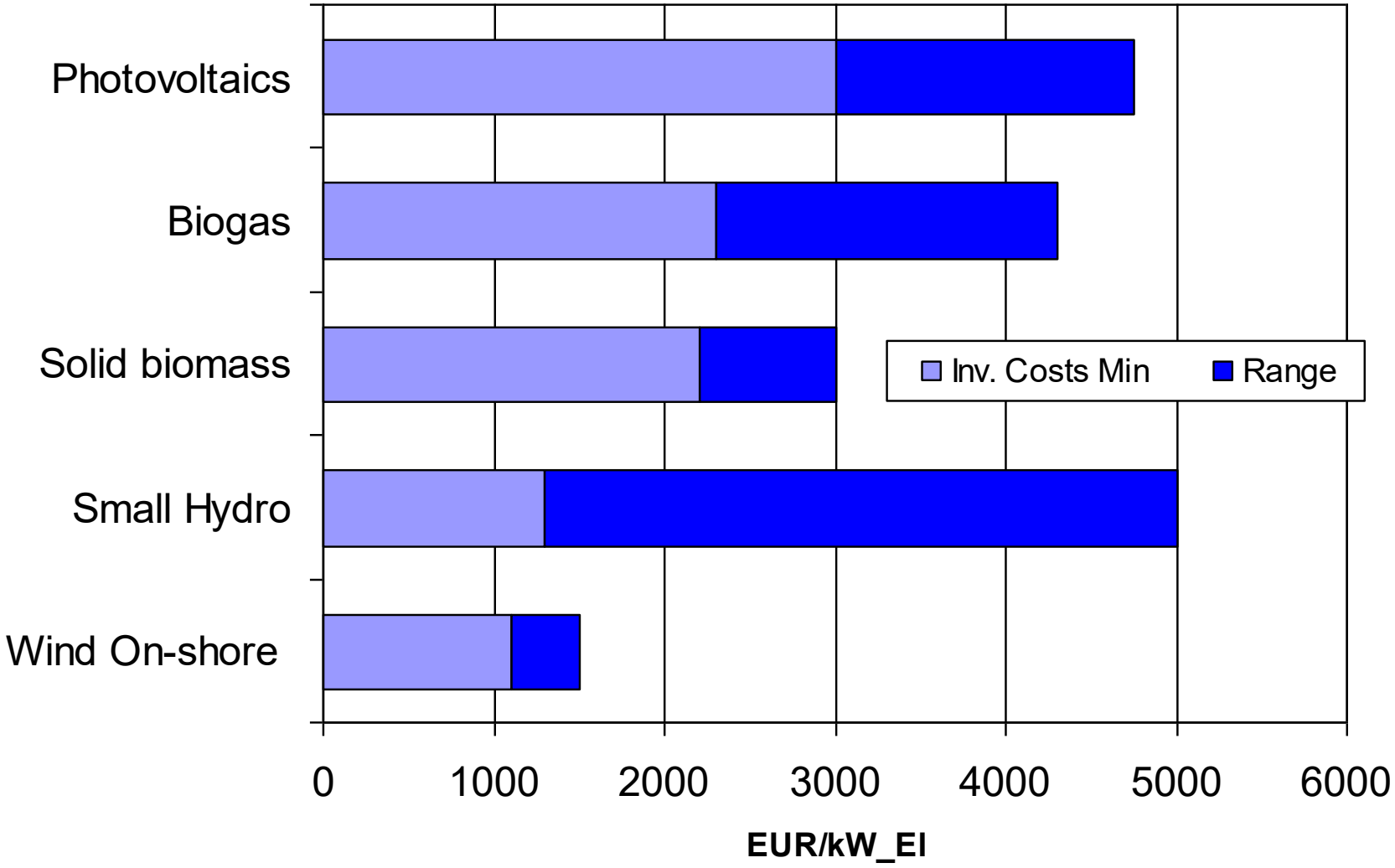
C_{CO2} …Price of CO2: 5 EUR/ton Carbon)

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

Example: Costs of electricity generation from CCGT

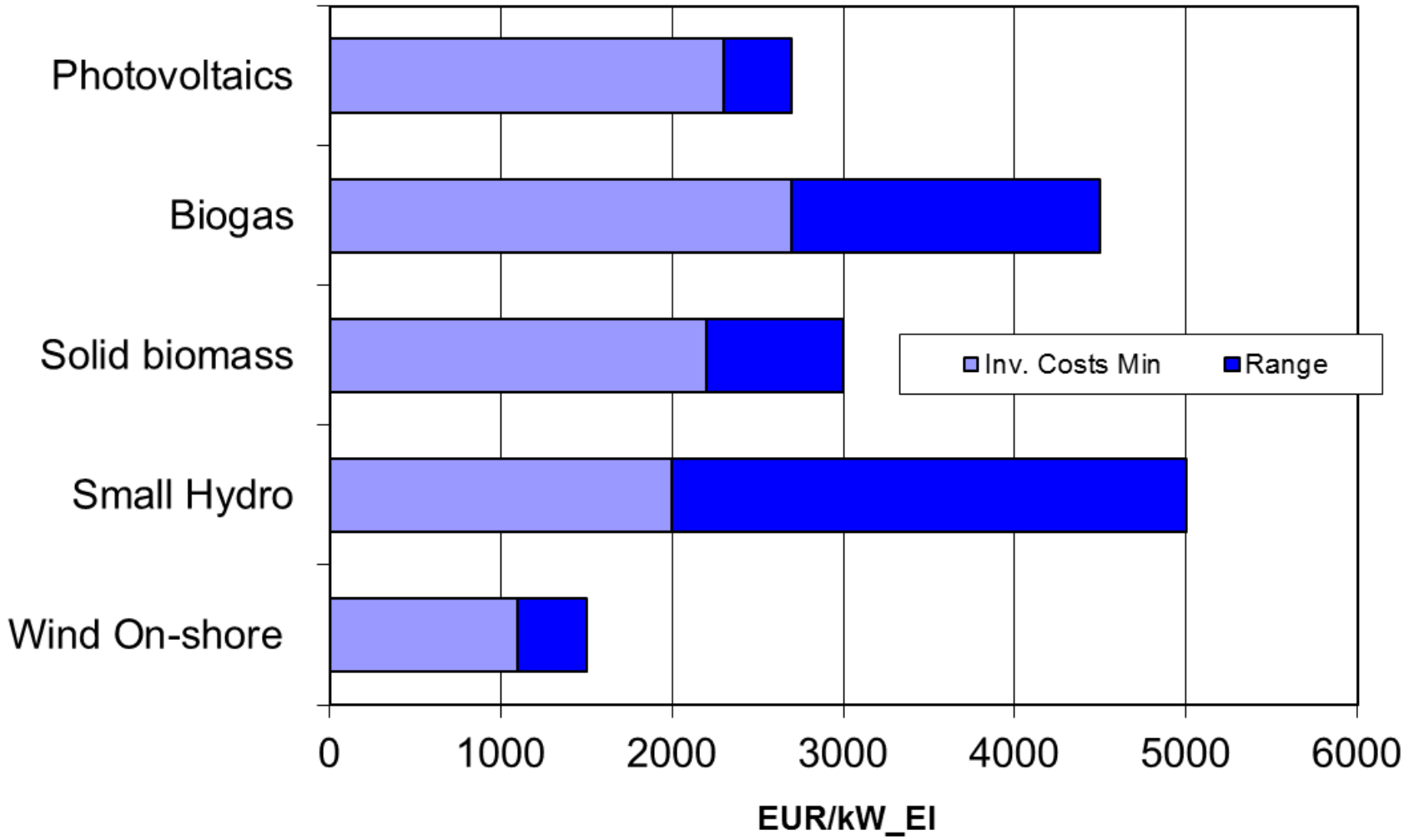
Investment costs

Electricity from new renewables 2010



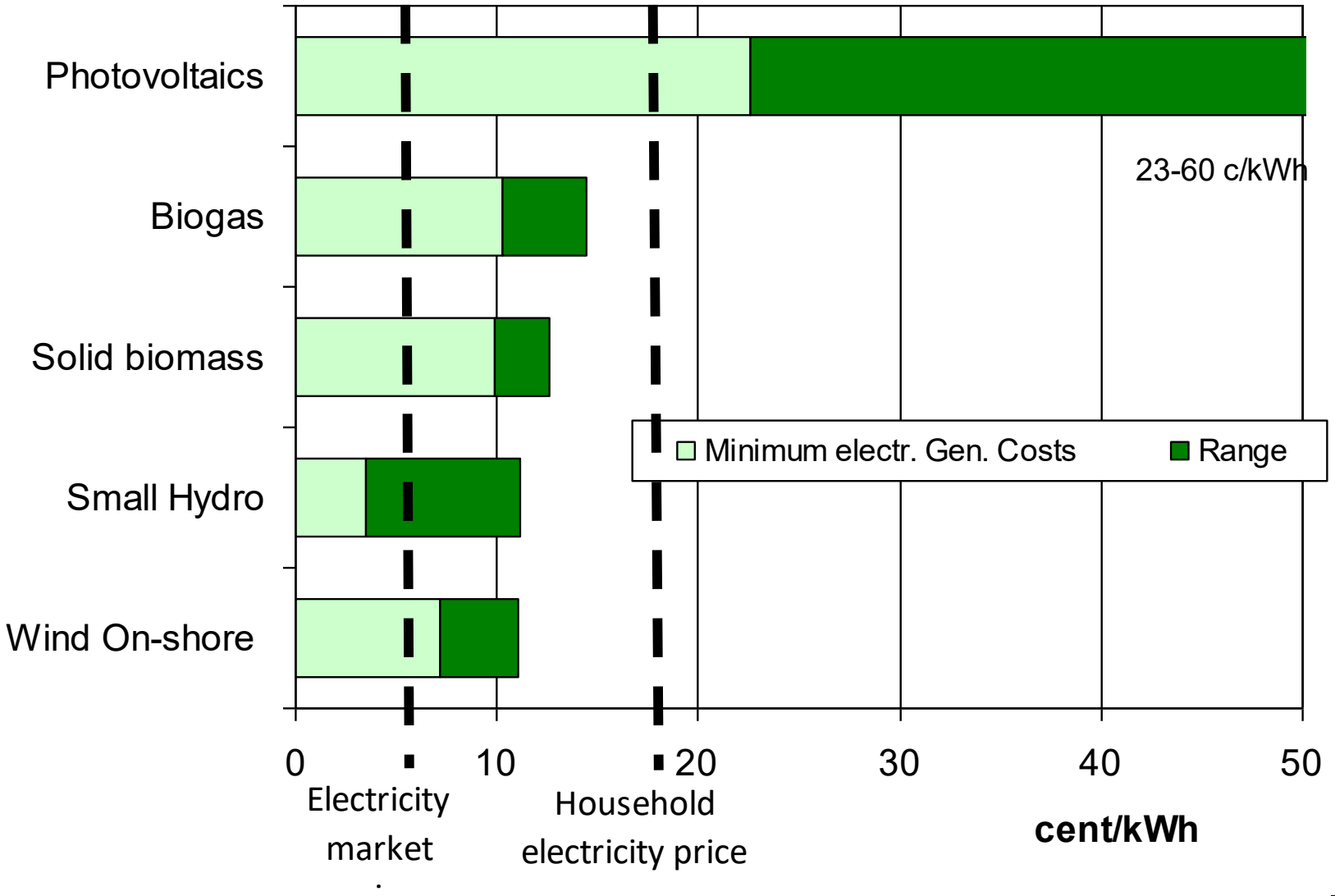
Investment costs

Electricity from new renewables 2017



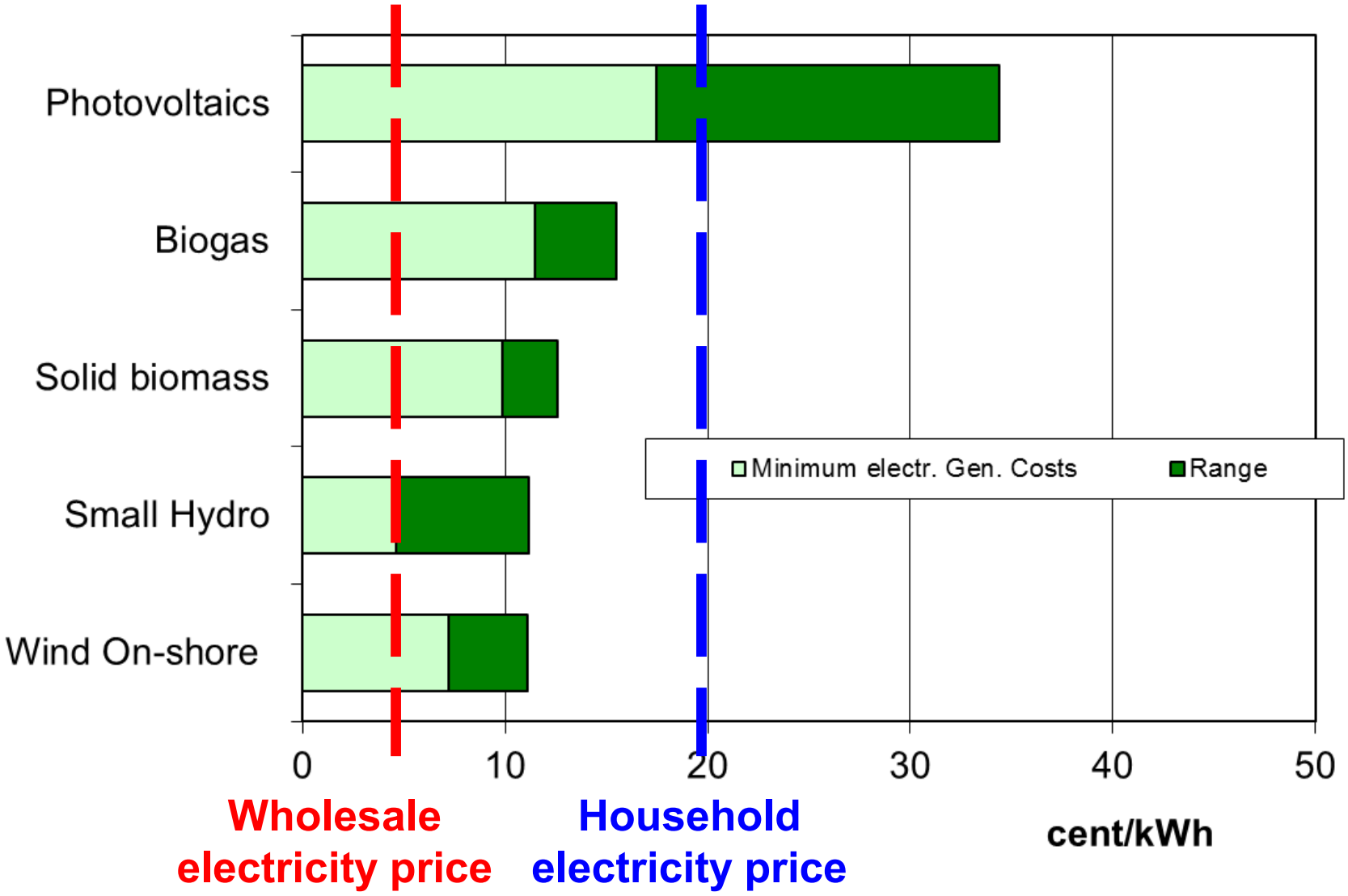
Generation costs

Electricity from new renewables 2010



Generation costs

Electricity from new renewables 2017



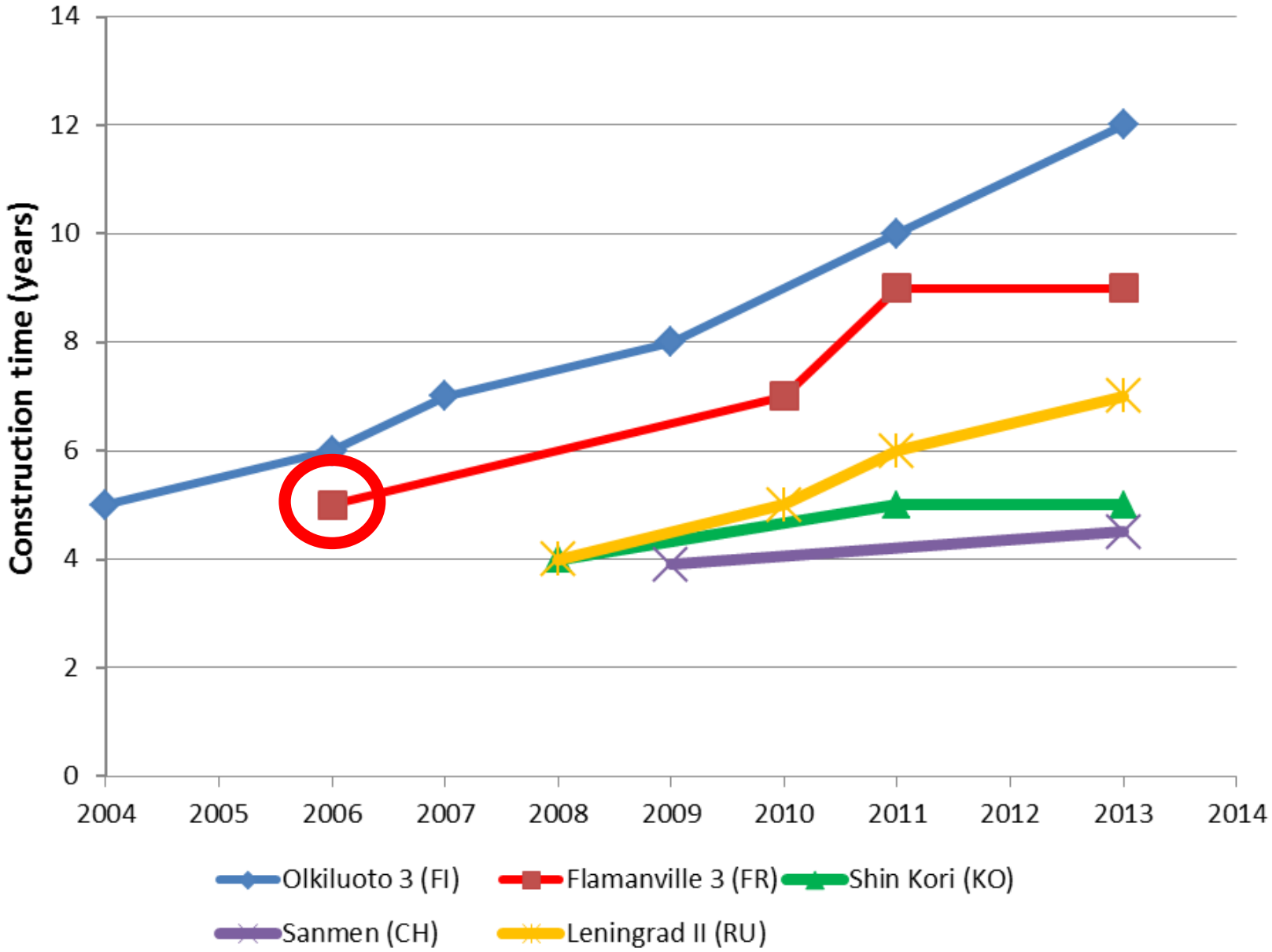
6. RECENT DEVELOPMENT OF NUCLEAR COSTS

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

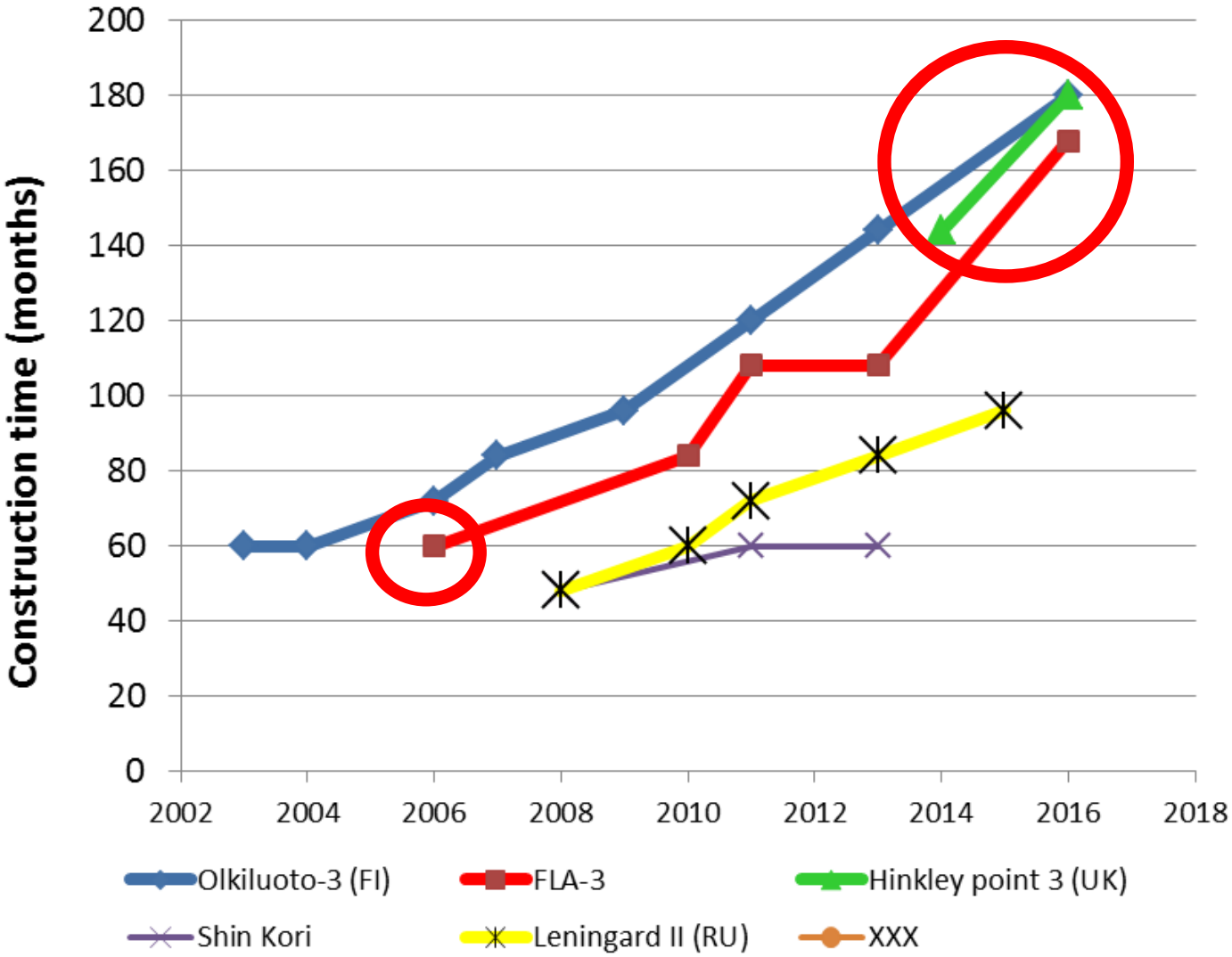
- Flamanville-3 (France): Construction started in 2006, now expected to be completed 2019 (originally: 2011); 1600 MW

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

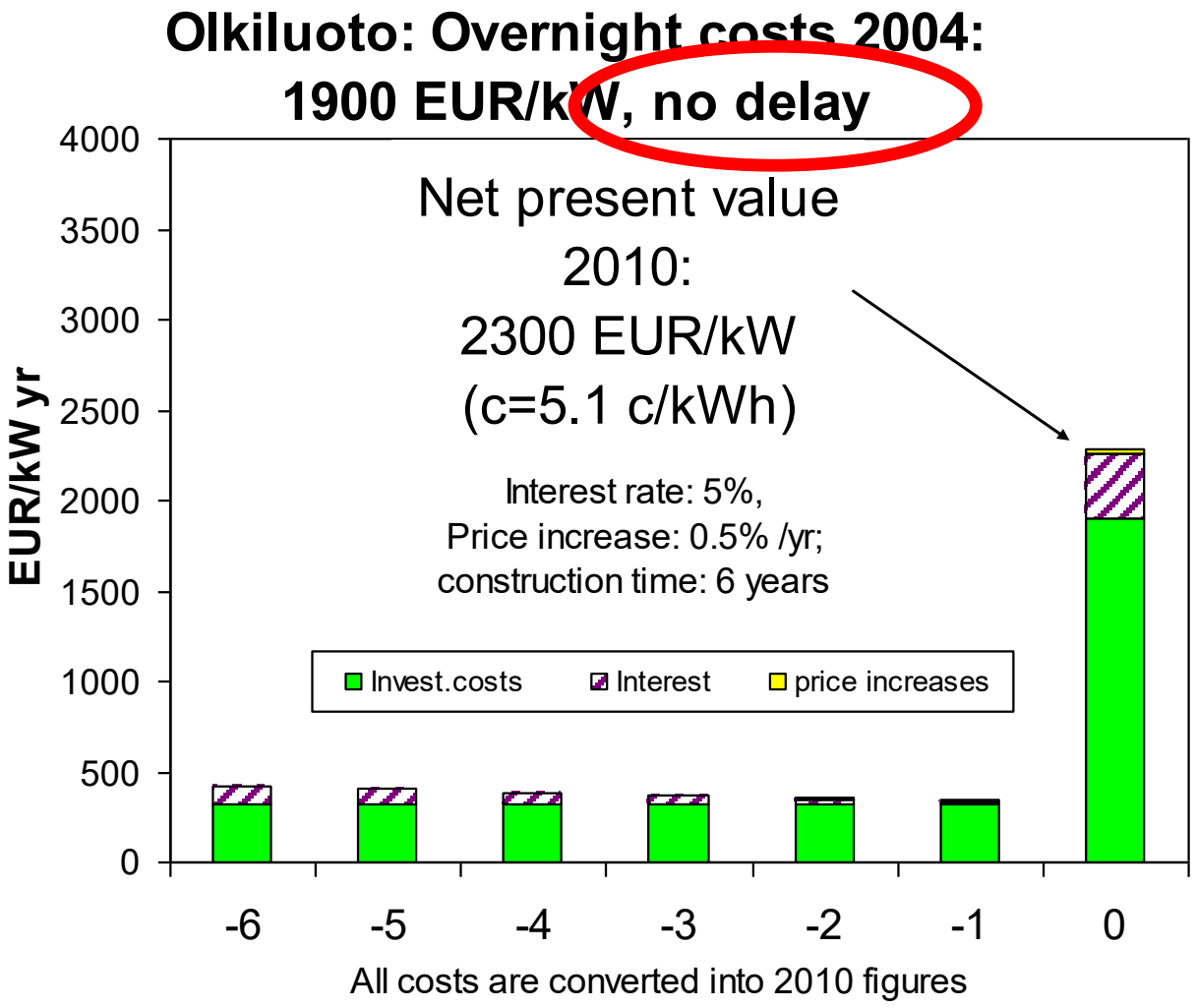
Construction times



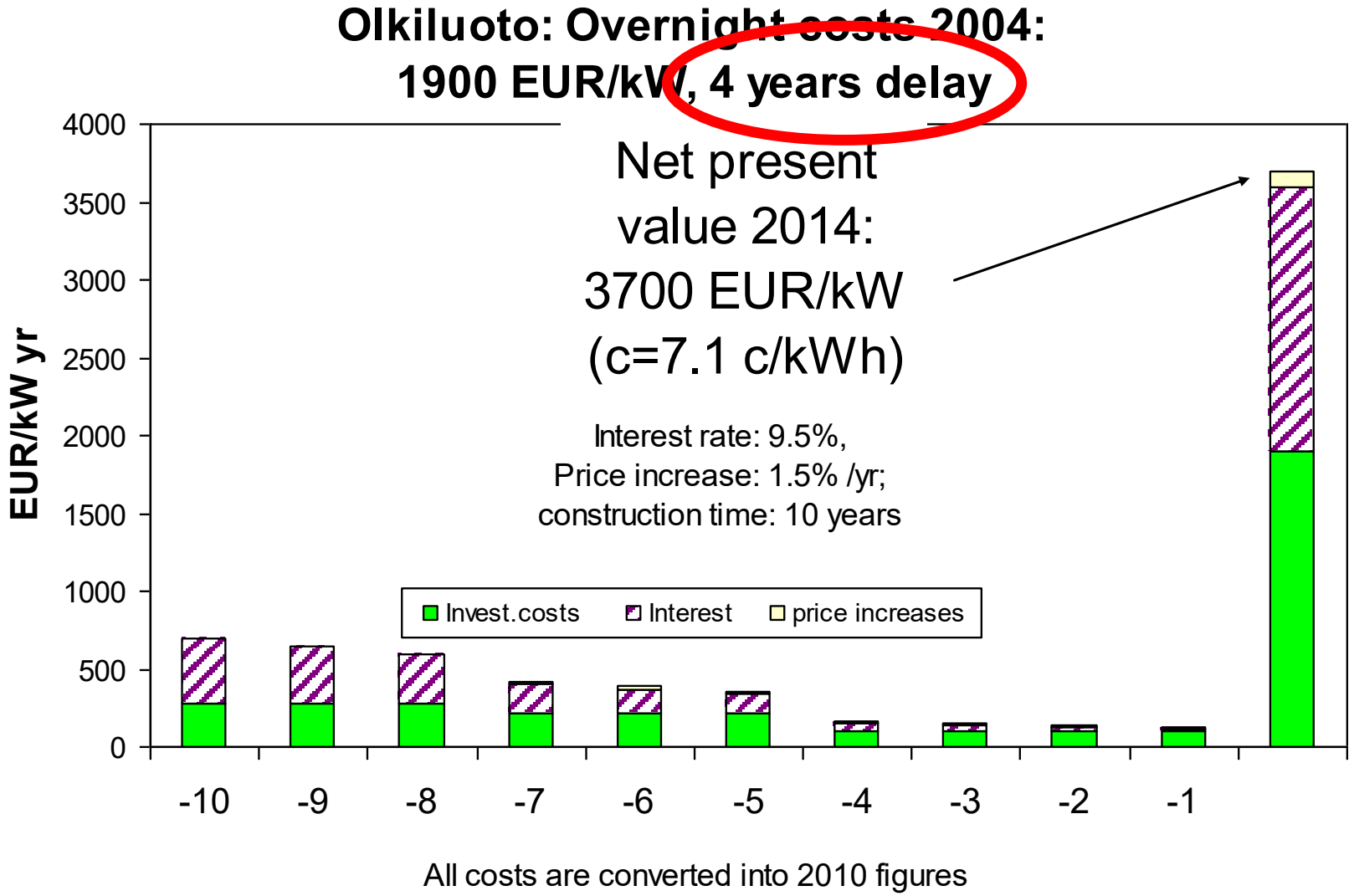
Construction times



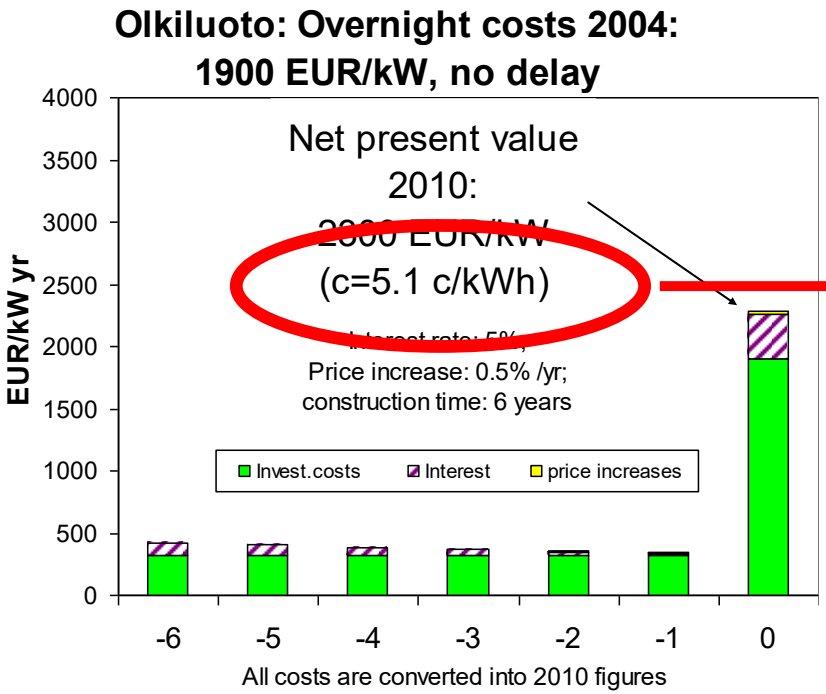
Impact of construction time on investment costs: Example Olkiluoto

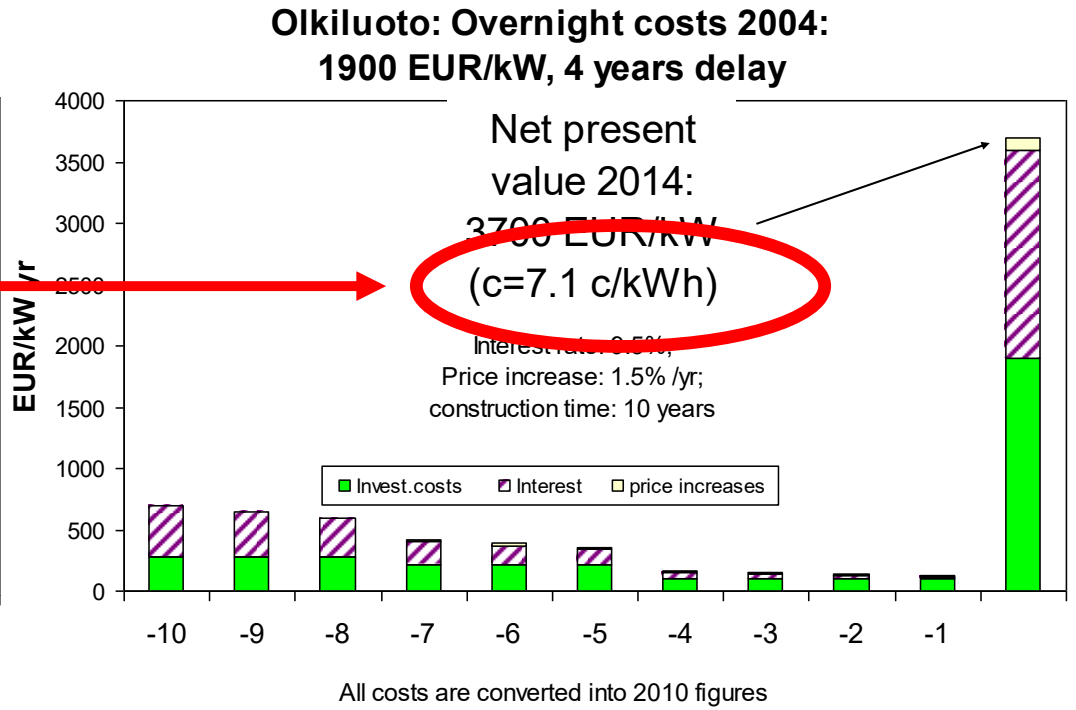


Impact of construction time on investment costs: Example Olkiluoto

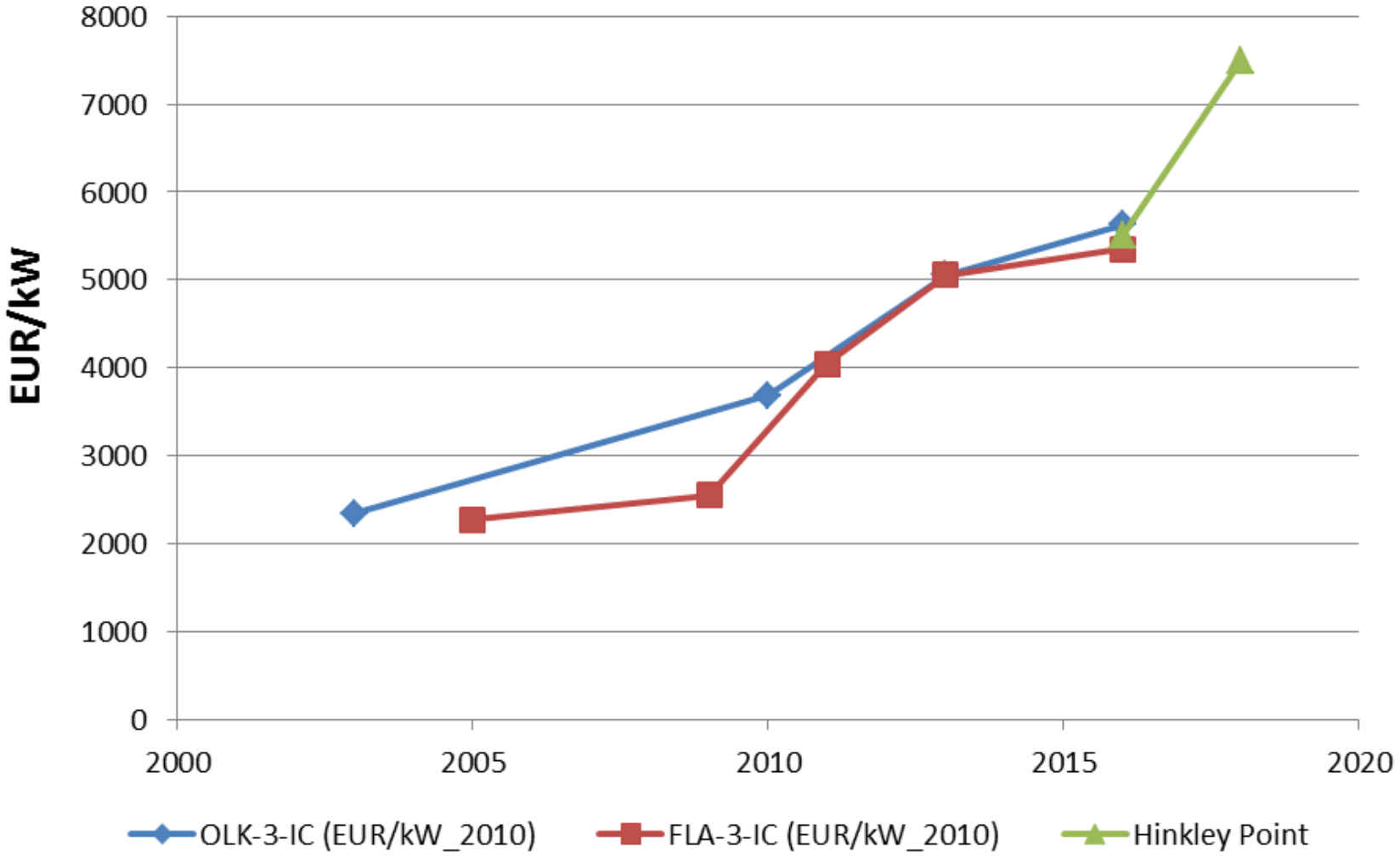


All costs are converted into 2010 figures

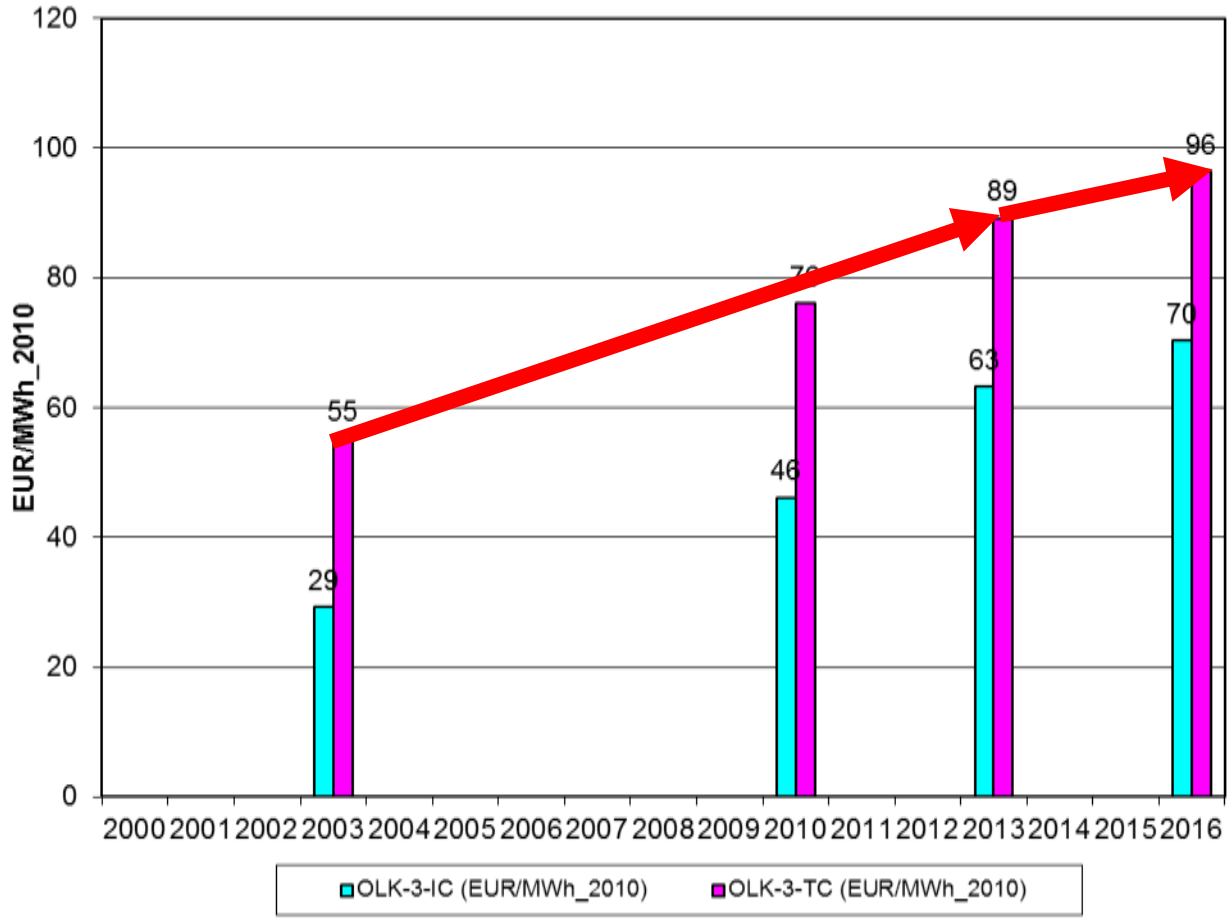

Olkiluoto: Overnight costs 2004:
1900 EUR/kW, no delay
Net present value
2010:
(c=5.1 c/kWh)
Price increase: 0.5% /yr;
construction time: 6 years
Invest.costs
Interest
price increases
EUR/kW yr
4000
3500
3000
2500
2000
1500
1000
500
0
-6
-5
-4
-3
-2
-1
0
All costs are converted into 2010 figures


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

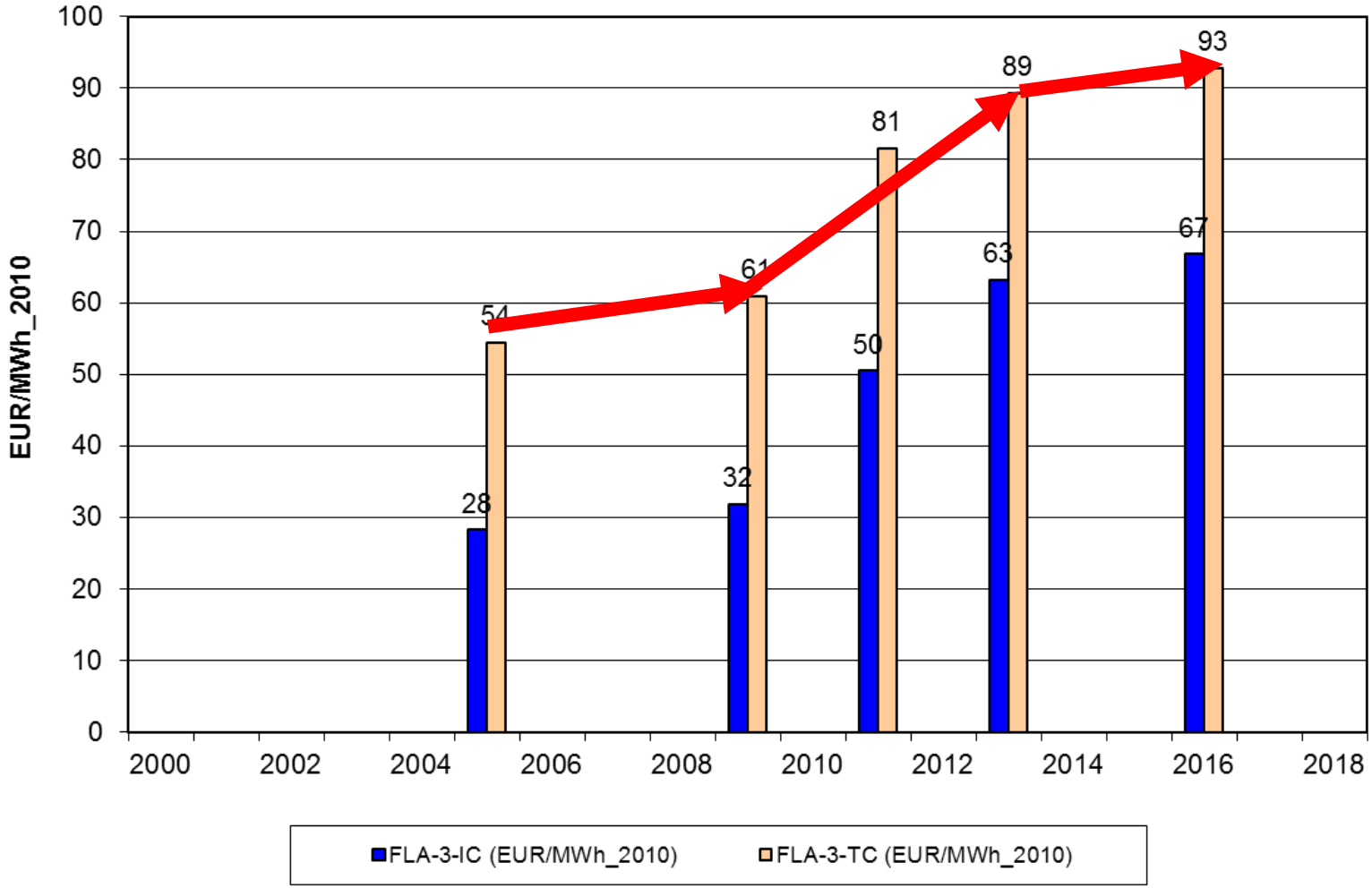


„Total“ Cost development Olkiluoto



No insurance costs considered!

„Total“ Cost development Flamanville-3



No insurance costs considered

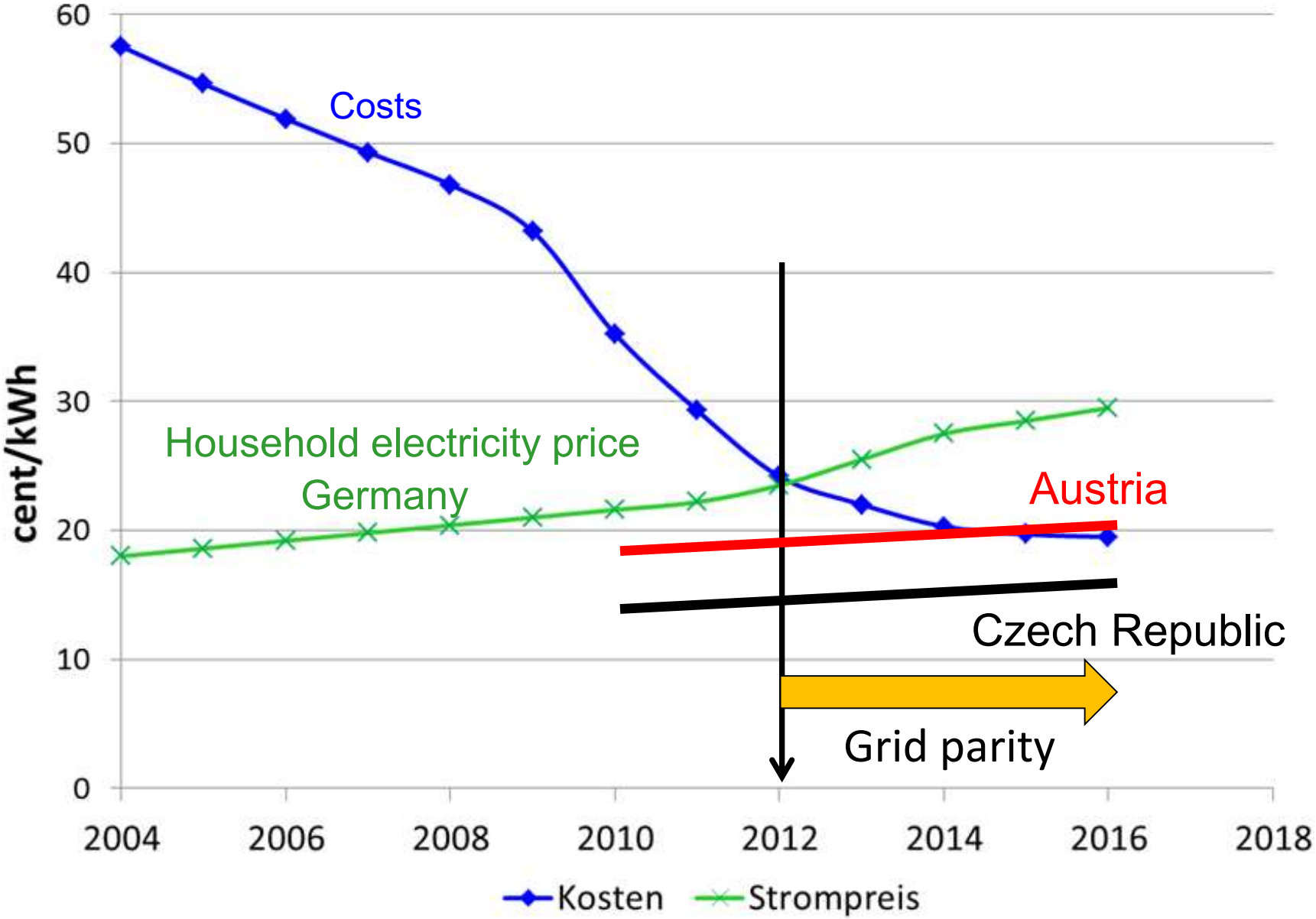
7. THE ROLE OF RENEWABLES

CORE MOTIVATION:

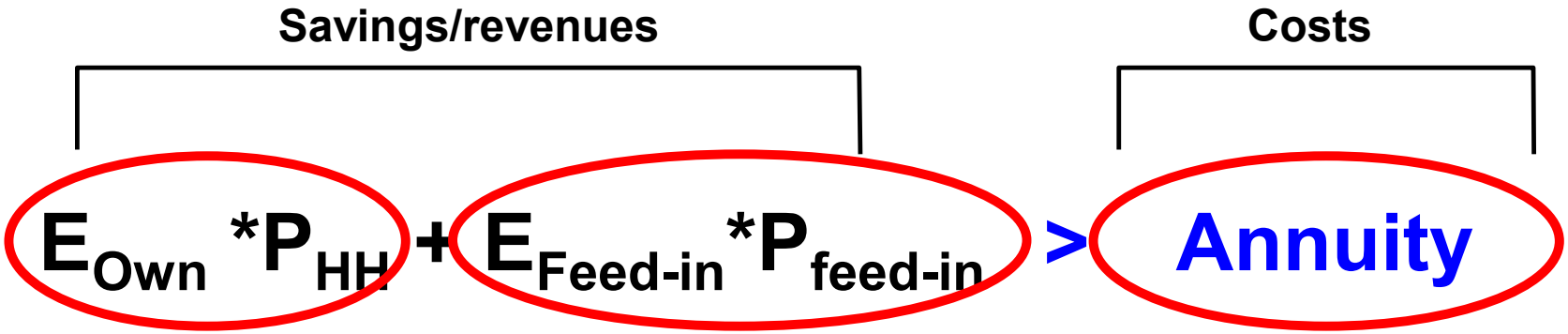
Policy targets for an INCREASE of RES-E!

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

Grid parity: PV-costs and household electricity prices



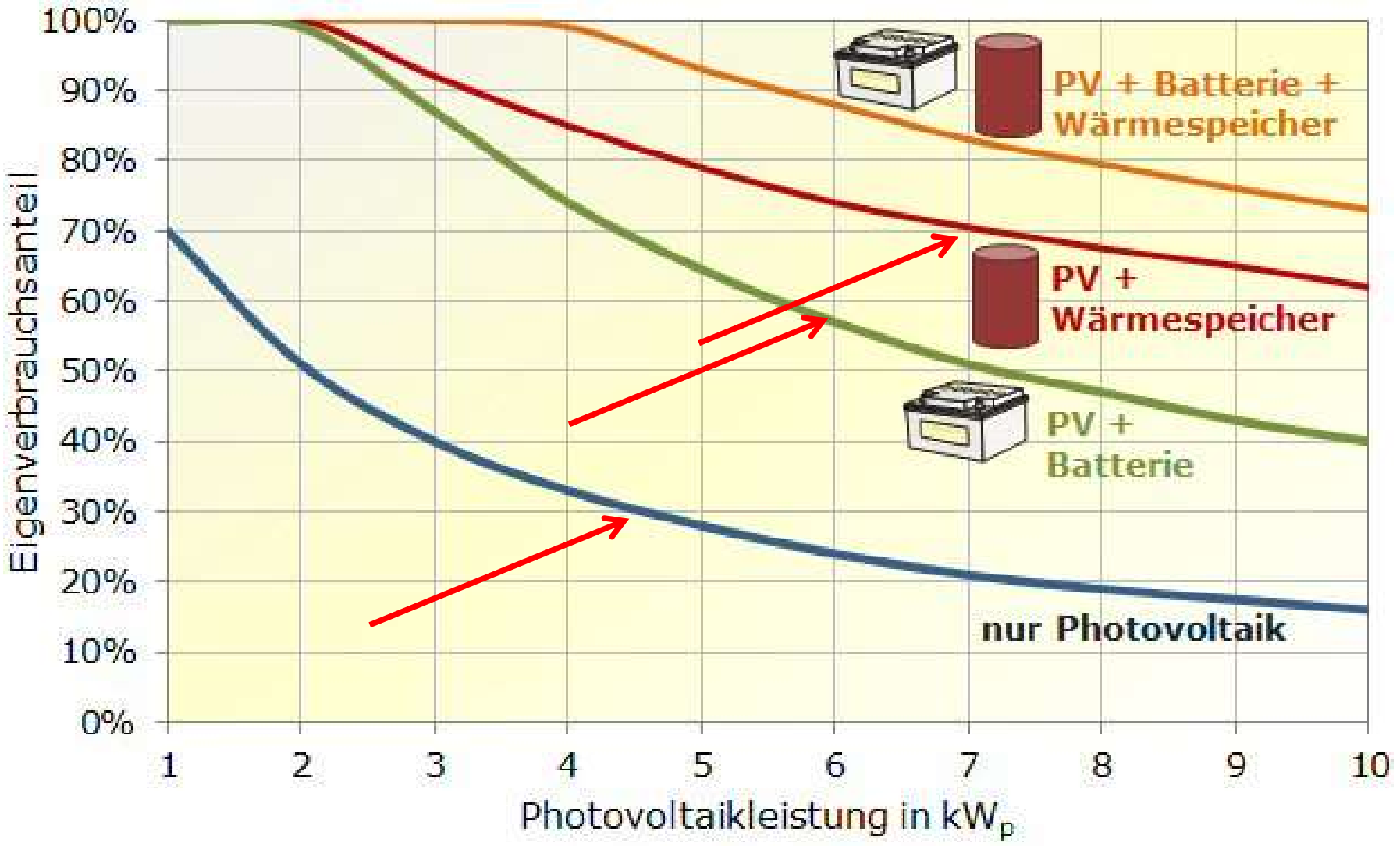
Assessment of Grid Parity



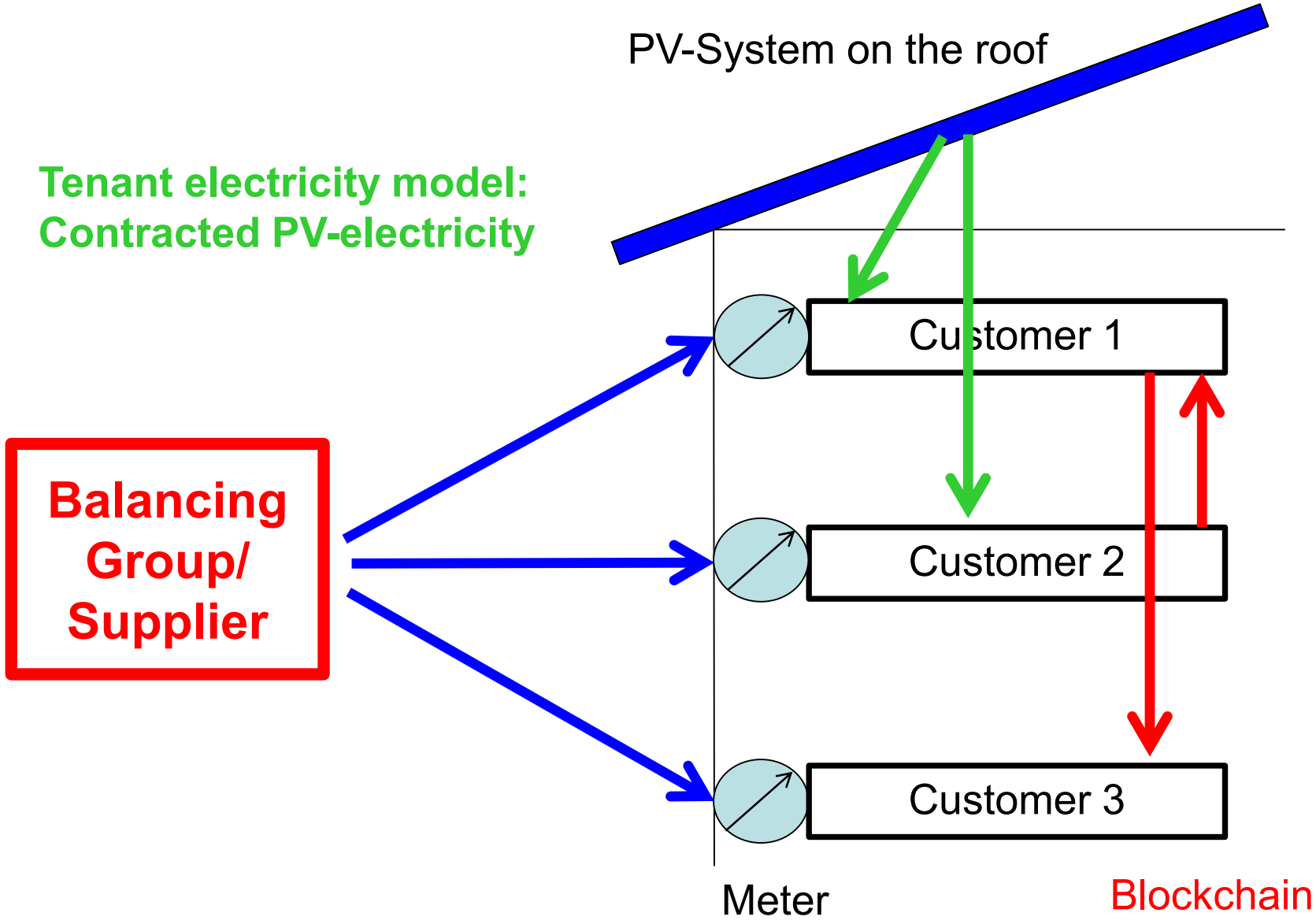
Grid parity term

Subsidy still necessary?

Share of own consumption



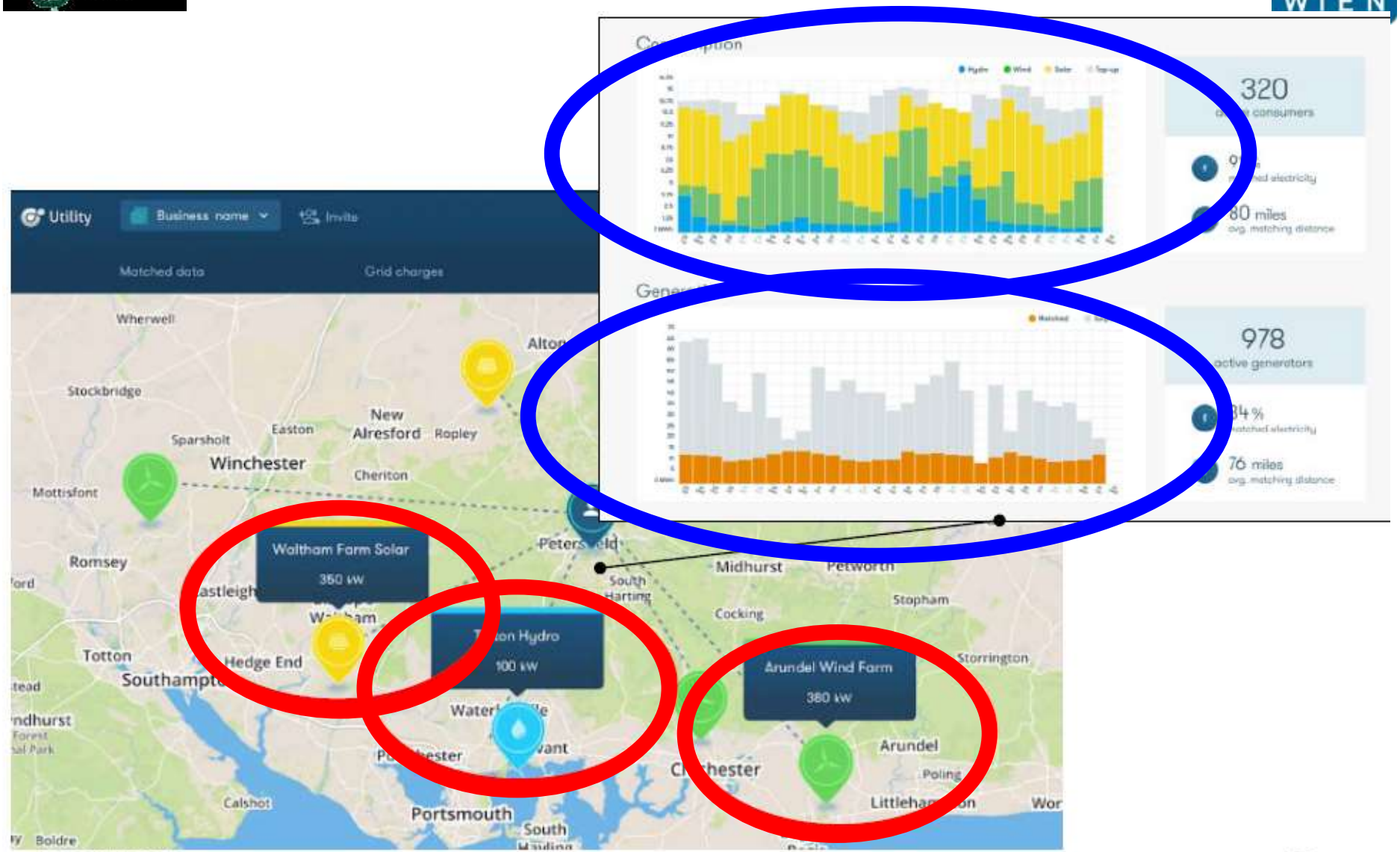
Tenant electricity model and Blockchain



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

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