# ELECTRICITY MARKETS AND THE ROLE OF RENEWABLES & NUCLEAR

**Reinhard Haas**

Energy Economics Group,
Vienna University of Technology

**Praha, 30.1.2024**

# 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**

# A revised **EU electricity market design** to:

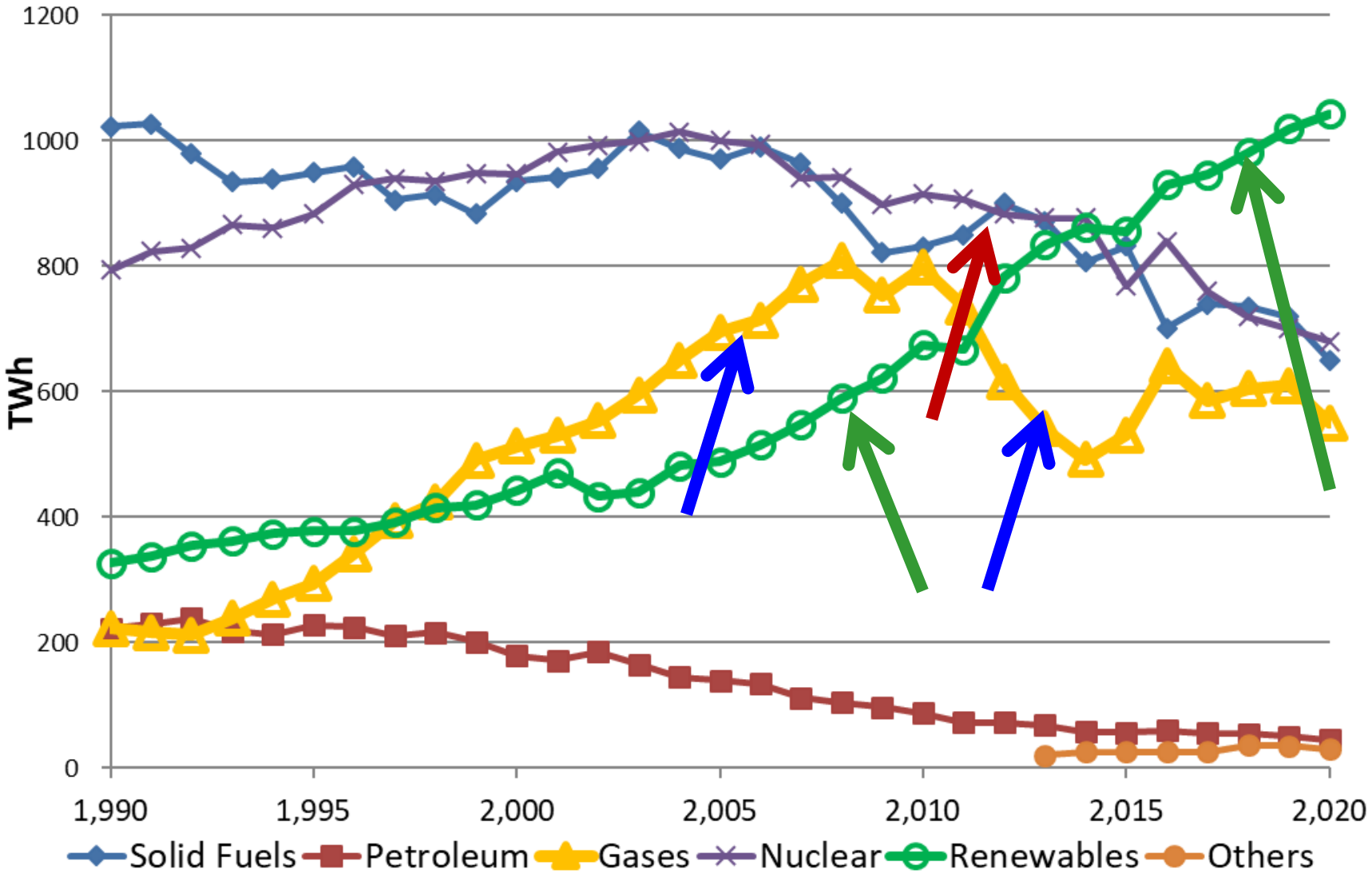
Boost renewable energy investments

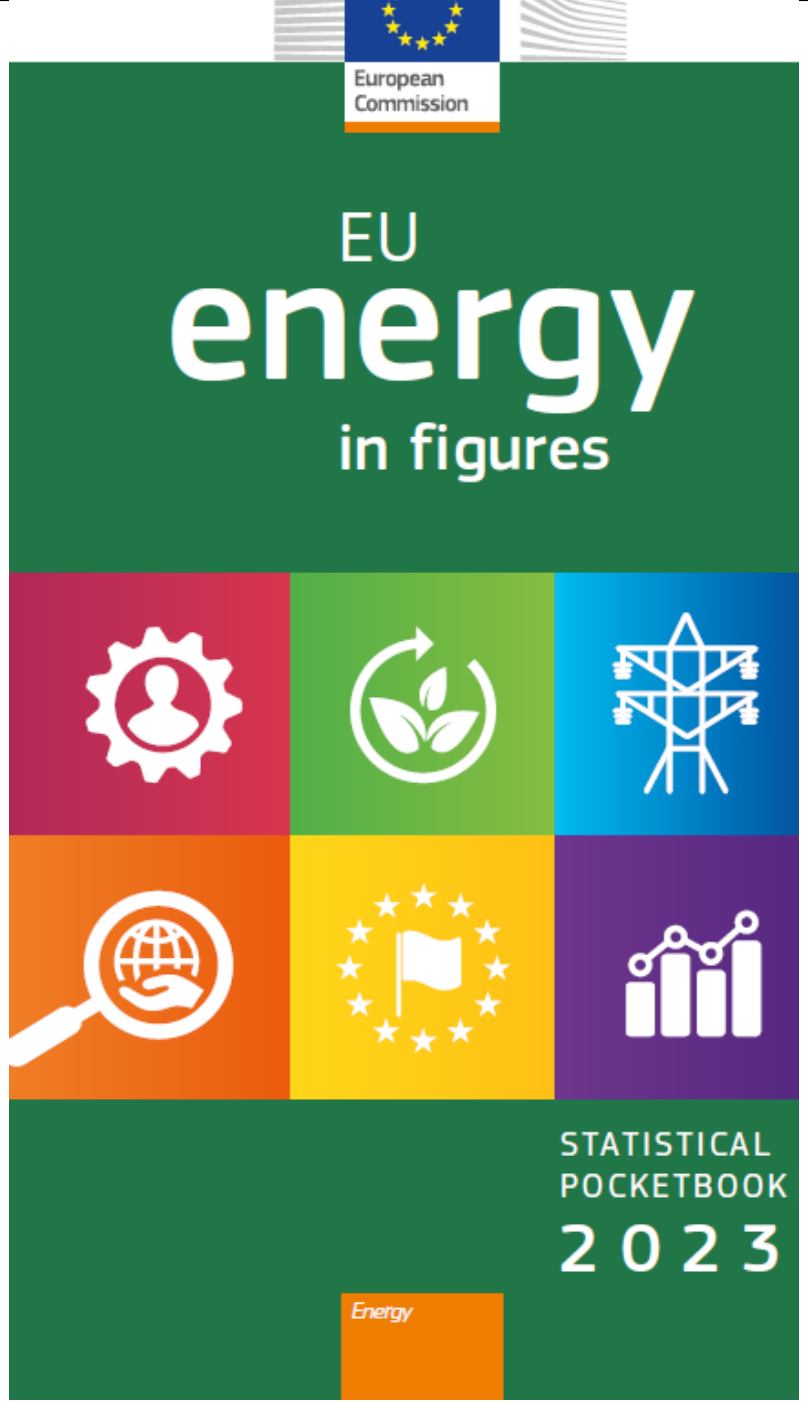
Better protect and empower EU consumers

Enhance the competitiveness of EU industry

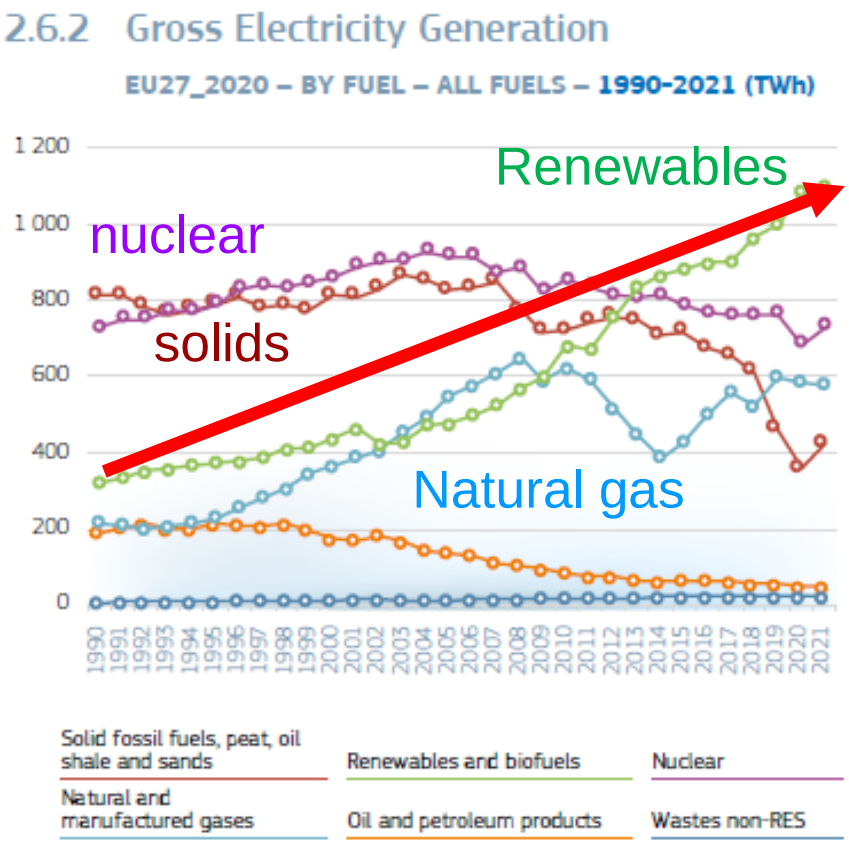
European Commission

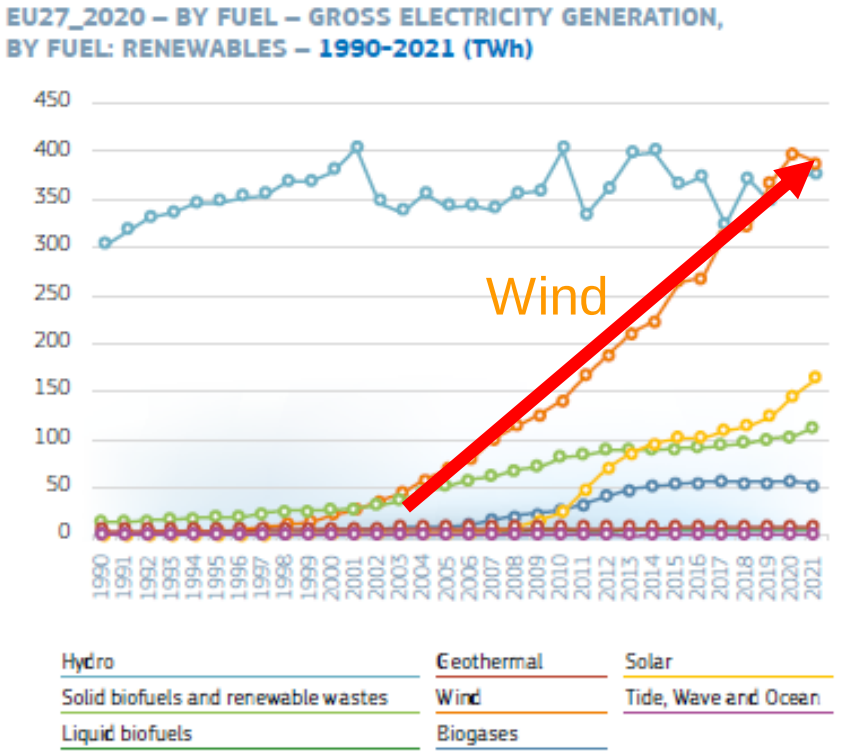
# Electricity generation EU-28



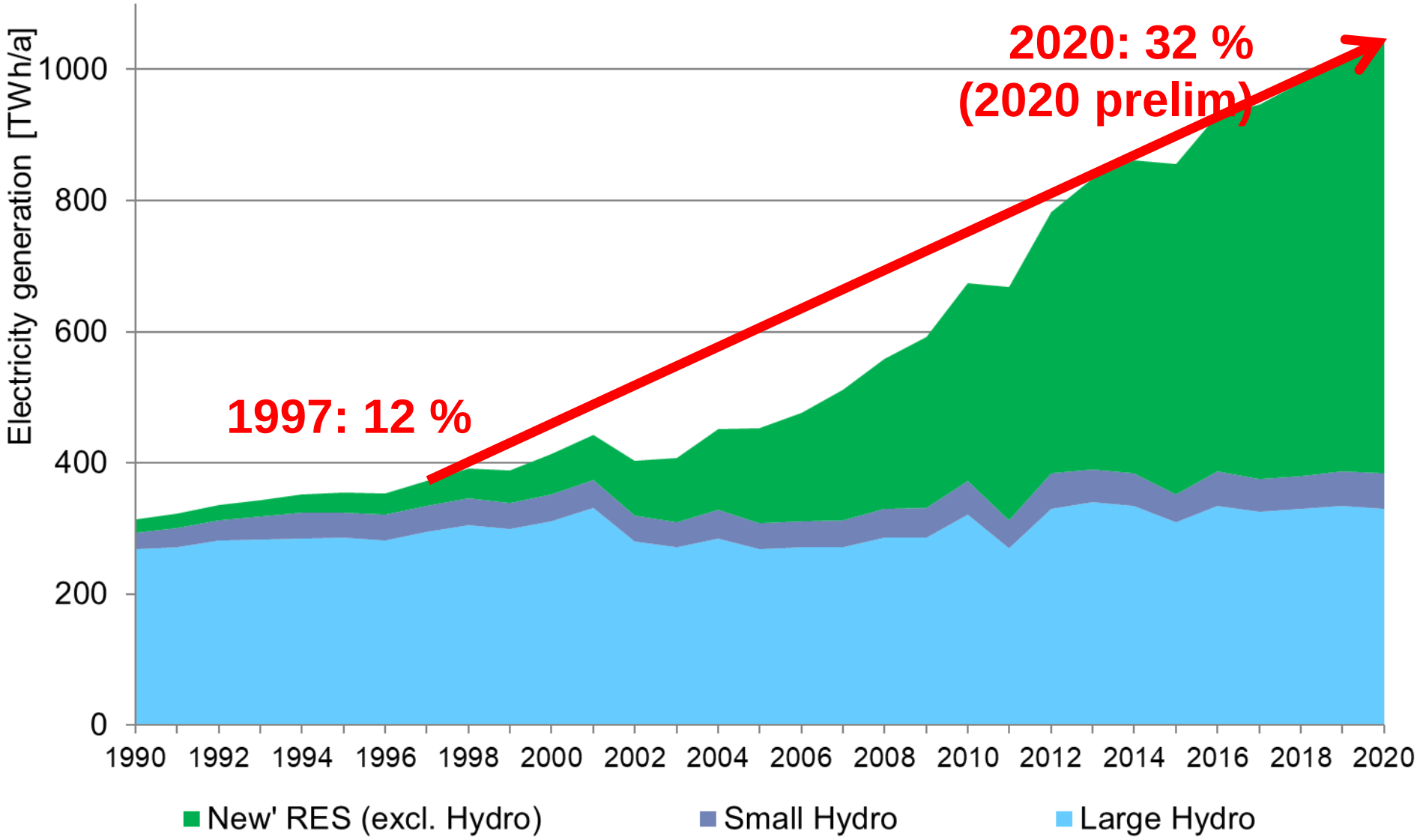

European Commission
EU
energy
in figures
STATISTICAL
POCKETBOOK
2023
Energy

# Electricity generation EU-27



# Electricity generation RES EU-28

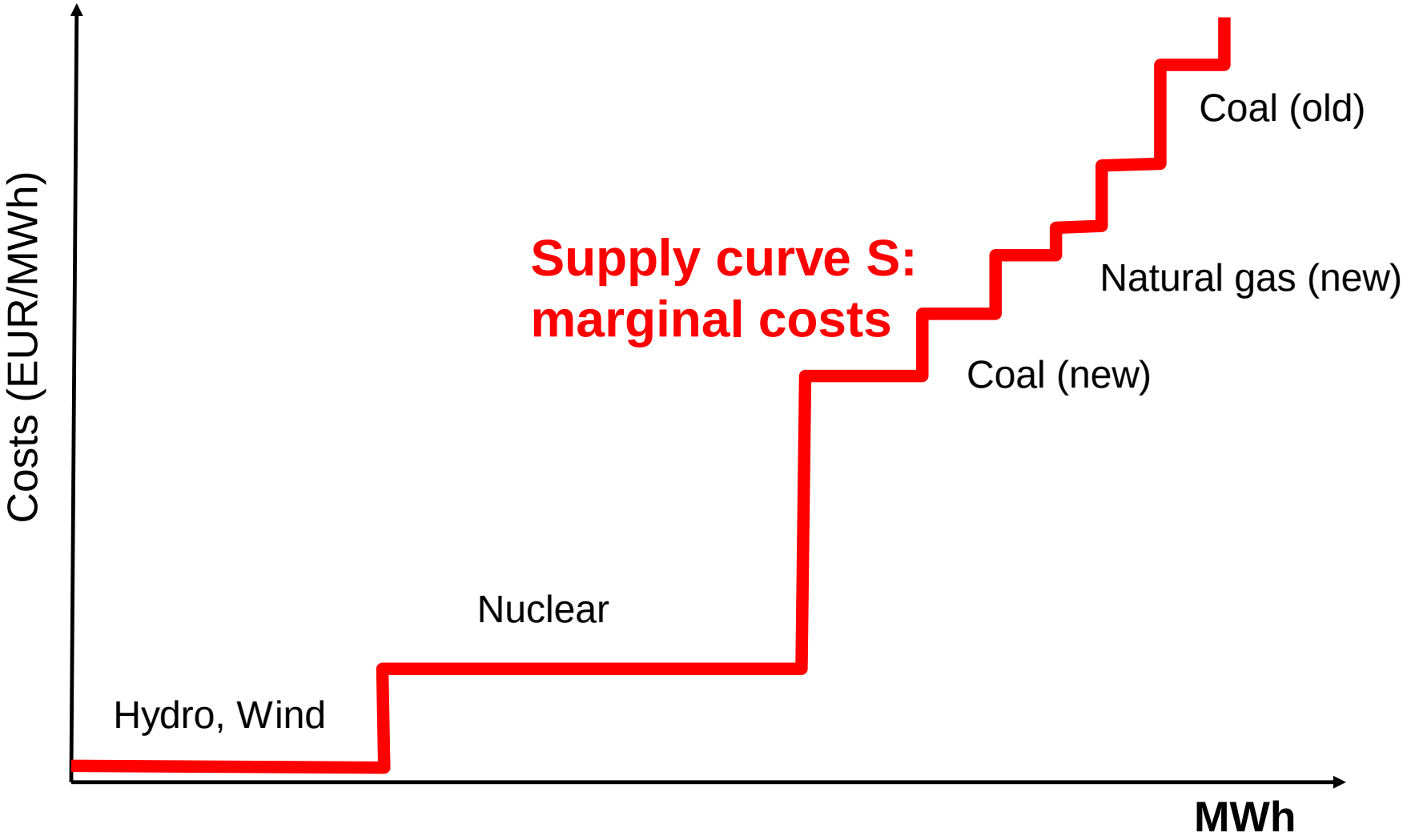



Source: EUROSTAT, own estimations

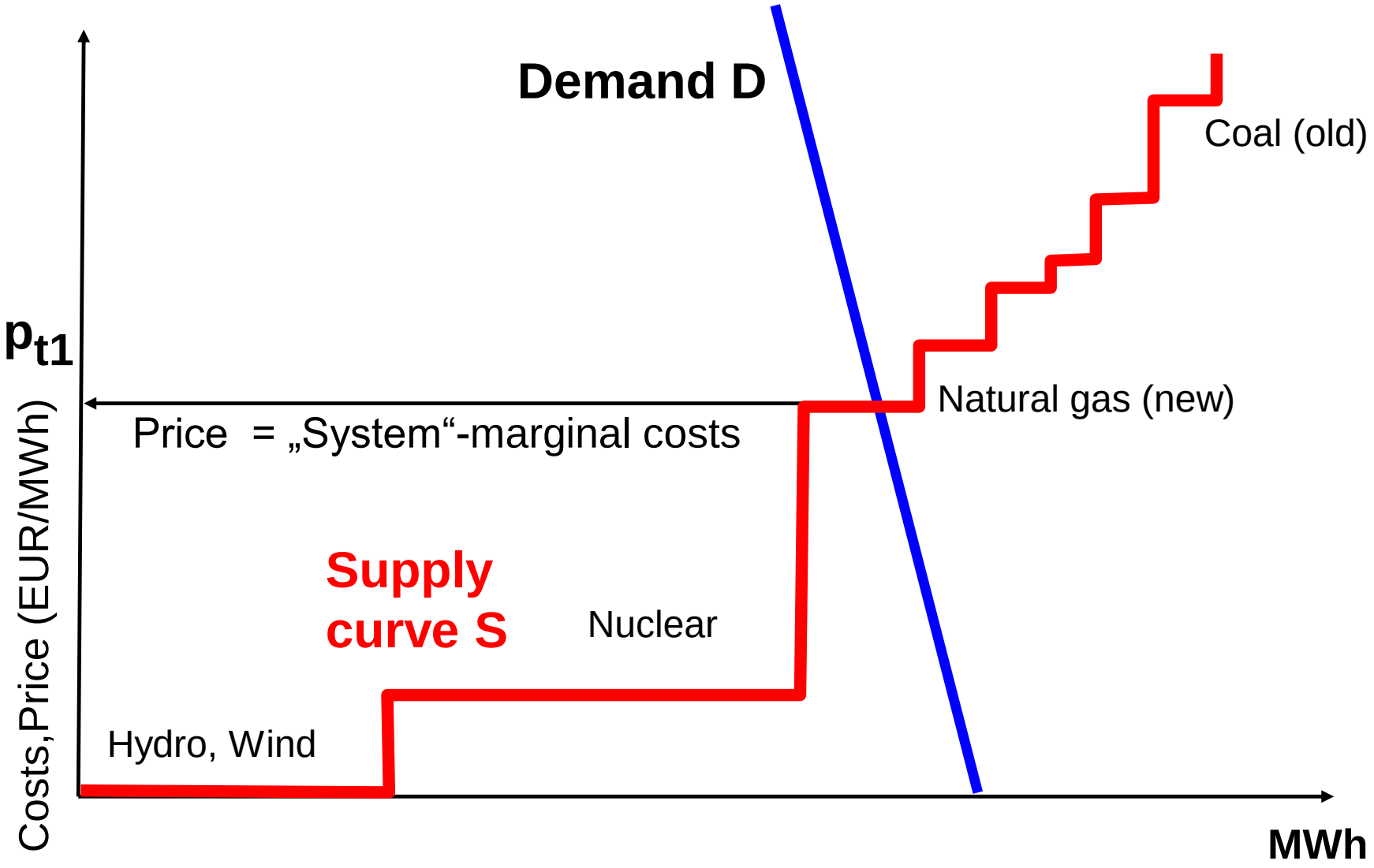
# 2. How prices come about

## THE *MERIT-ORDER* CURVE OF SUPPLY

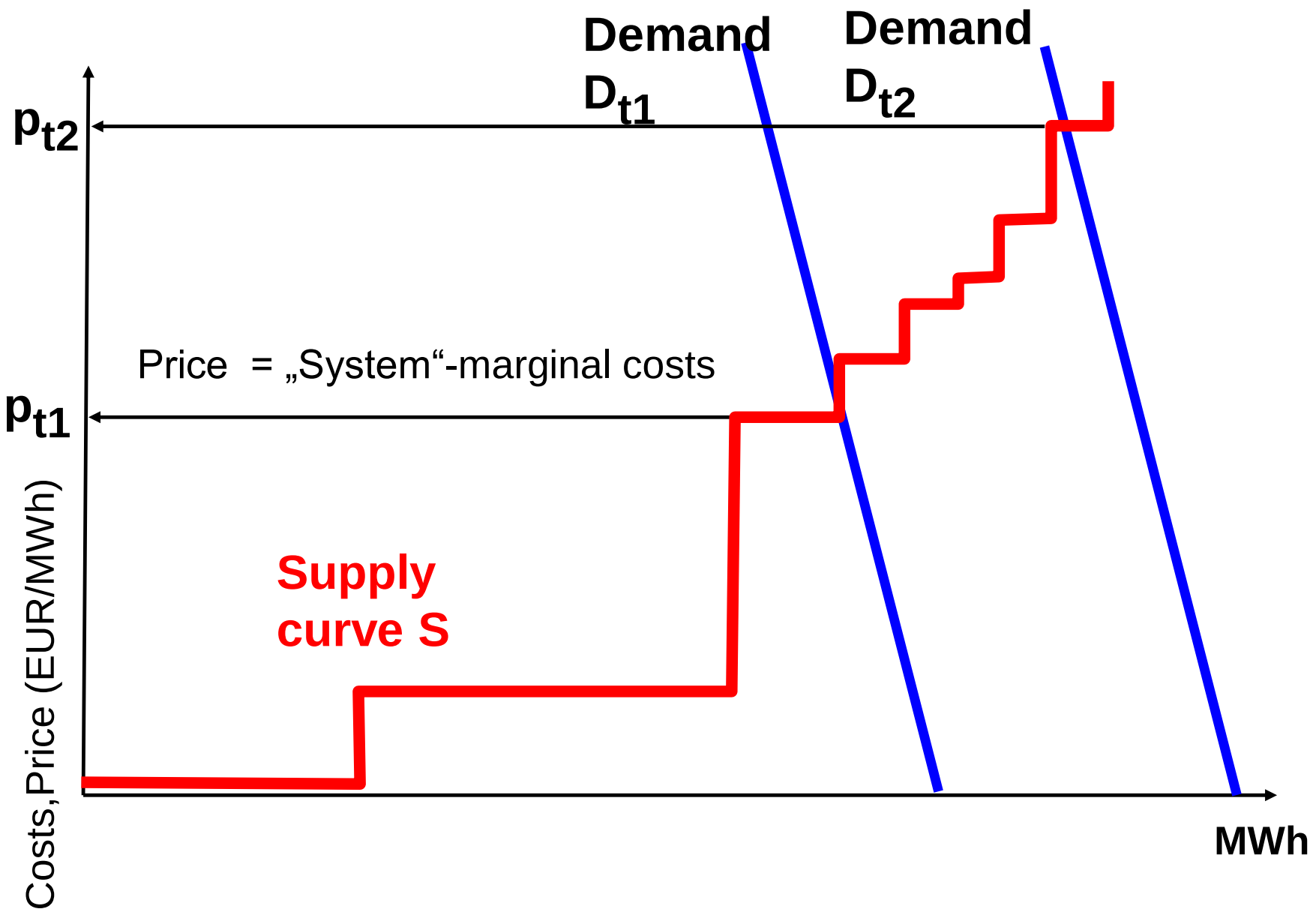
based on short-term marginal costs (MC)



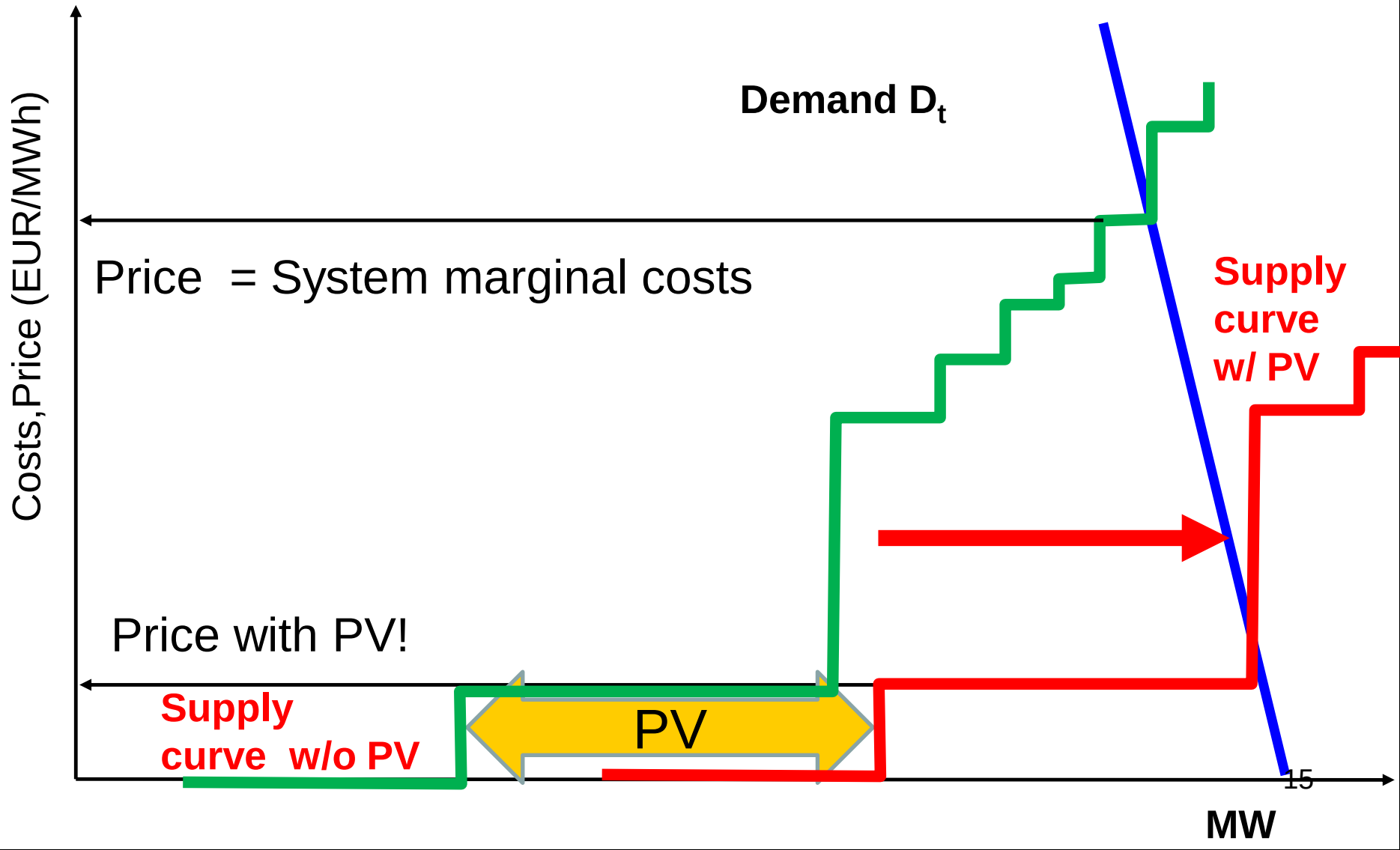
# BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



# BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS

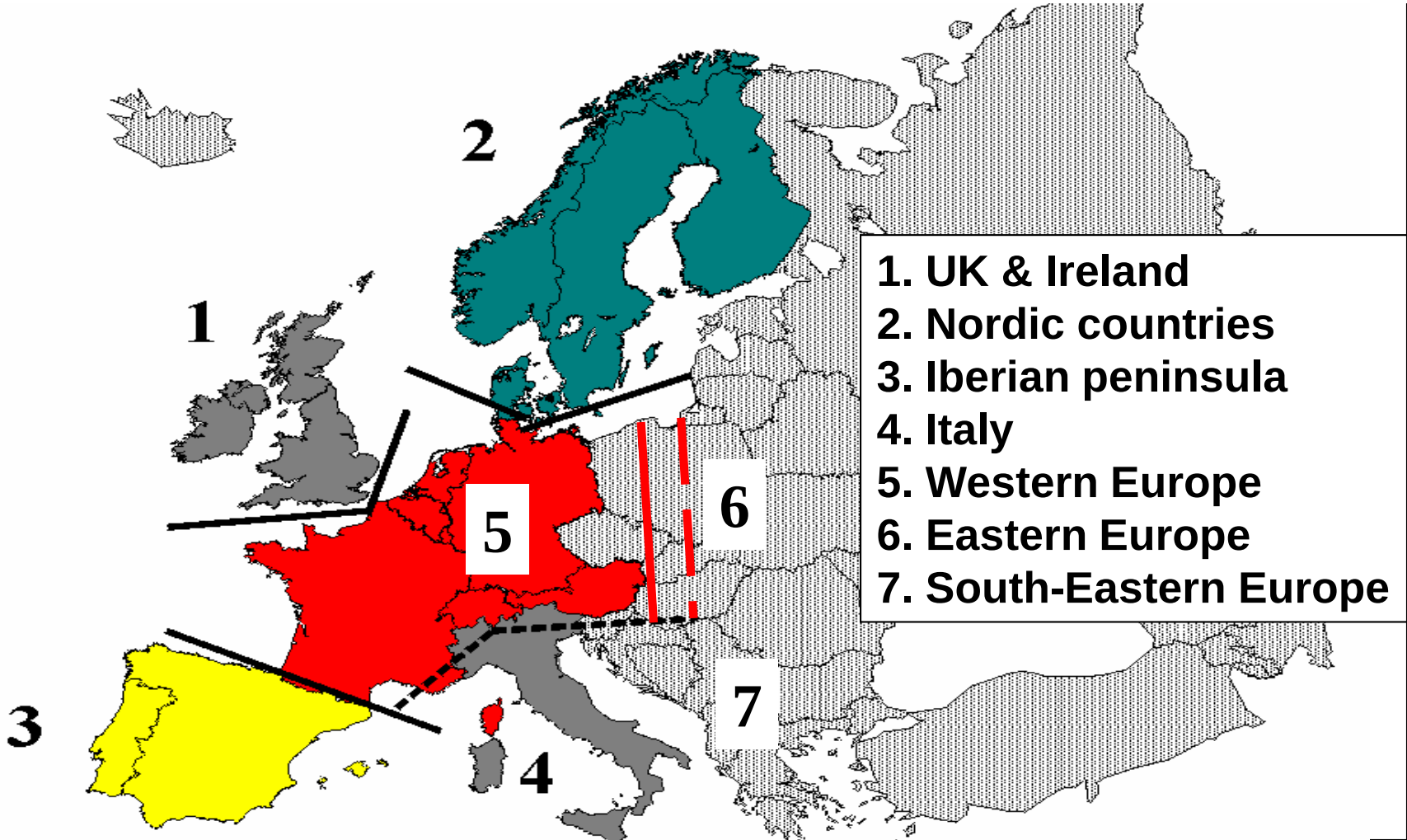


# Example: prices without and with PV

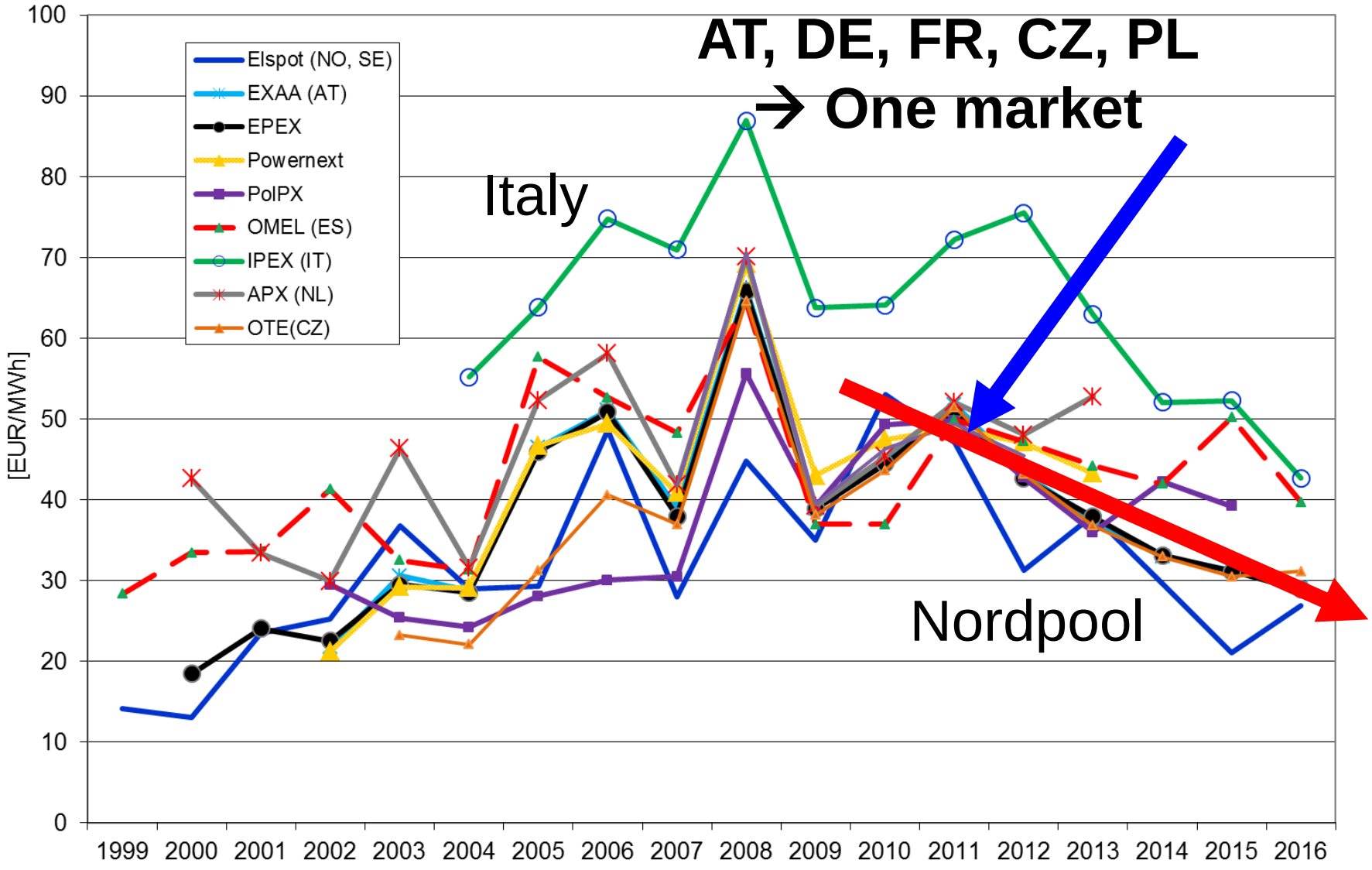


# 3 HOW PRICES DEVELOPED IN EUROPE

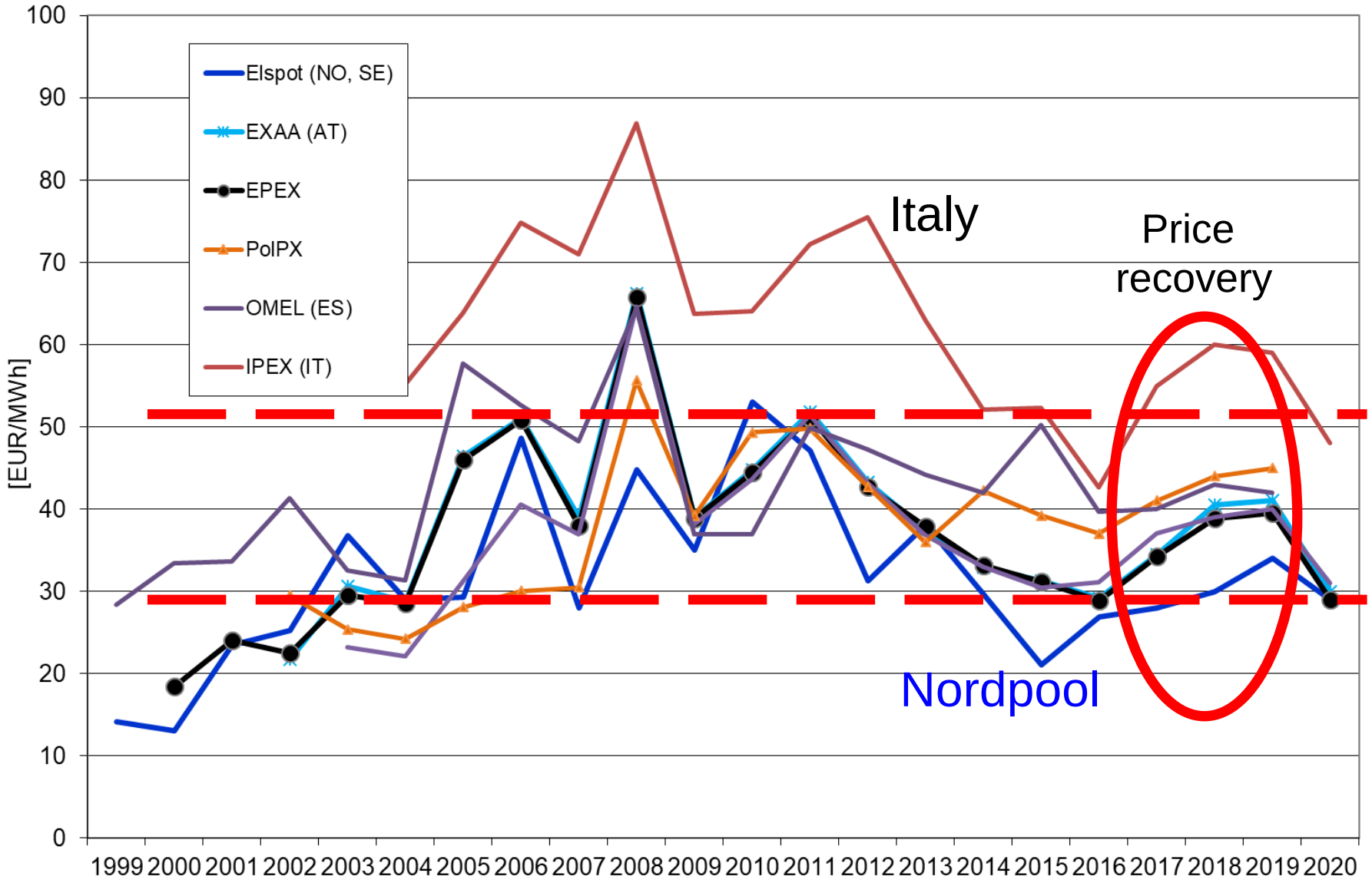
## EUROPEAN ELECTRICITY SUB-MARKETS

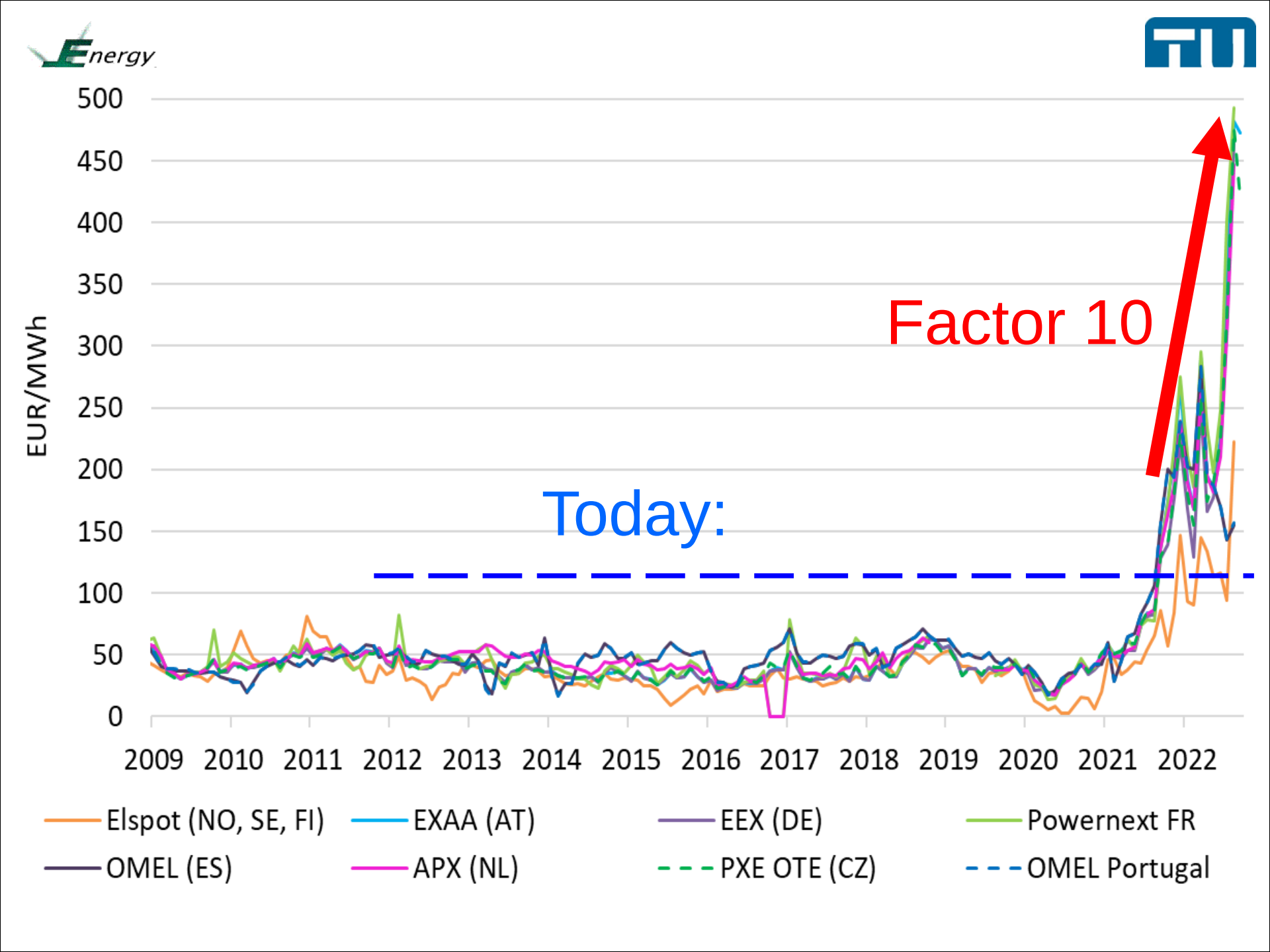


# Development of day-ahead electricity prices in Europe per year (1)

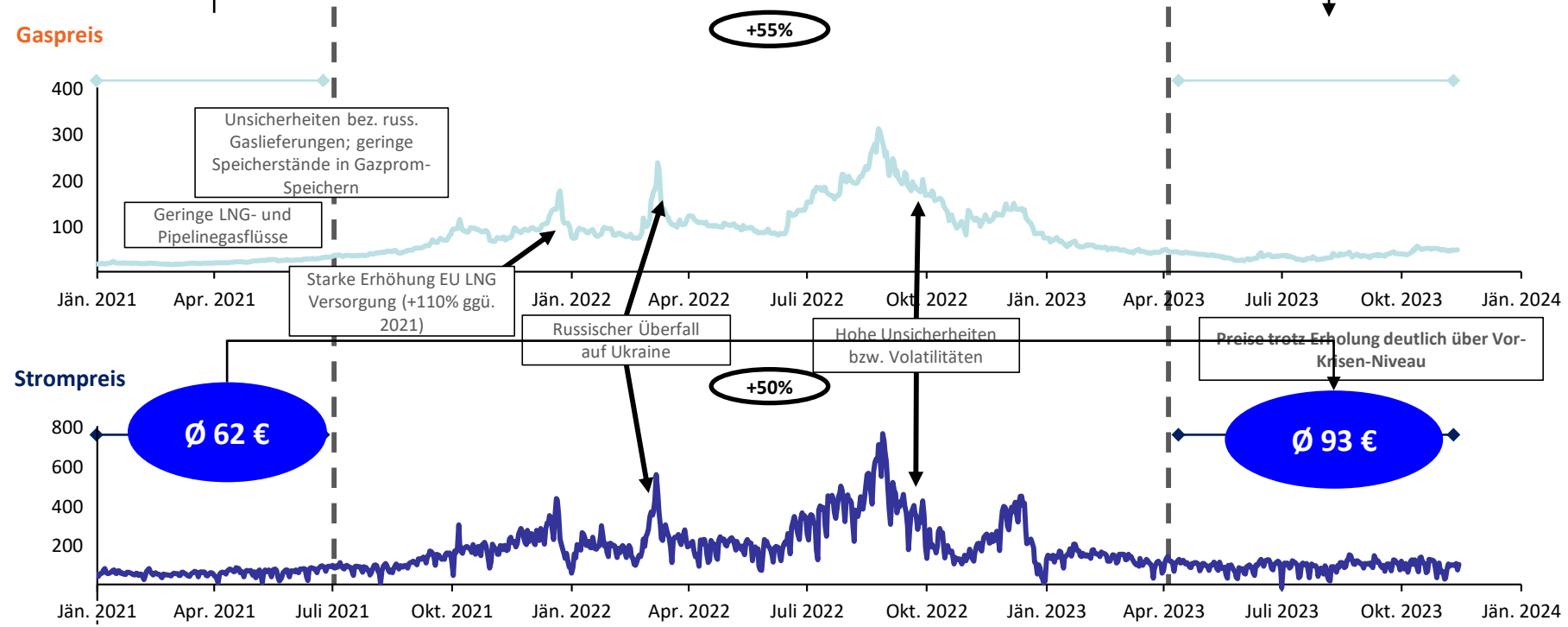


# Development of day-ahead electricity prices in Europe per year (2)




Energy
500
450
400
350
300
250
200
150
100
50
0
EUR/MWh
Factor 10
Today:
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Elspot (NO, SE, FI)
EXAA (AT)
EEX (DE)
Powernext FR
OMEL (ES)
APX (NL)
PXE OTE (CZ)
OMEL Portugal

**Marktentwicklung ~~Gas- und Strompreis (Spotmarkt)~~** (in EUR / MWh)





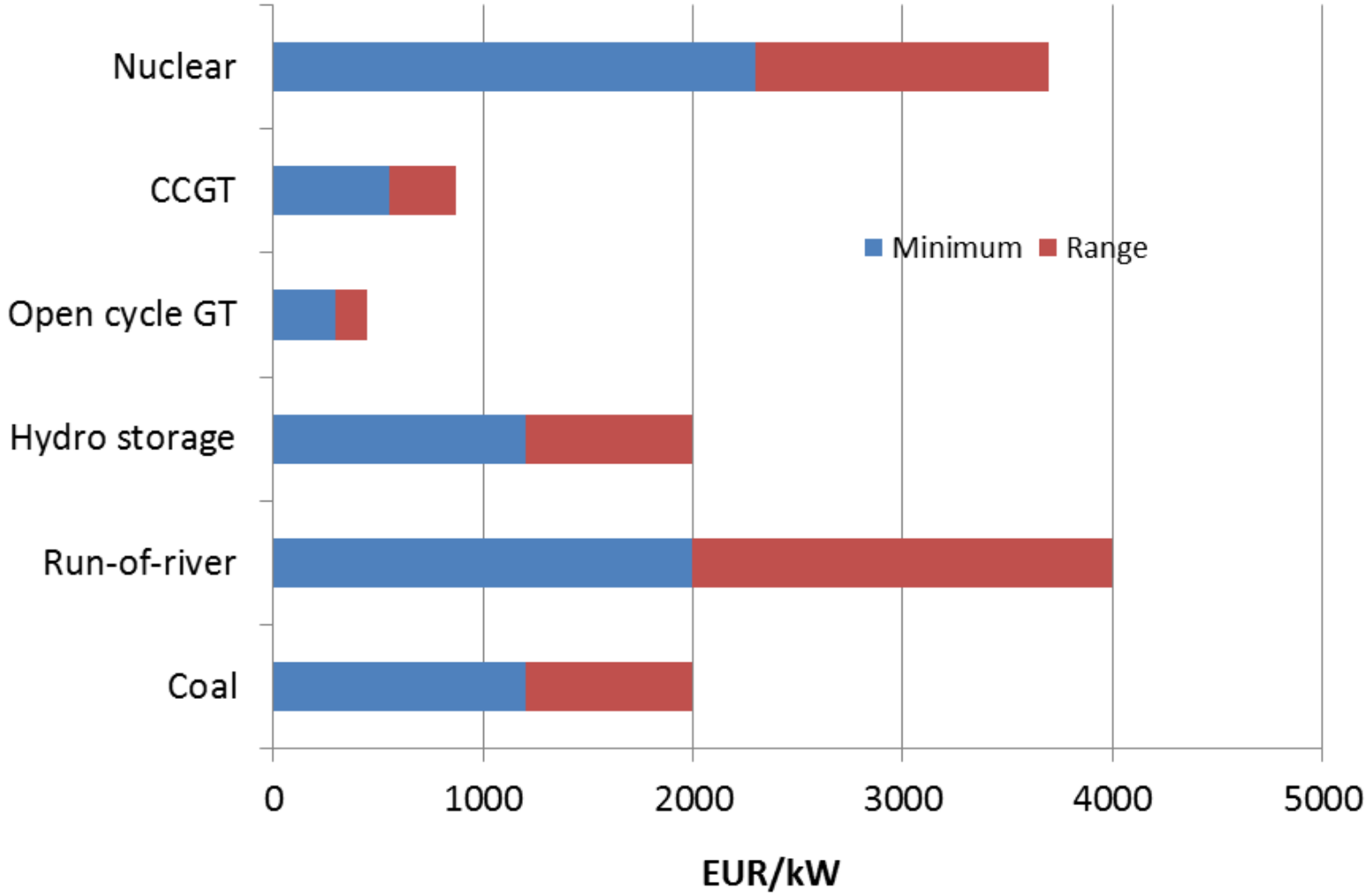

Stand 13.11.2023

18.01.2024

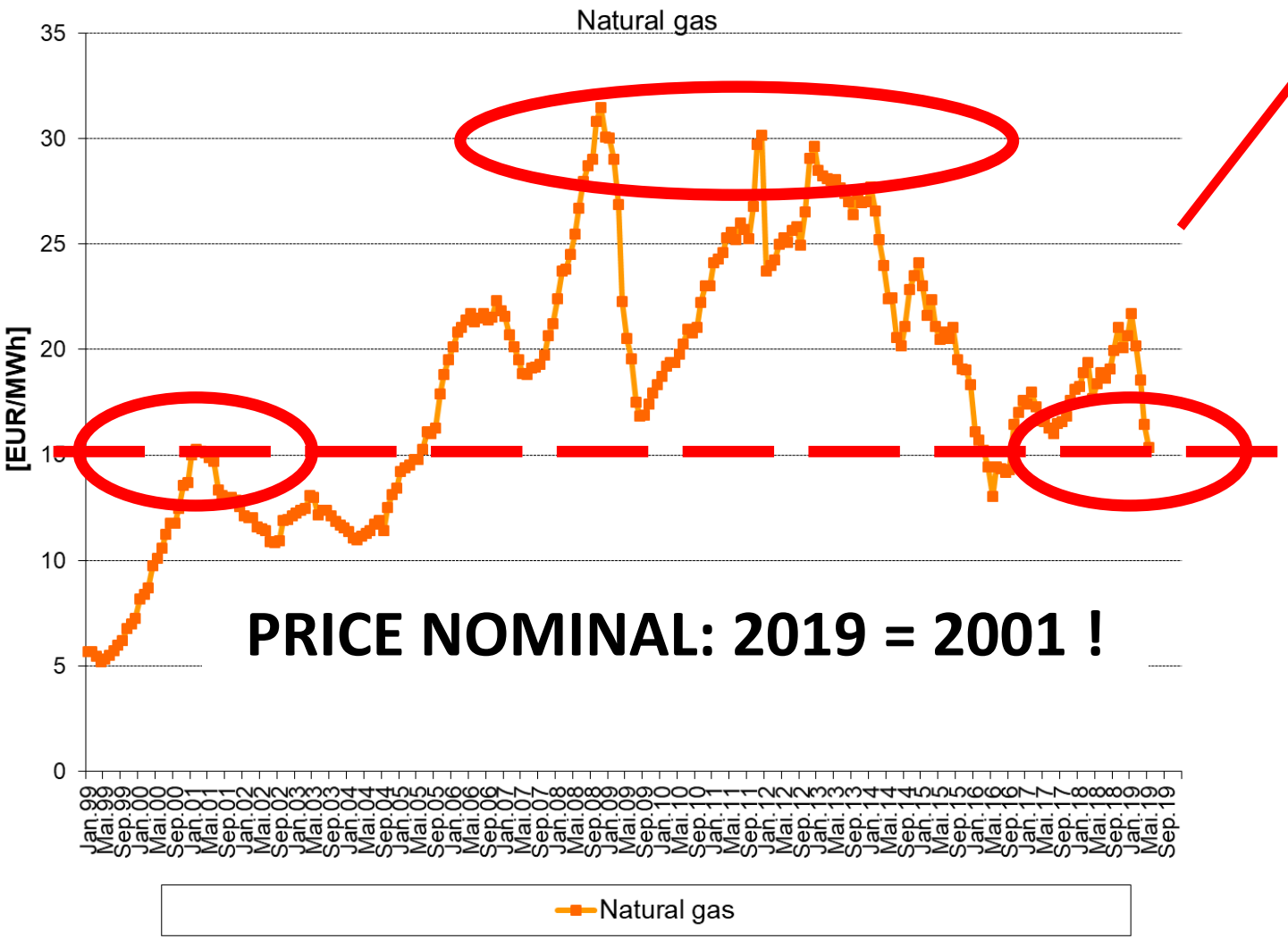
# WHAT ARE IMPORTANT IMPACT PARAMETERS ON ELECTRICITY PRICES AND COSTS?

# Investment costs

## Electricity generation Conventional 2018



# THE MARKET PRICE OF NATURAL GAS




300 !!!

**PRICE NOMINAL: 2019 = 2001 !**

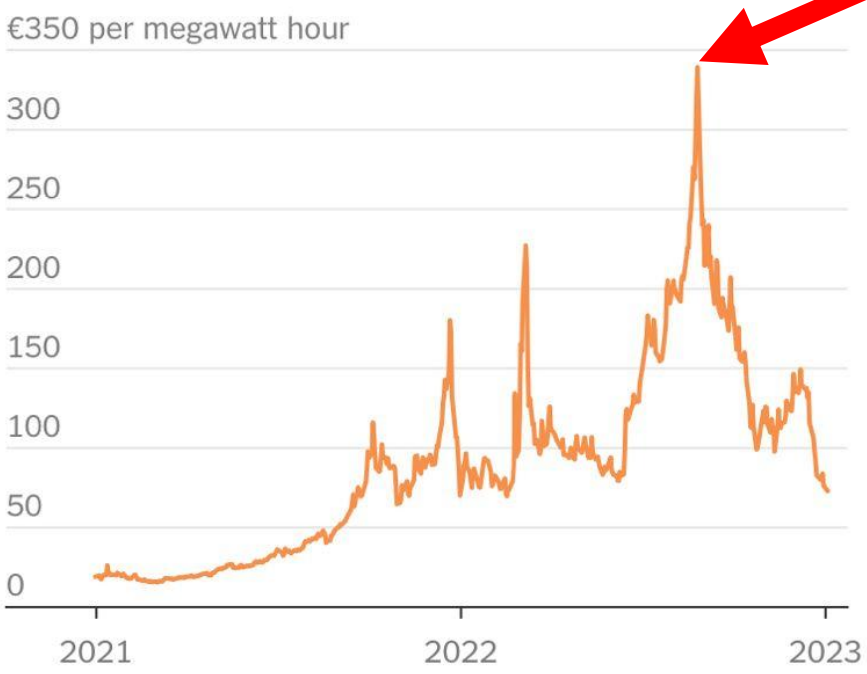
# *Natural Gas Prices in Europe Fall to Pre-Invasion Levels*

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

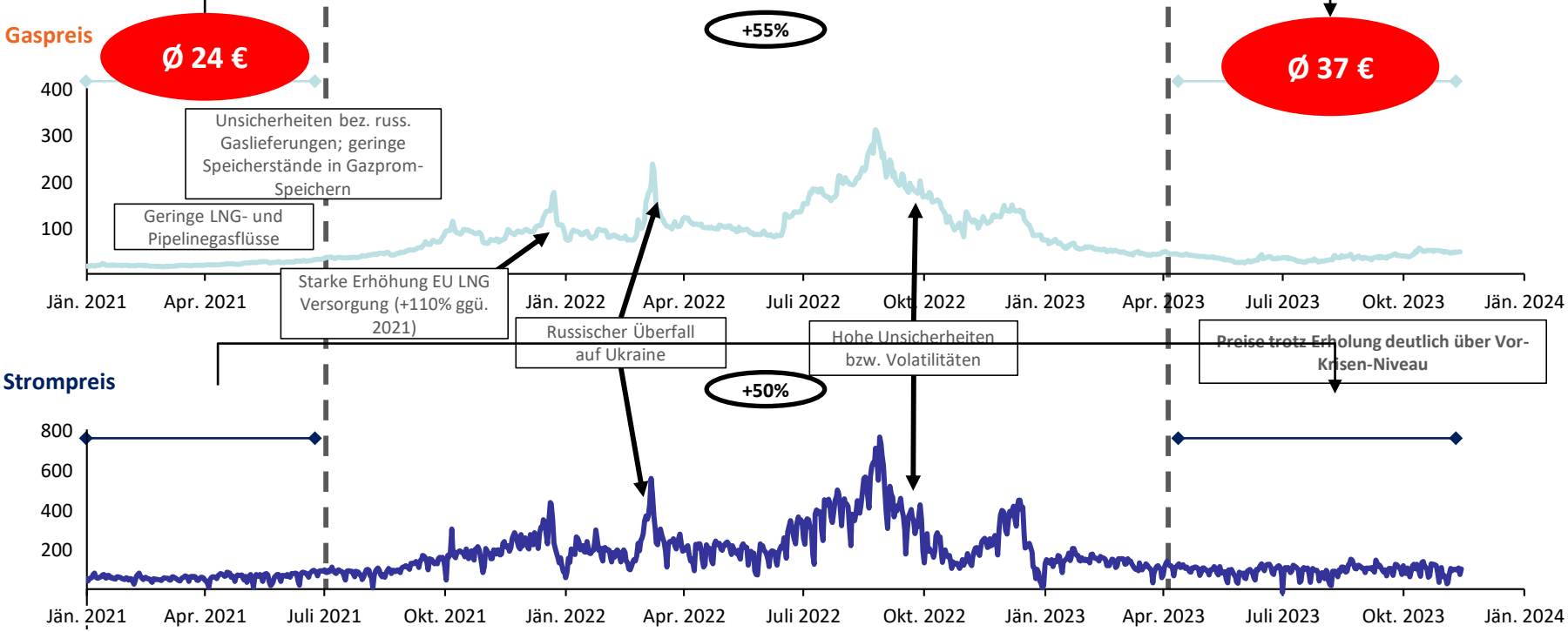
Give this article | 98 | Read in app

346 €/MWh !!!

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



**Marktentwicklung ~~Gas- und Strompreis (Spotmarkt)~~** (in EUR / MWh)






Stand 13.11.2023

18.01.2024

# TASK FOR STUDENTS: SEARCH FOR TODAY'S PRICES FOR :

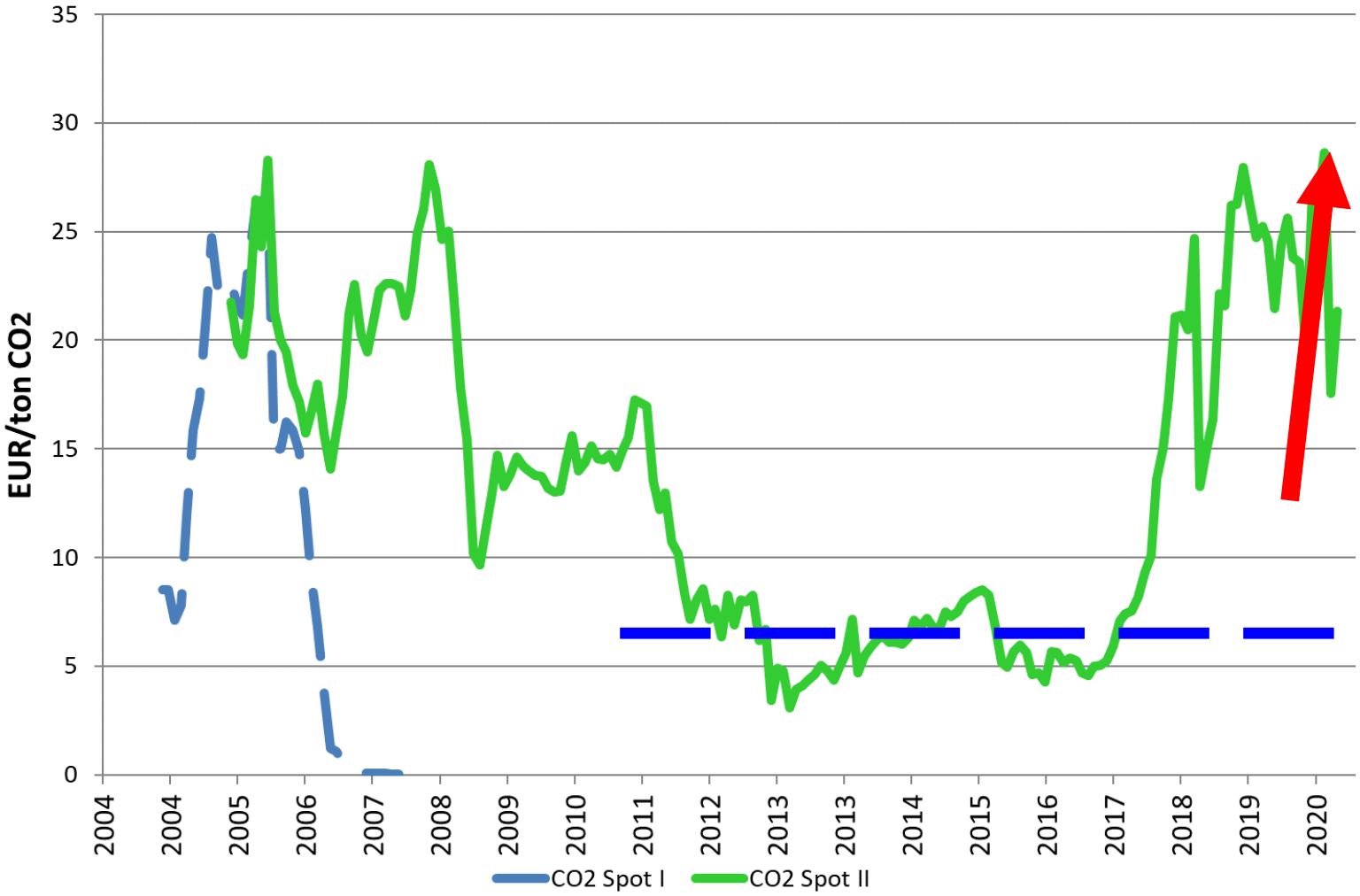
- NATURAL GAS;
- ELECTRICITY PRICES
- CO2 CERTIFICATES

# 4 ENVIRONMENTAL ASPECTS – THE CO2-PRICE

# Der CO2-Preis in Europa

80 (!)

56 (!)



# 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)

$\alpha$ … 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 m³)

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

$\eta$ …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)

# 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/m³ natural gas)

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

$\eta$ …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)

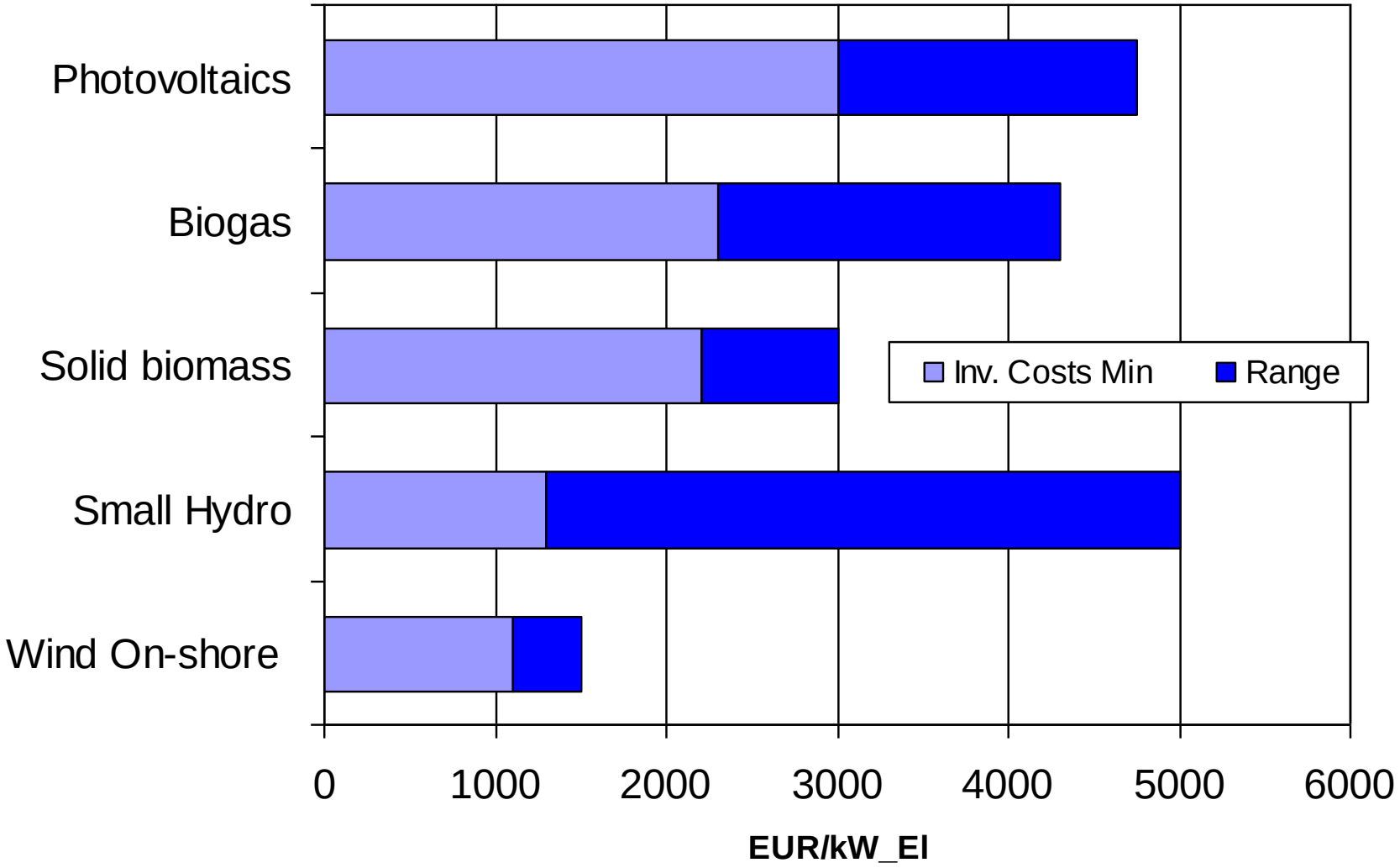
# Example 1: Costs of electricity generation

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

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

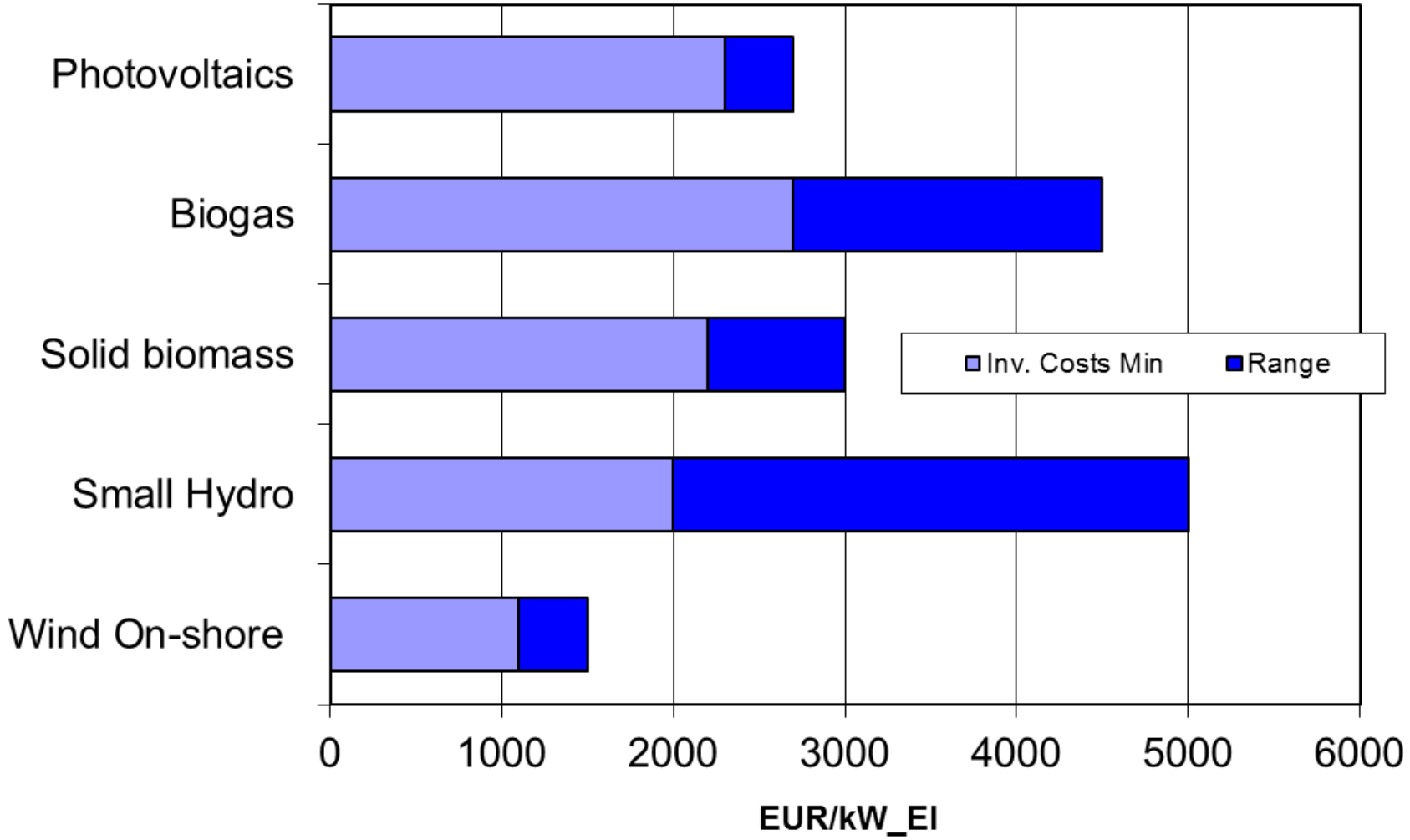
# Investment costs

## Electricity from new renewables 2010



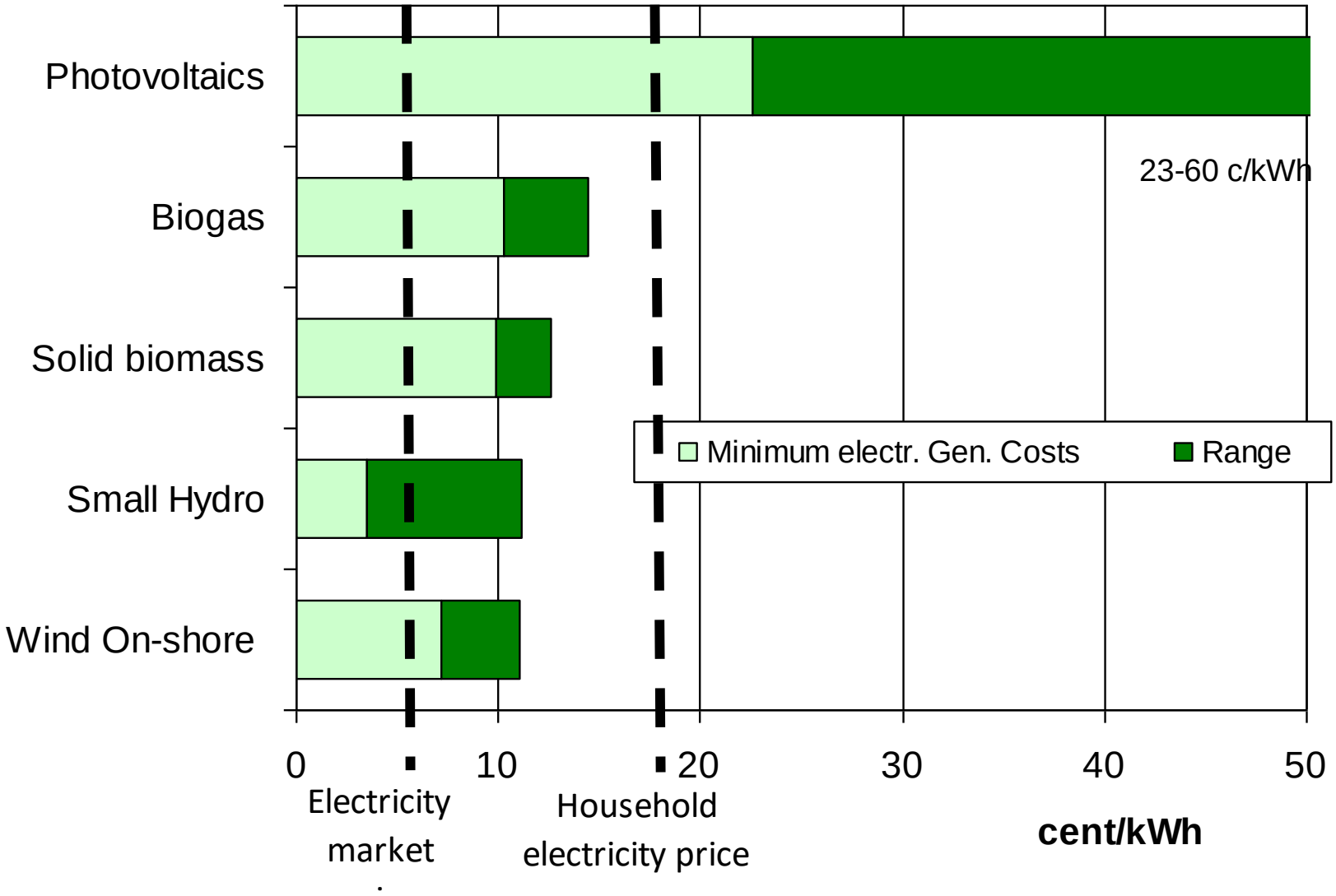
# Investment costs

## Electricity from new renewables 2020



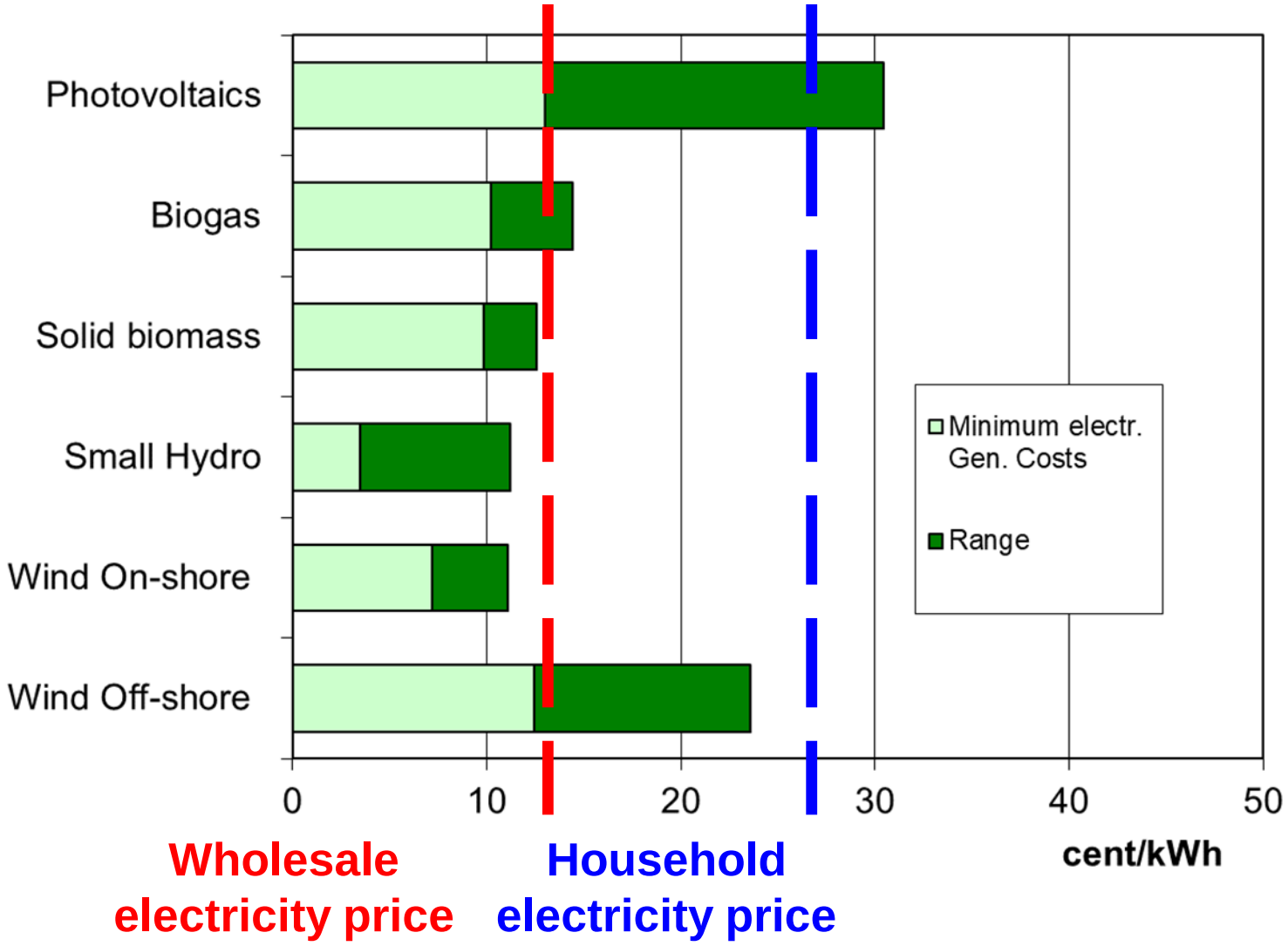
# Generation costs

## Electricity from new renewables 2010



# Generation costs

## Electricity from new renewables 2023



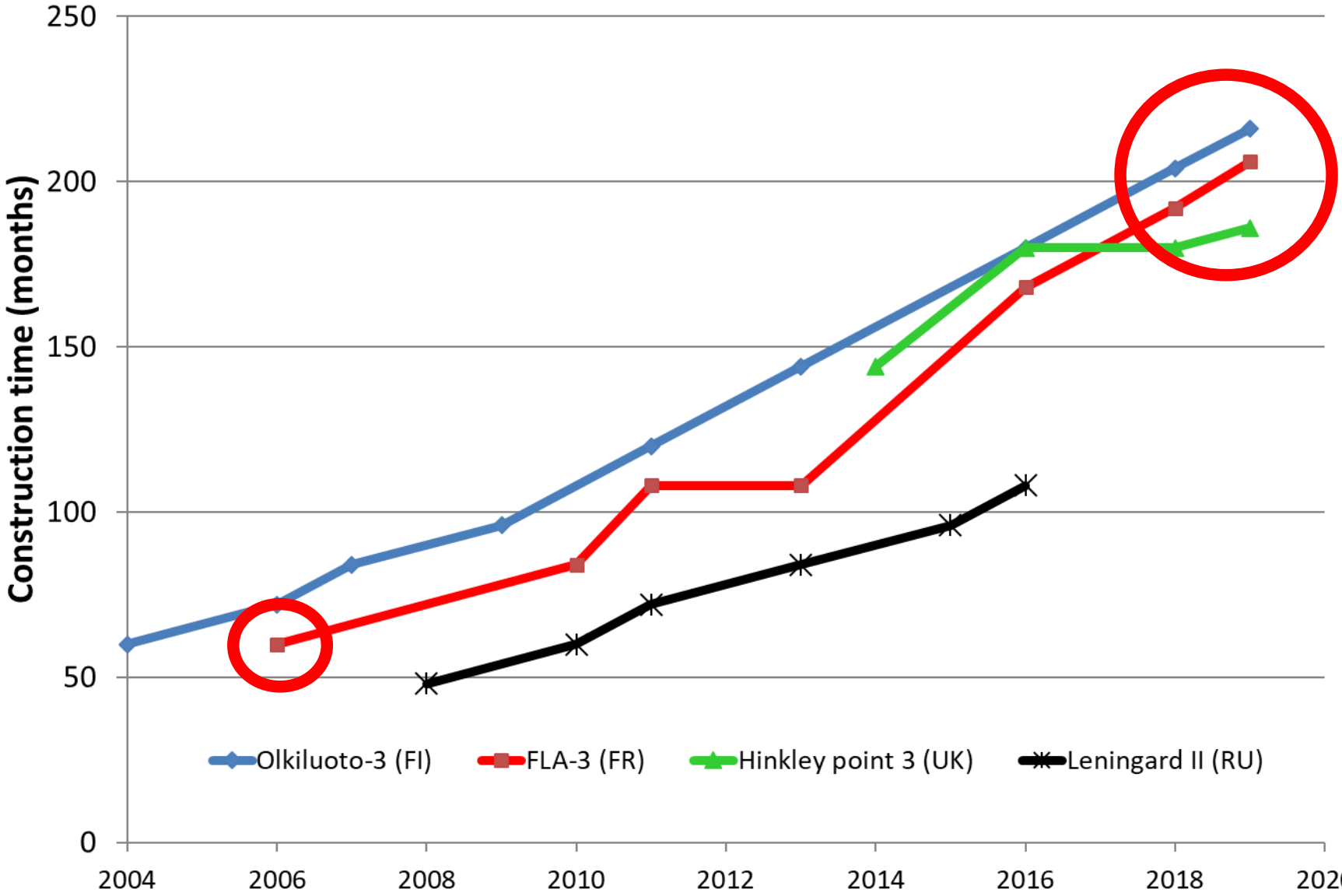
# 6. RECENT DEVELOPMENT OF NUCLEAR COSTS

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

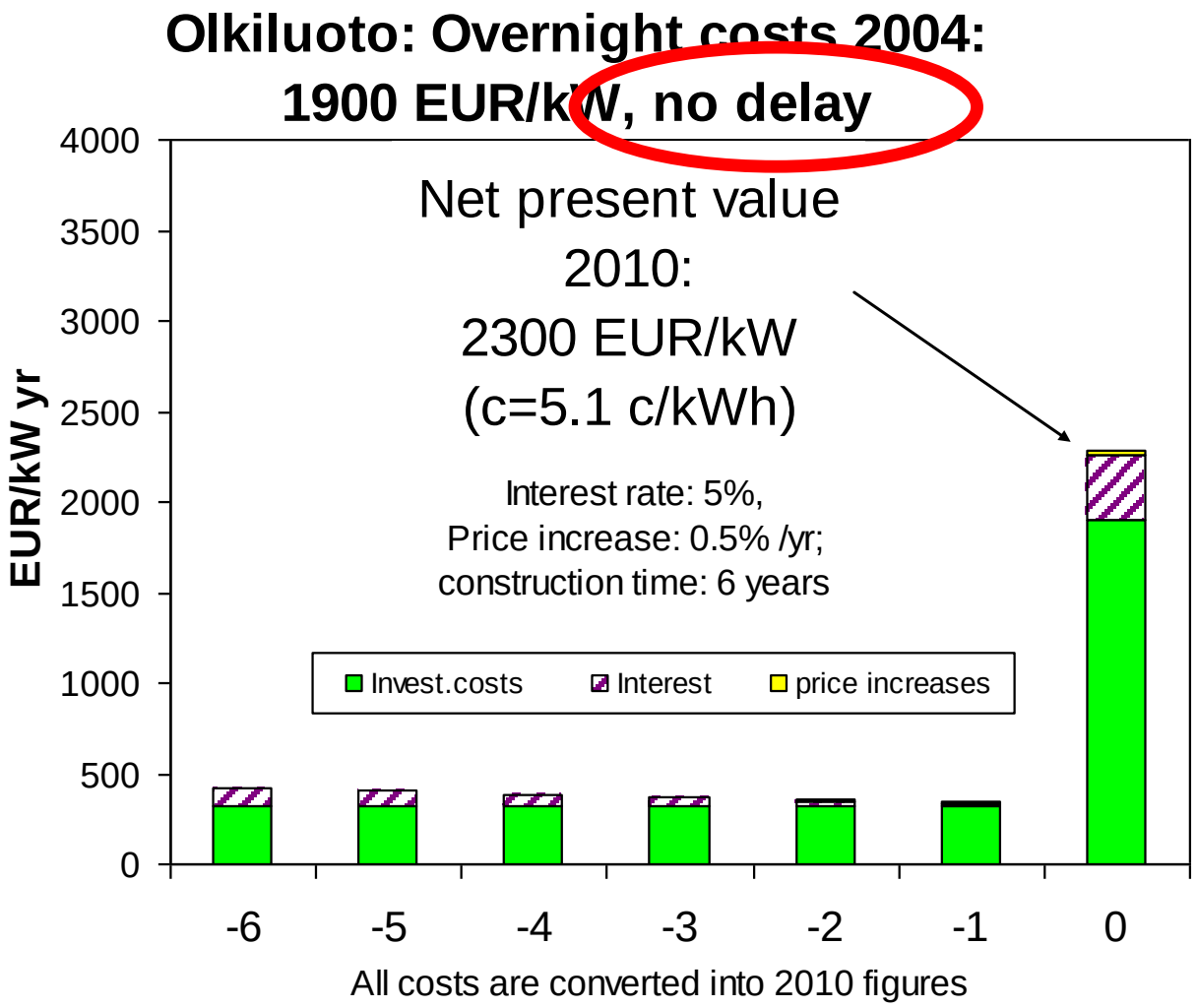
- Flamanville-3 (France): Construction started in 2006, now expected to be completed 2019 (originally: 2011); 1600 MW

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

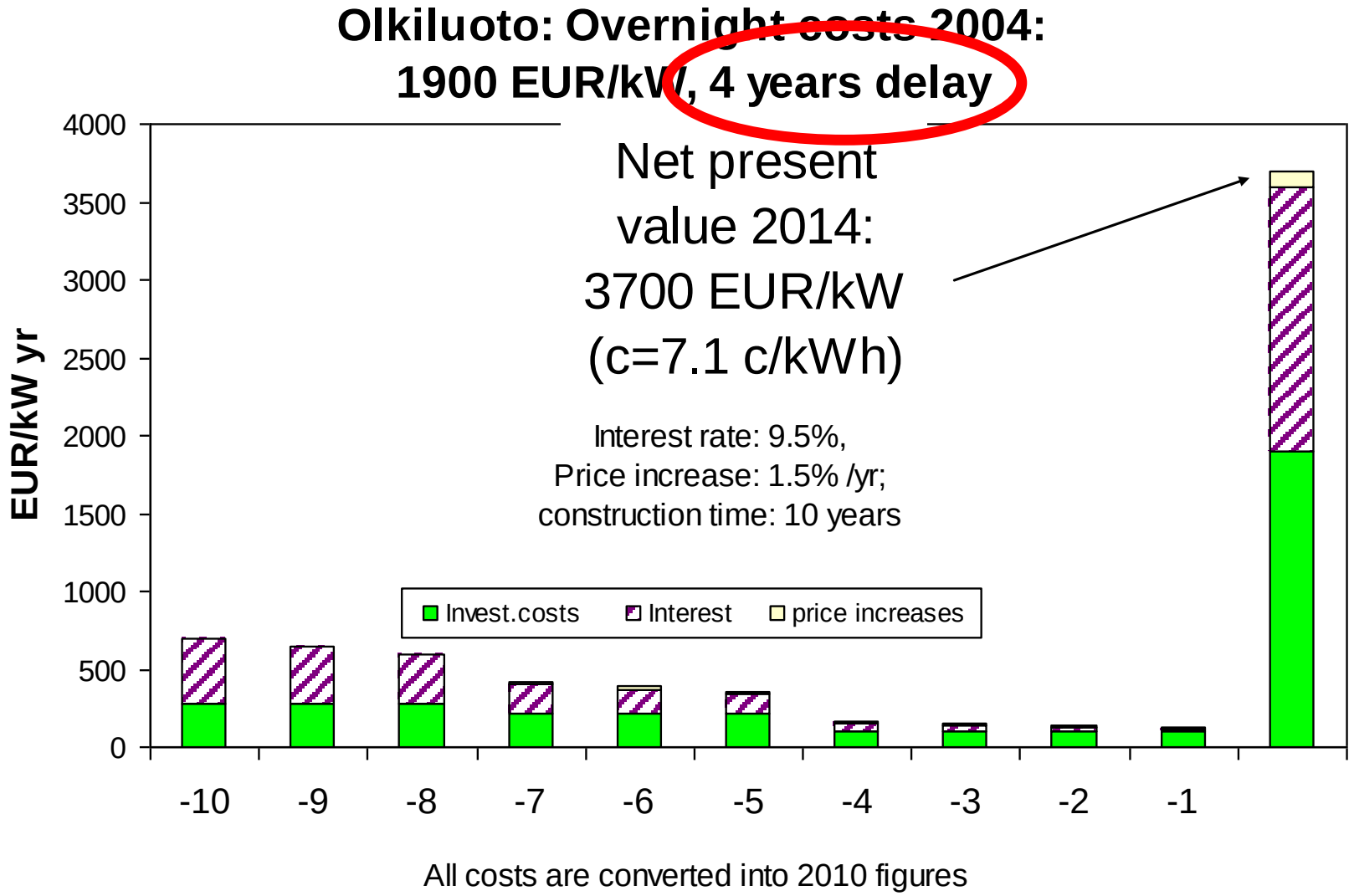
# Construction times

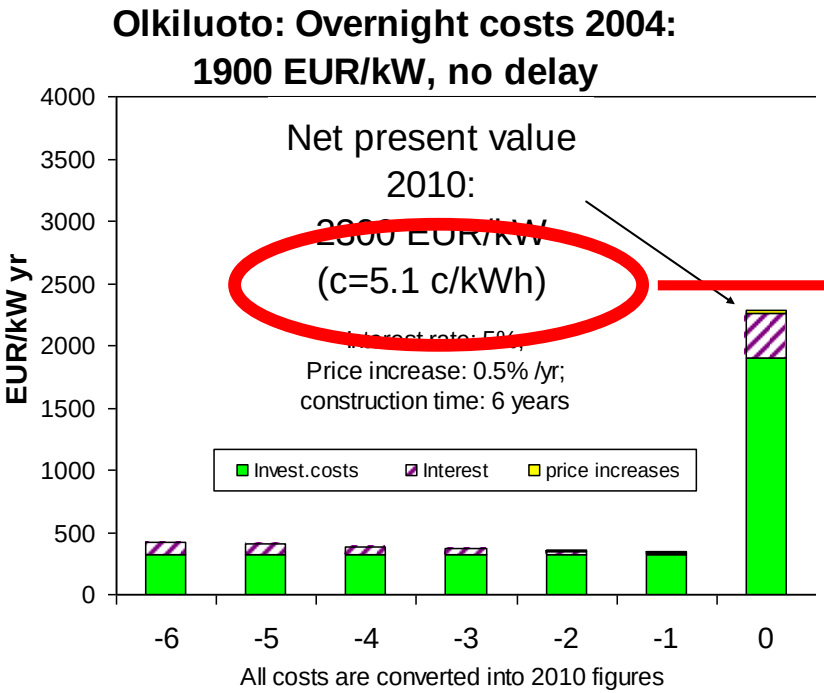


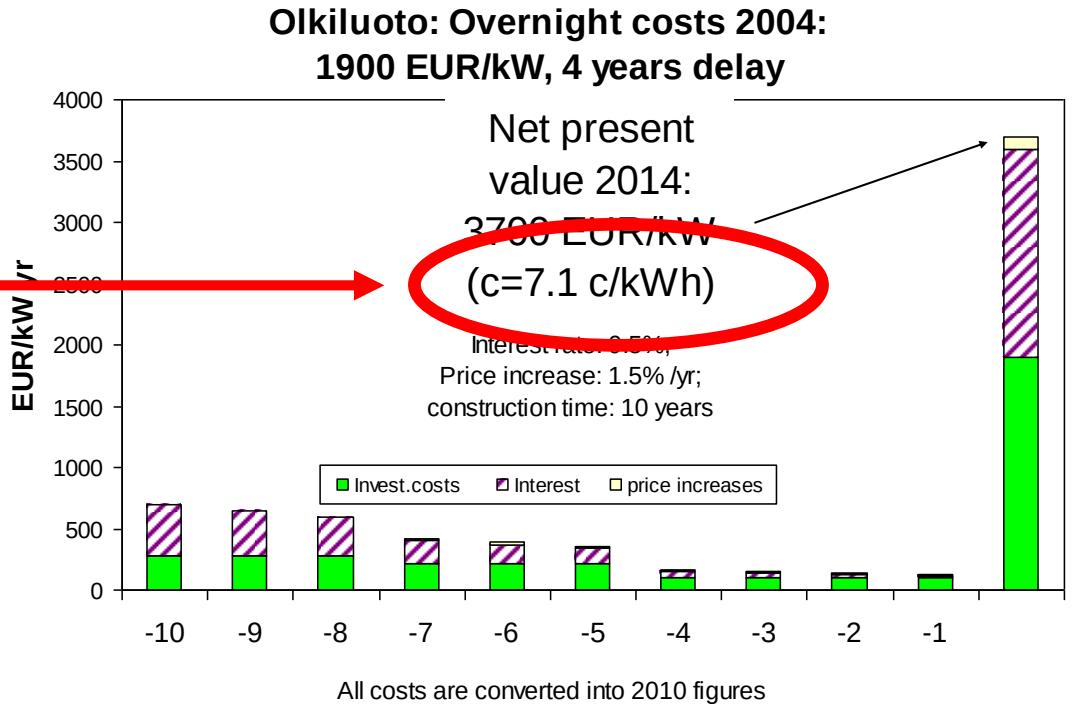
# Impact of construction time on investment costs: Example Olkiluoto



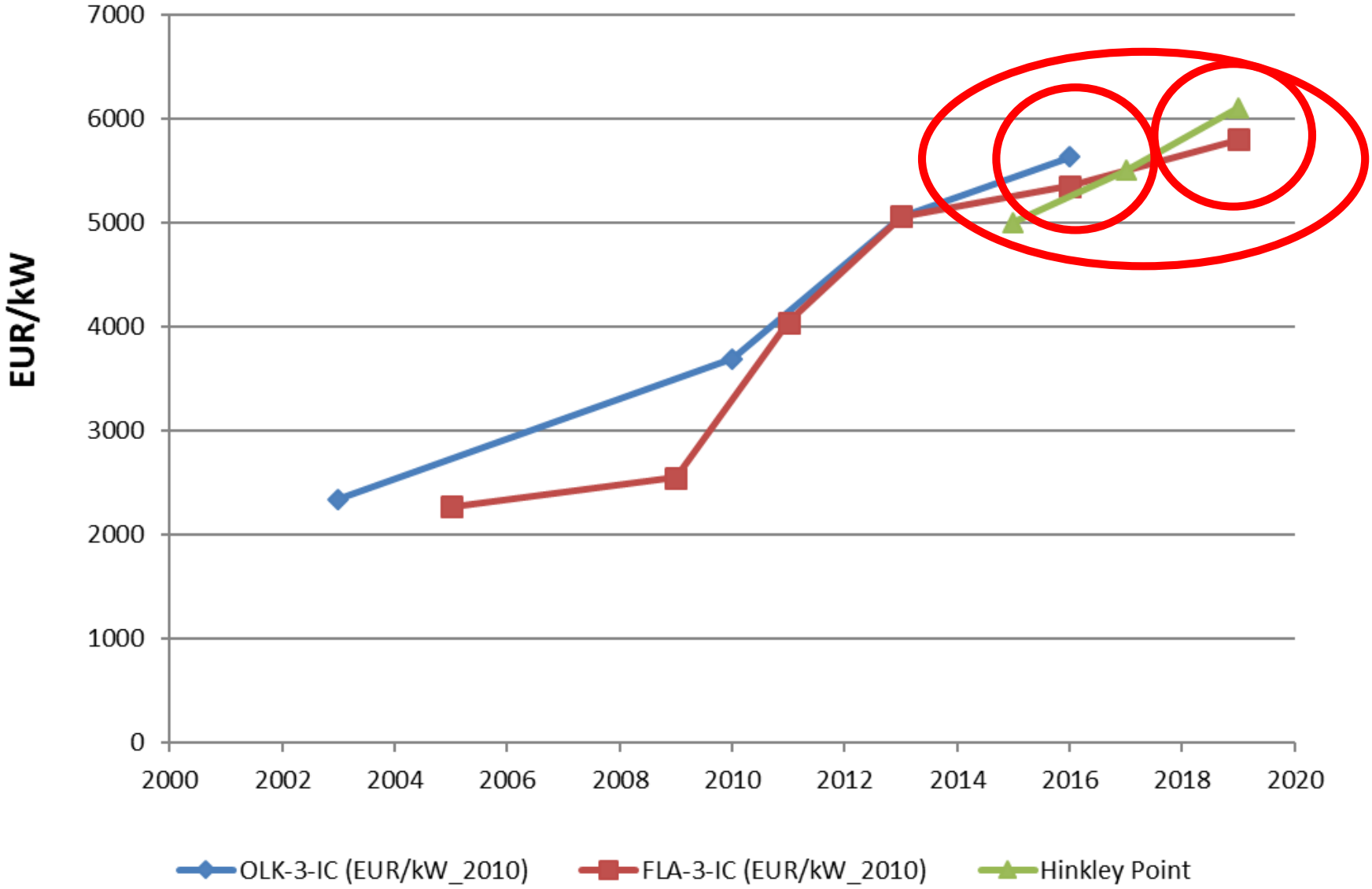
# Impact of construction time on investment costs: Example Olkiluoto




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

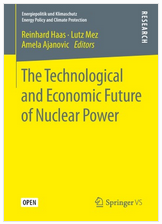

Olkiluoto: Overnight costs 2004:
1900 EUR/kW, 4 years delay
Net present value 2014:
(c=7.1 c/kWh)
Price increase: 1.5% /yr;
construction time: 10 years
Invest.costs
Interest
price increases
EUR/kW yr
4000
3500
3000
2500
2000
1500
1000
500
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
All costs are converted into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

# Investment cost development Olkiluoto 3 vs Flamanville 3 vs HP



# CONCLUSIONS:

- **Nuclear will come to late for reducing GHG emissions**
- **Nuclear is to expensive (Hinkley Point: 12 cent/kWh)**
- **The money invested in nuclear power is not available for RES and energy efficiency**






# The Technological and Economic Future of Nuclear Power

**Editors** (view affiliations)
Reinhard Haas, Lutz Mez, Amela Ajanovic

New Open Access Articles in the Field of Nuclear Power Economics

Historical Review of the Nuclear Dream

Contributions to Increasing Construction Costs and Durations of Nuclear Power Plants

Open Access | Book

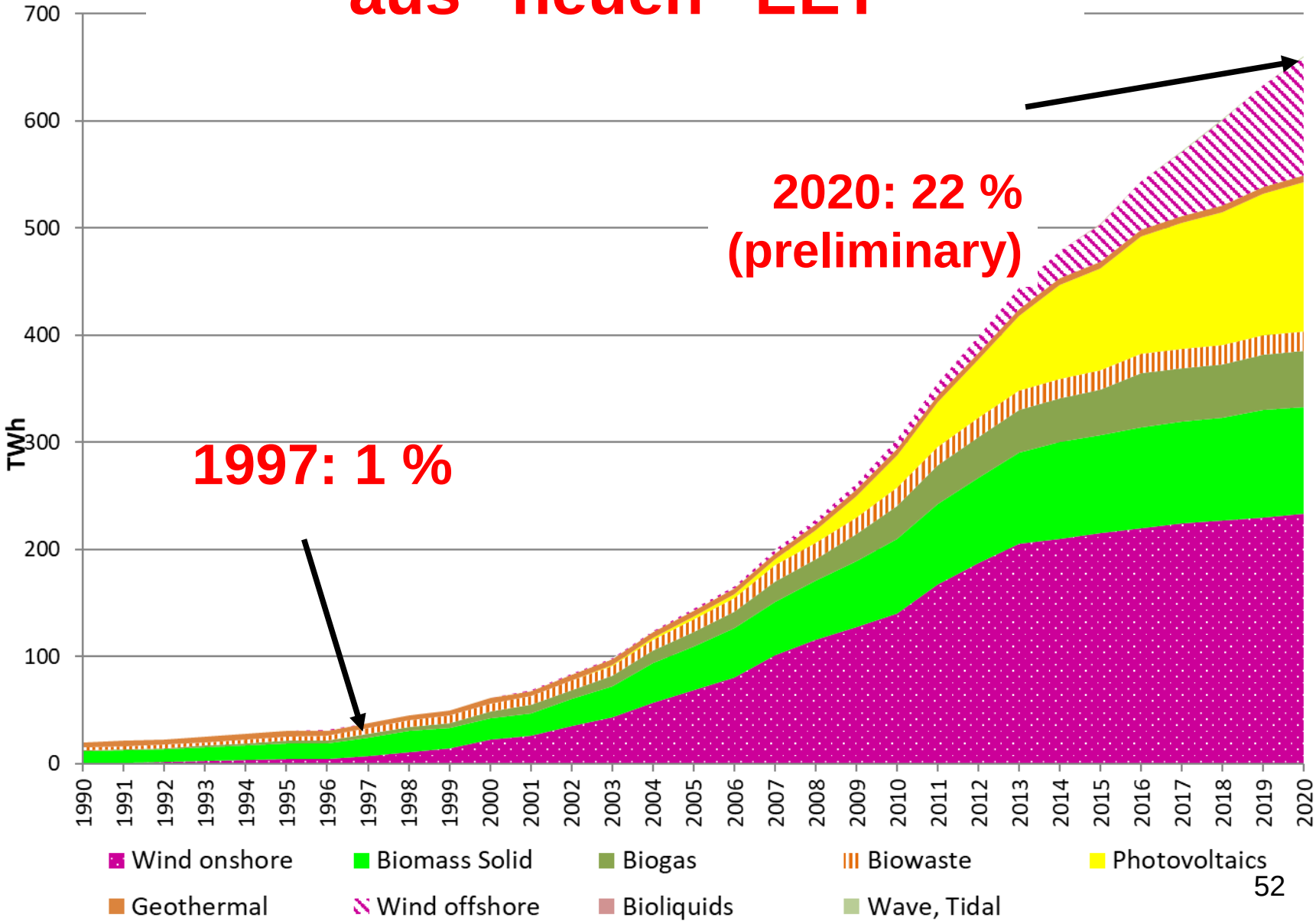
24 Citations | 20 Mentions | 91k Downloads

Part of the Energiepolitik und Klimaschutz. Energy Policy and Climate Protection book series (EPKS)

# APPENDIX: SOME ISSUES ON RENEWABLES

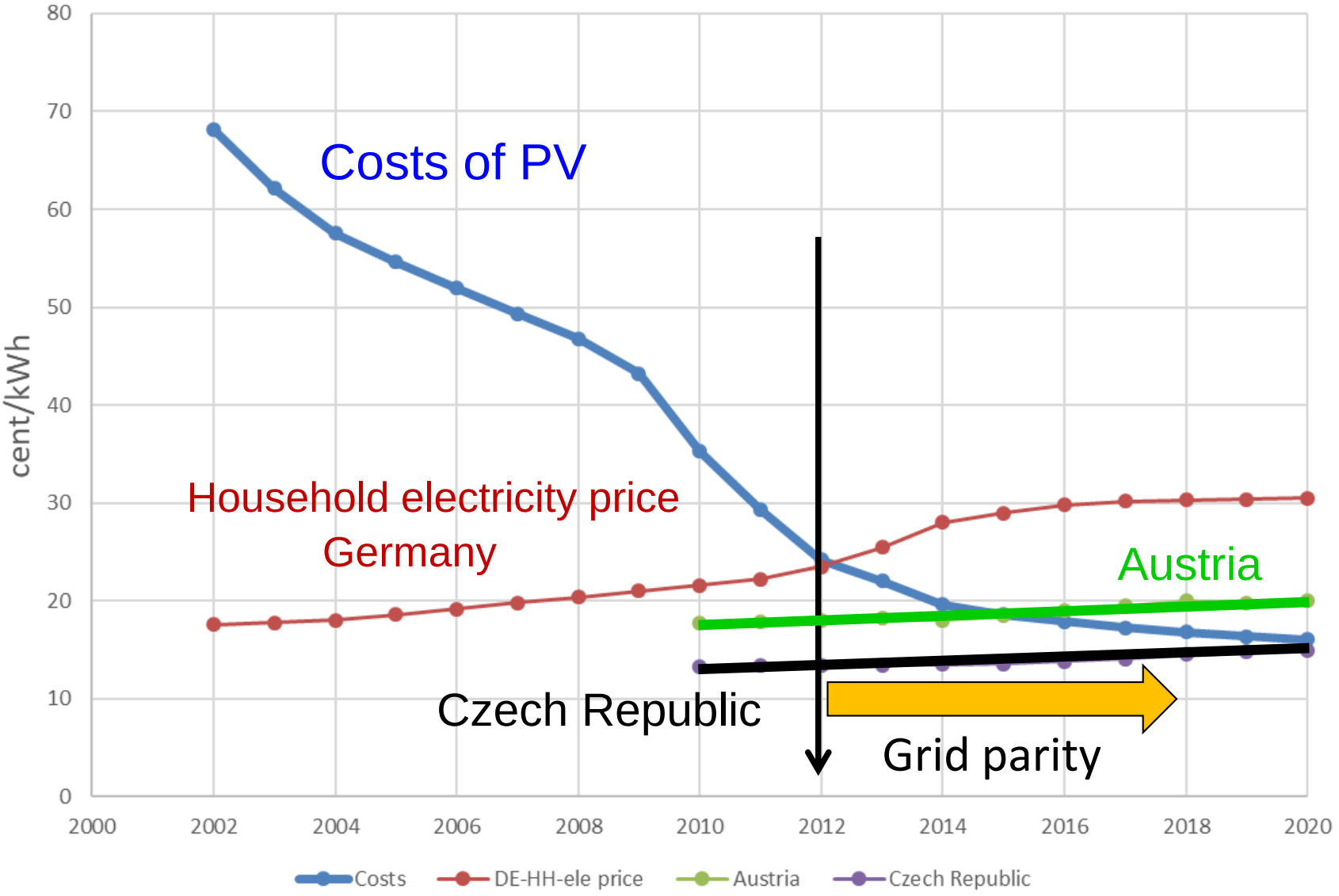
# WHY IS A NEW ELECTRICITY MARKET DESIGN NEEDED?

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

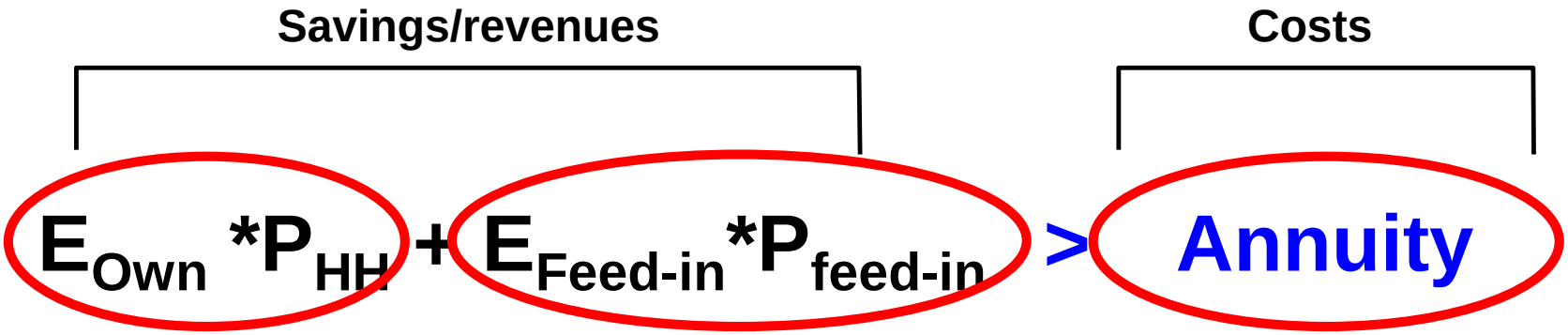



Source: EUROSTAT, own estimations

# Grid parity: PV-costs and household electricity prices



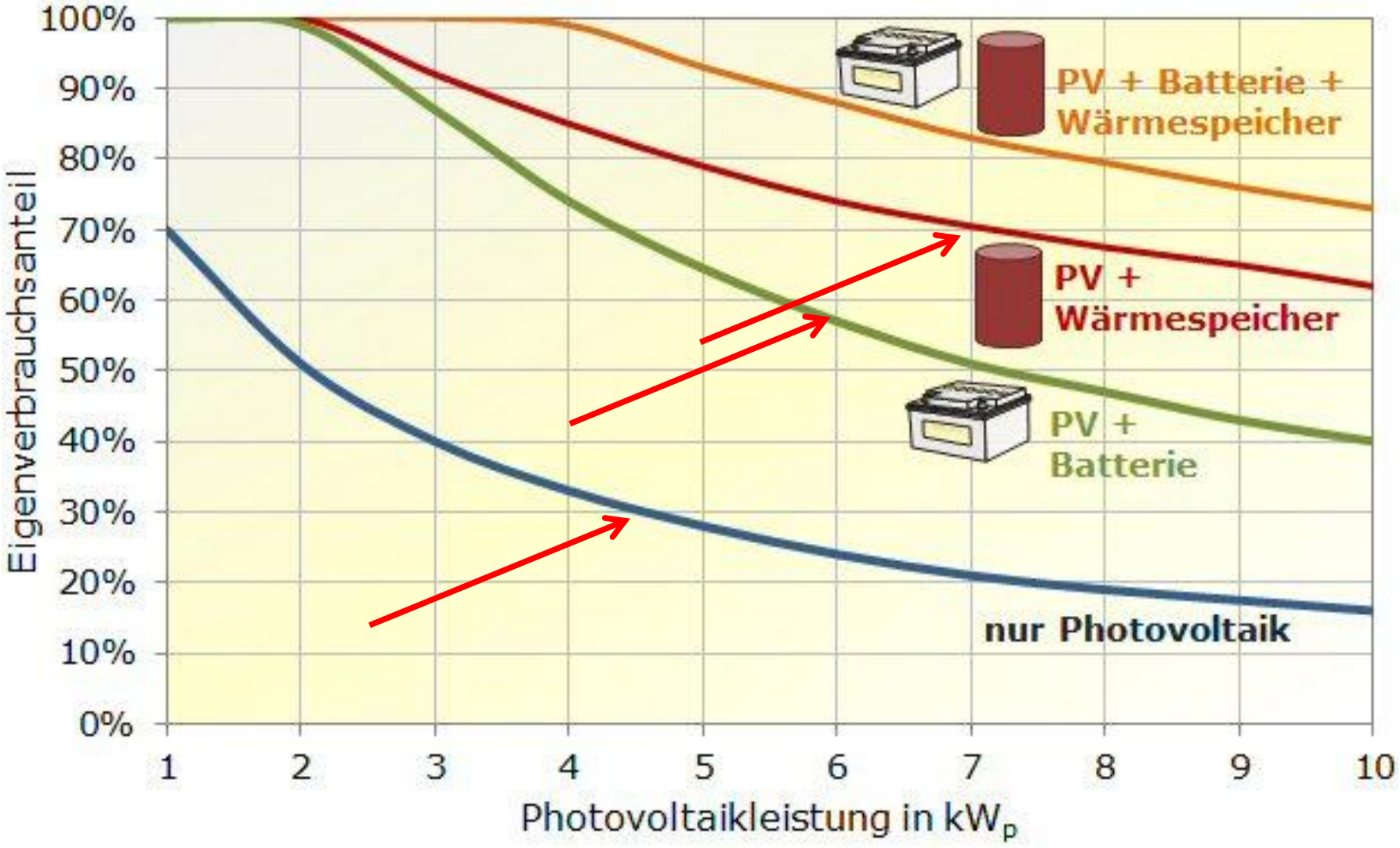
# Assessment of Grid Parity



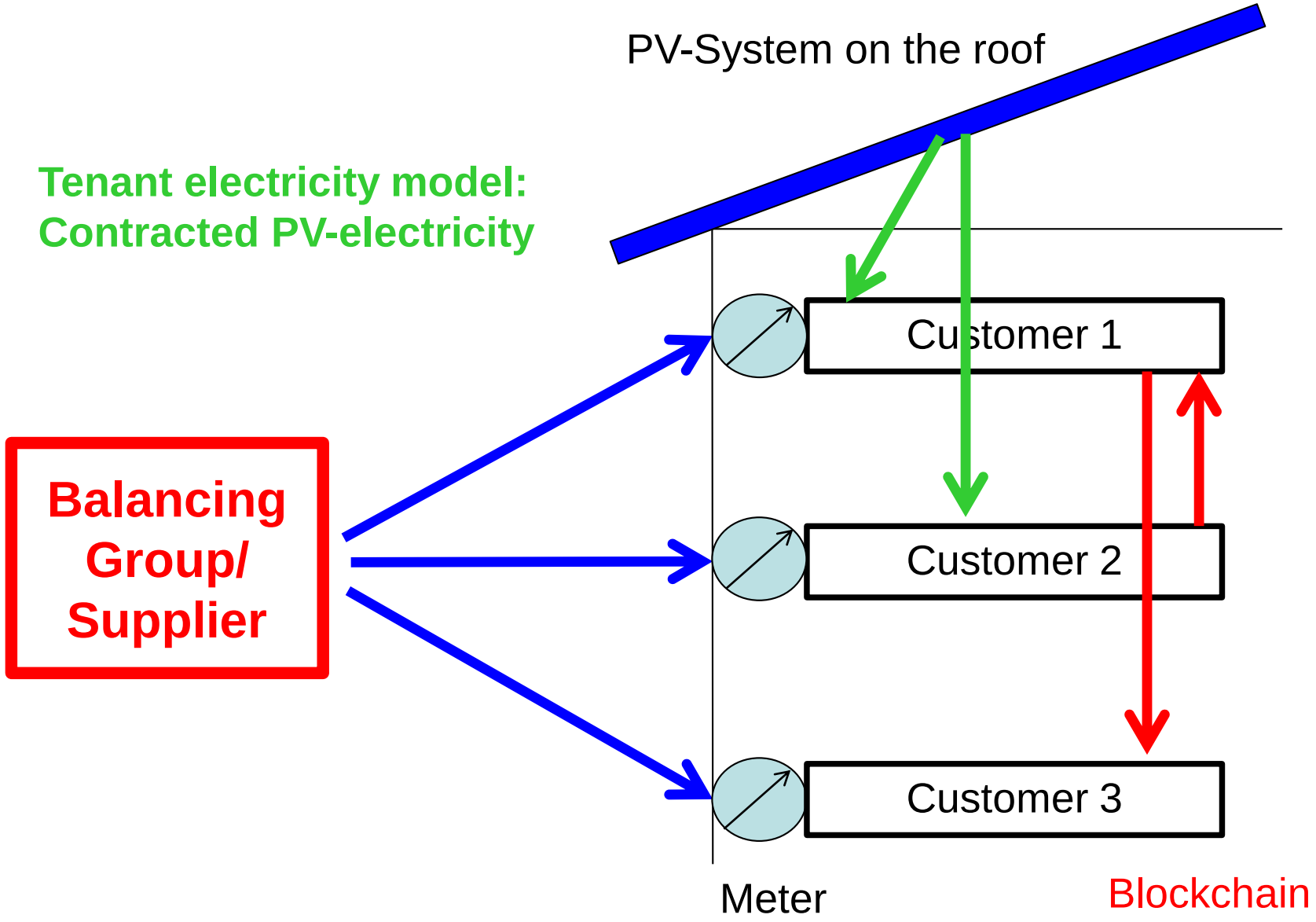

**Grid parity term**

**Subsidy still necessary?**

# Share of own consumption



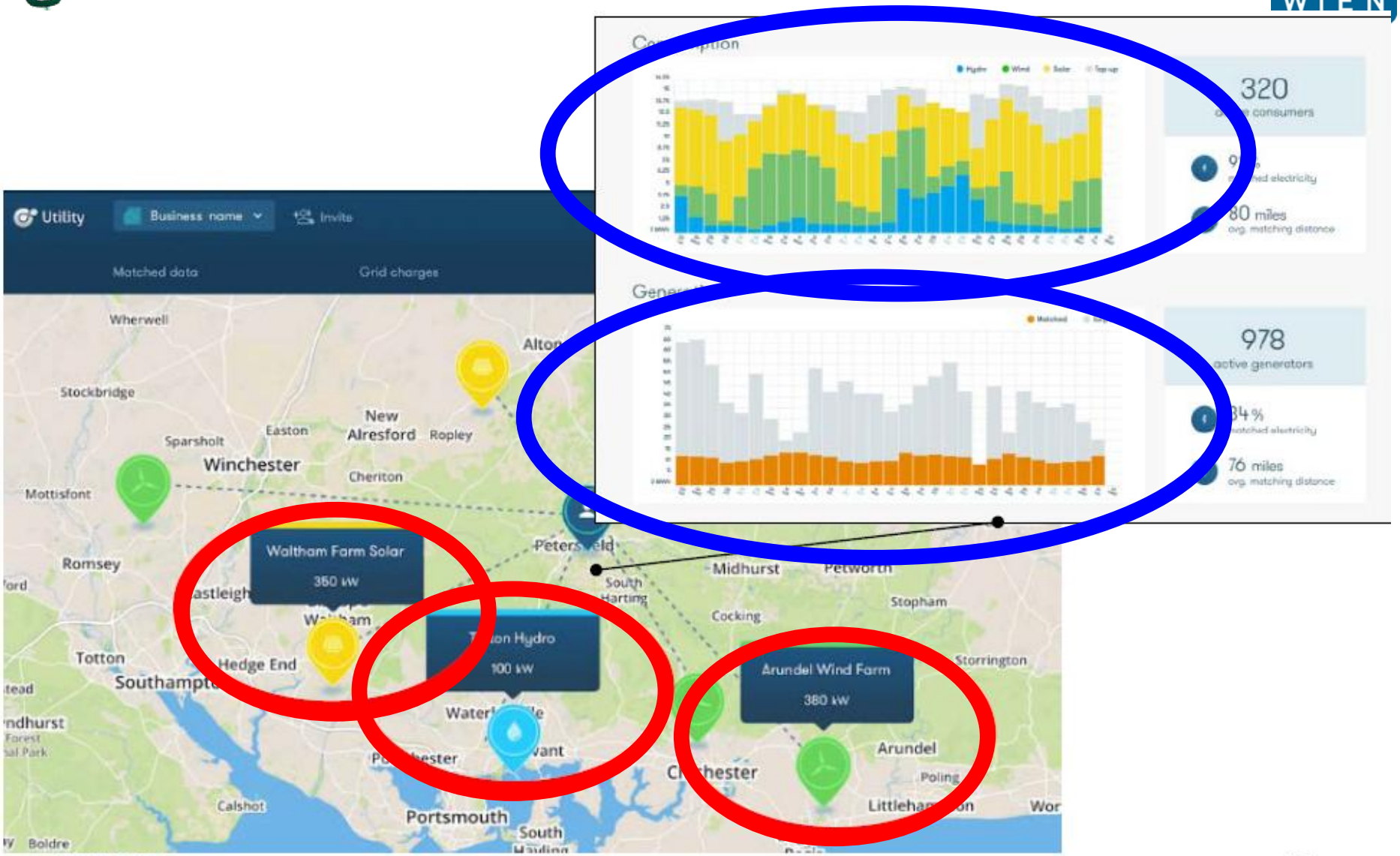
# Tenant electricity model and Blockchain



# 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%

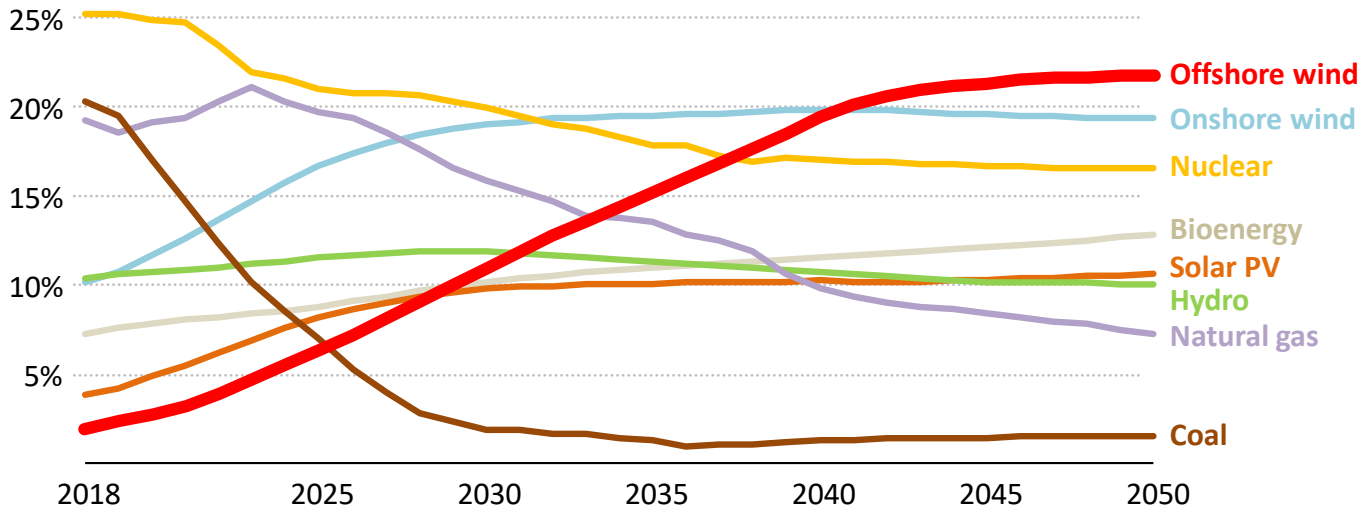
# Peer-to-peer




Source: piclo.co.uk

# A carbon neutral Europe puts offshore wind in front

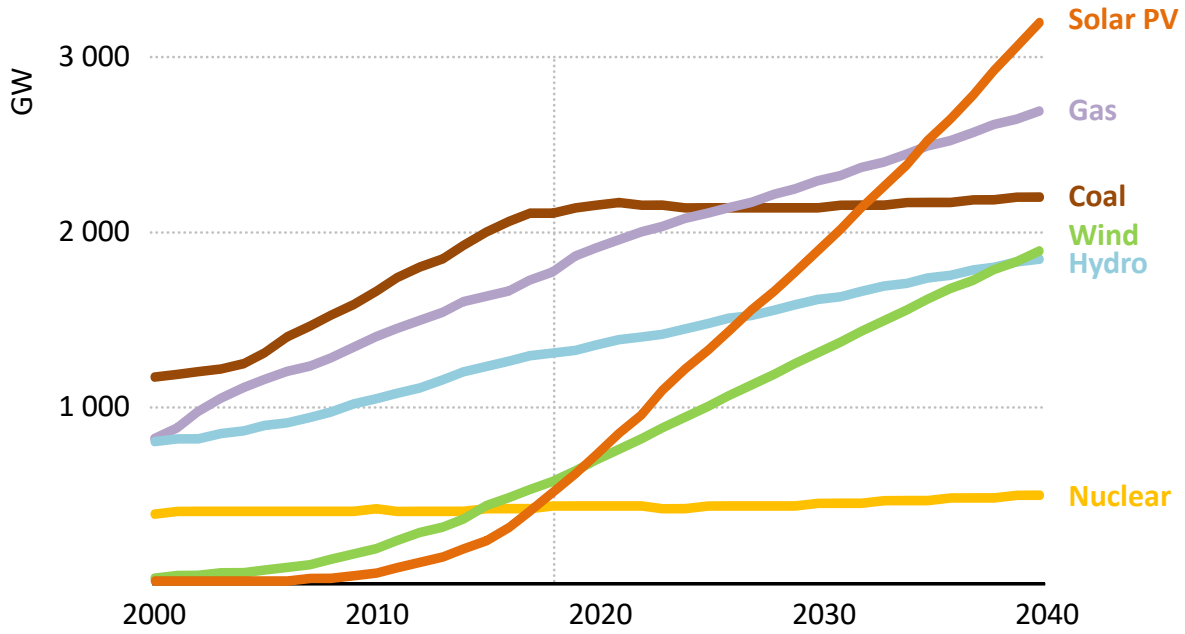
Shares of electricity generation by technology in the European Union, Sustainable Development Scenario




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