ELECTRICITY MARKETS AND THE ROLE OF RENEWABLES & NUCLEAR

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Energy Economics Group,
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Praha, 4.2.2025

SURVEY

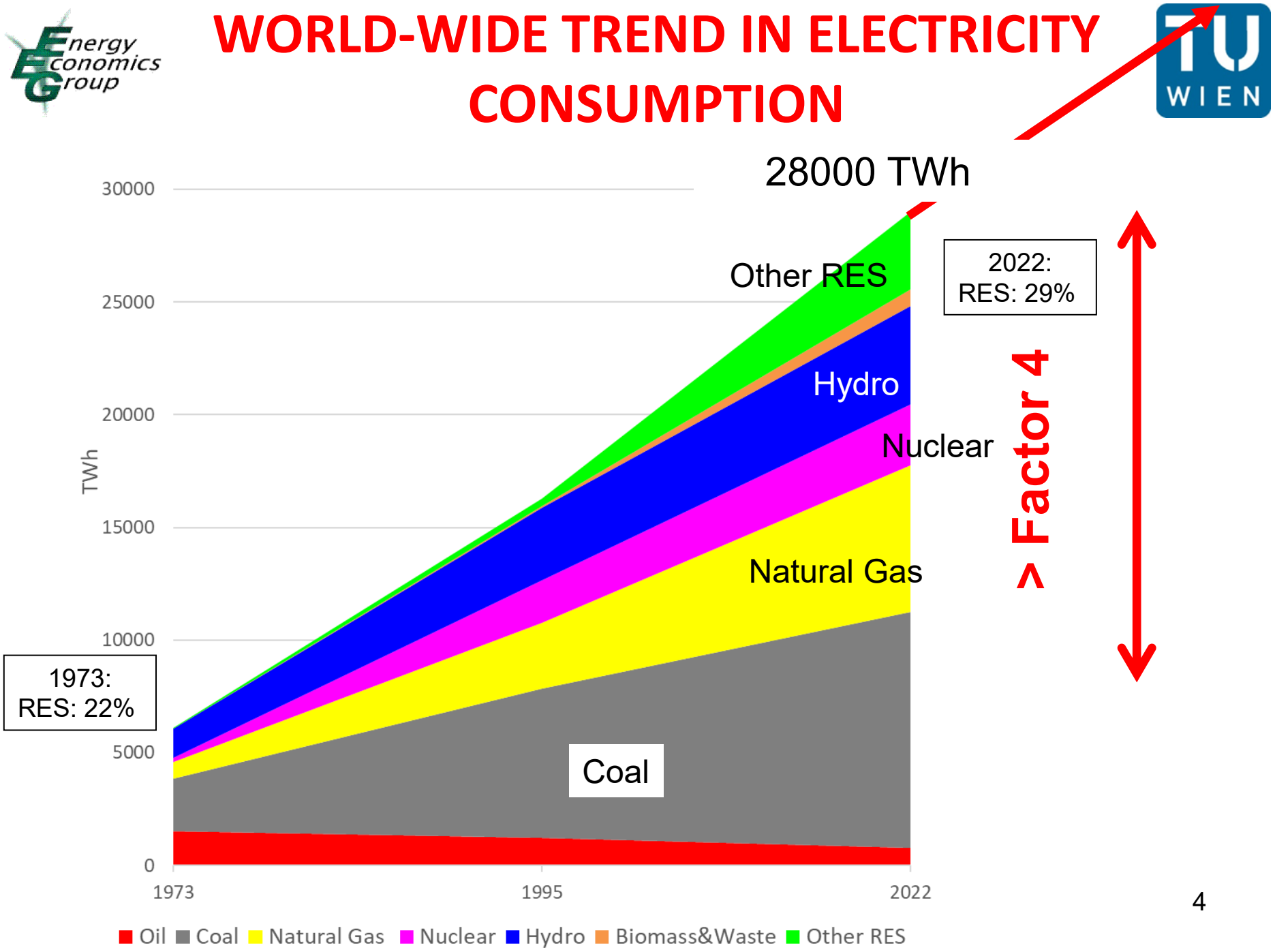
1. Introduction
2. How prices come about (theory)
3. How prices developed in Europe
4. Environmental issues: CO2-prices
5. Electricity generation costs
6. Recent developments of nuclear
7. The role of Renewables

OUR LIFE: PERMANENTLY UNDER

ELECTRICITY

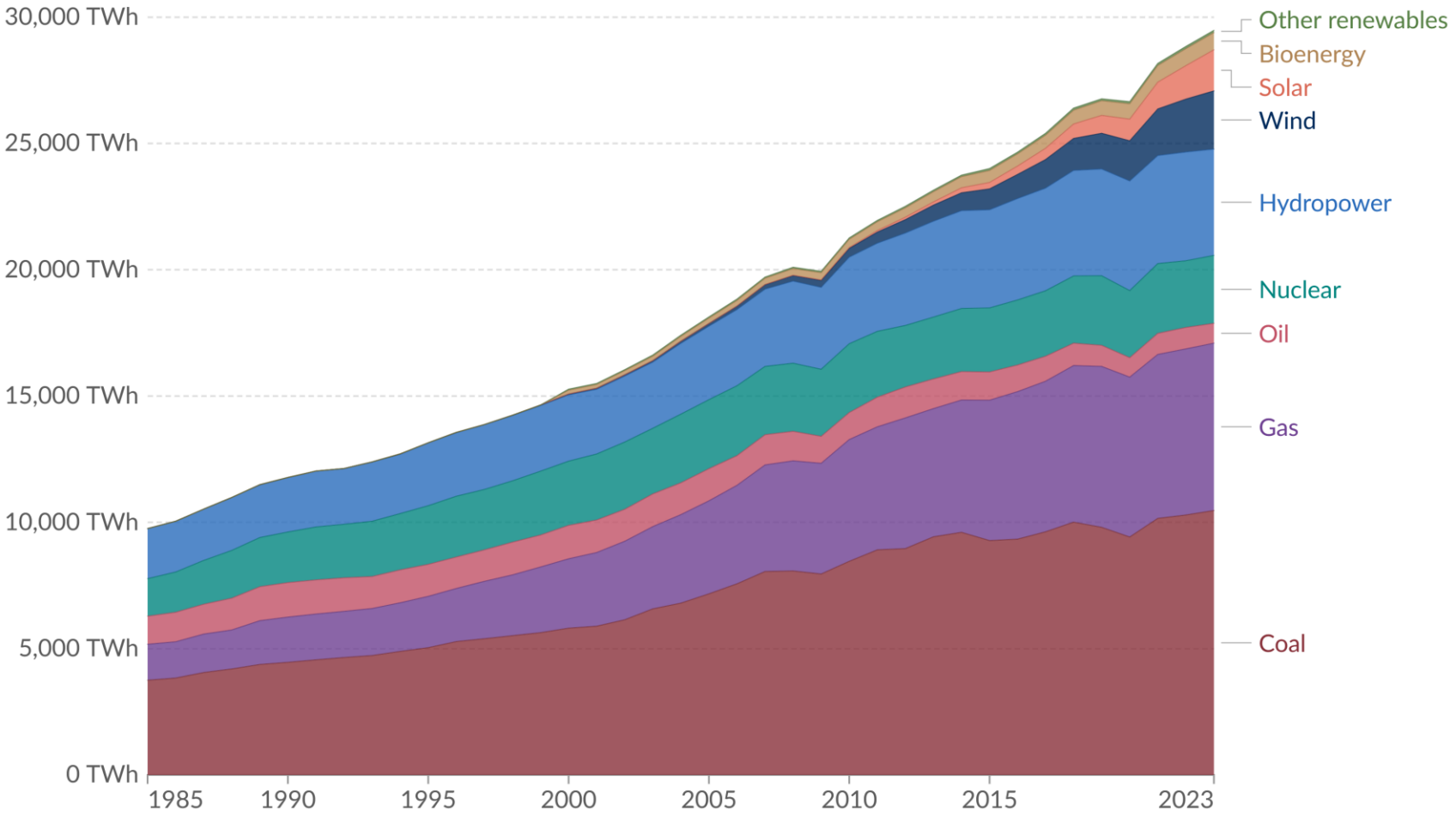
Electricity – THE universal technology for providing energy services

WORLD-WIDE TREND IN ELECTRICITY CONSUMPTION



Electricity production by source, World

Measured in terawatt-hours[1].

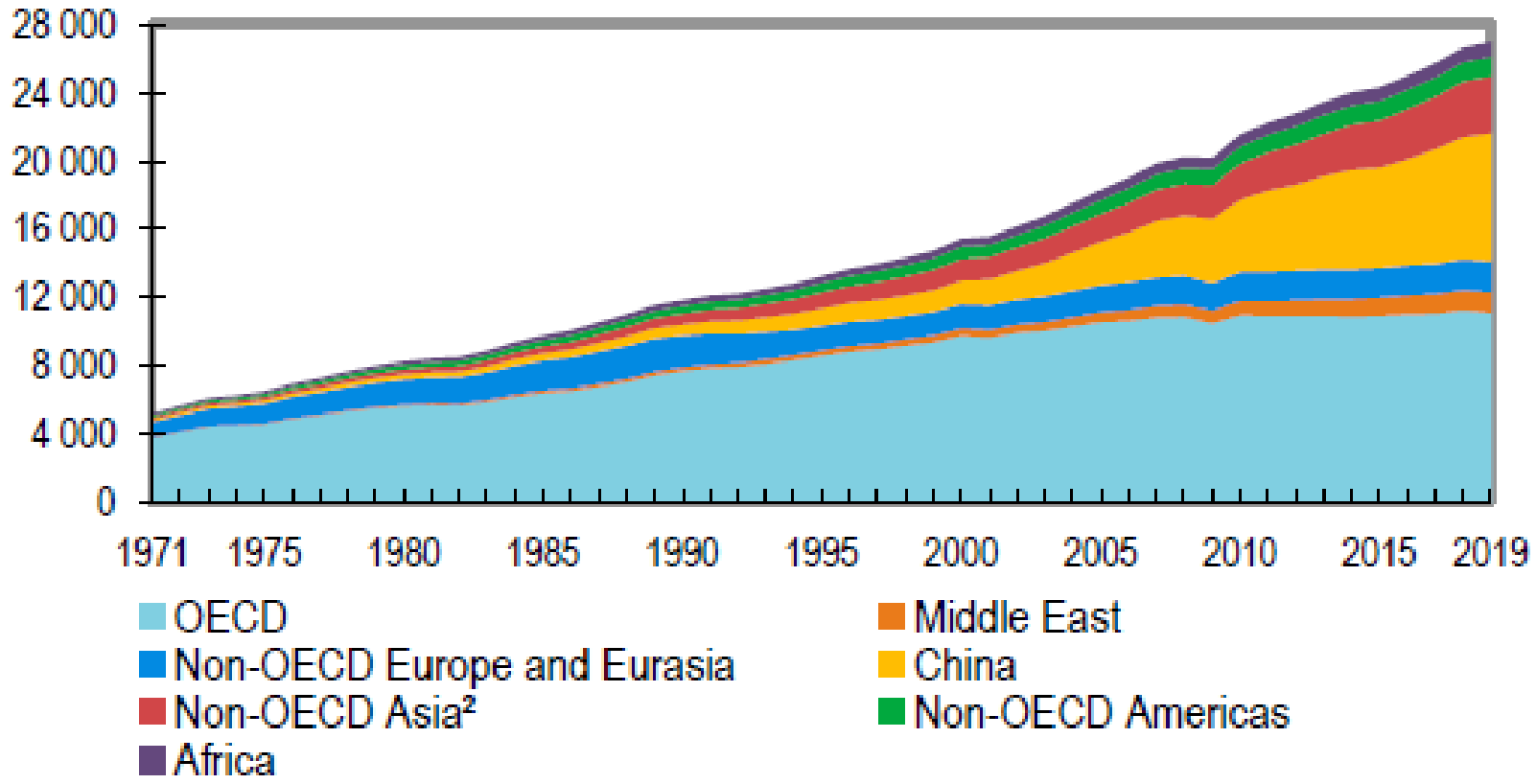


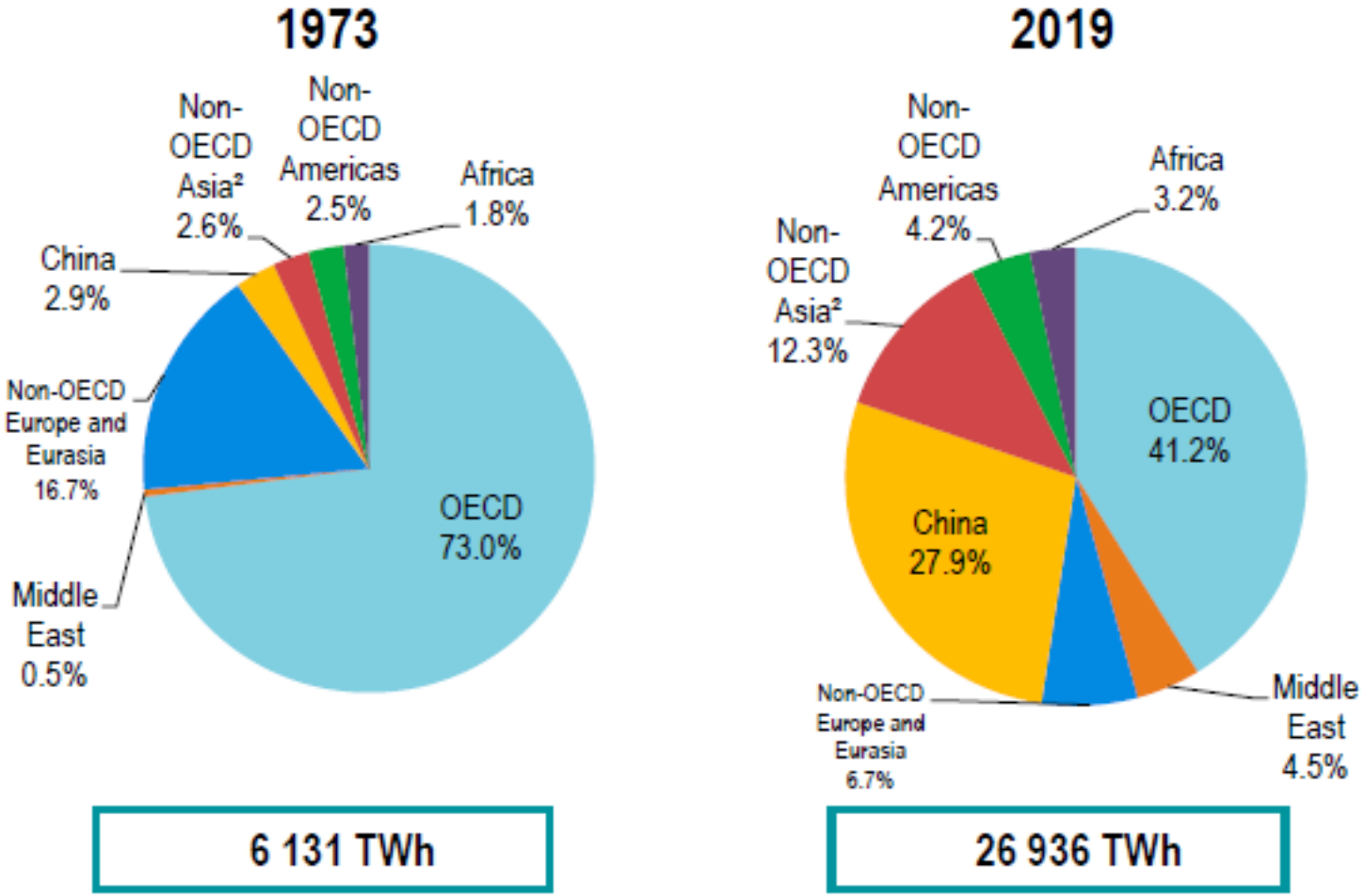
Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2024)

Note: "Other renewables" include waste, geothermal, wave, and tidal.

OurWorldinData.org/energy | CC BY

World electricity generation[1] by region, 1971-2019 (TWh)





1. Excludes electricity generation from pumped storage.
2. Non-OECD Asia excludes China.

Sources: IEA, World Energy Balances, 2021; IEA, Electricity Information, 2021.

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:

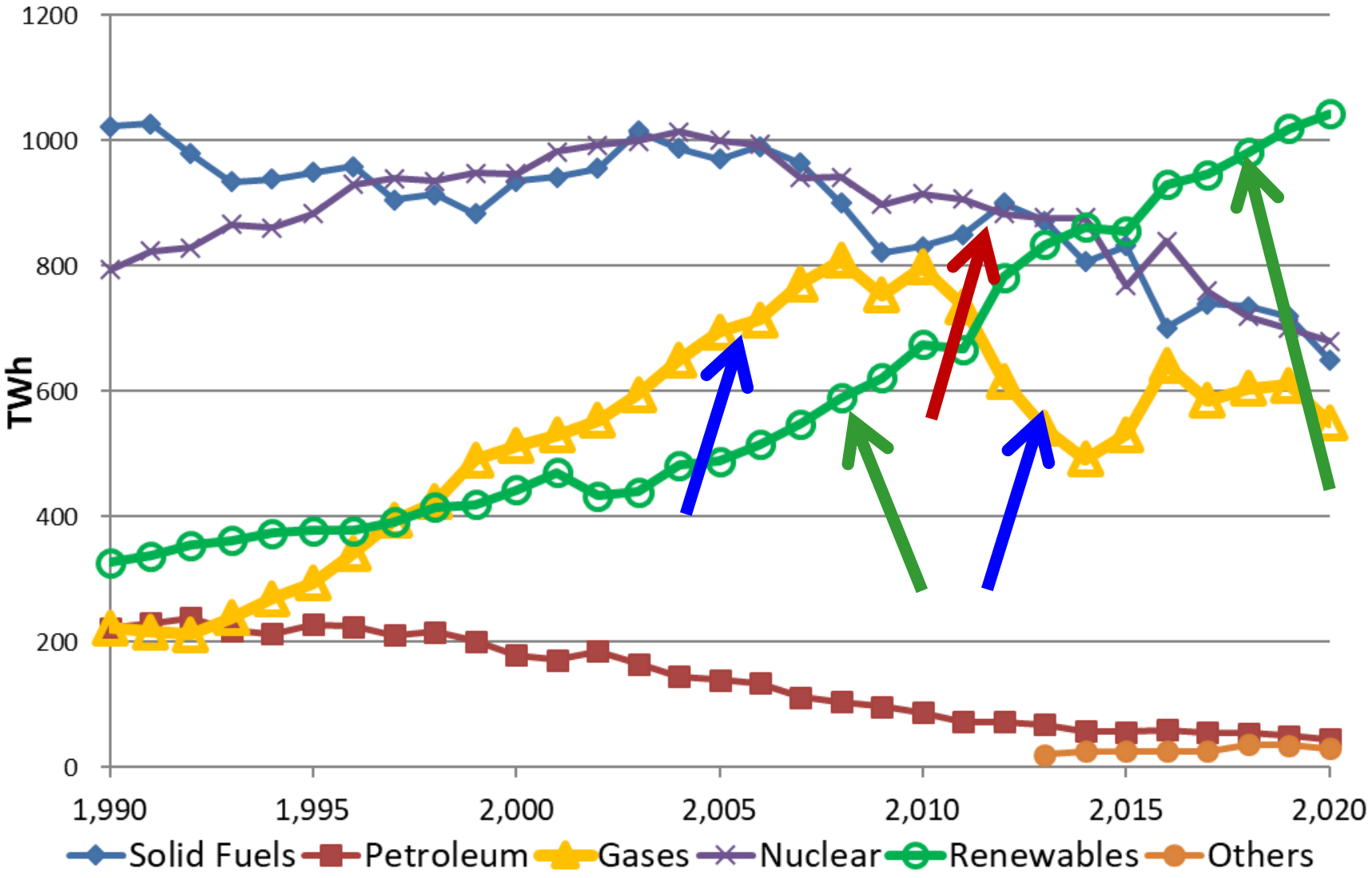
Boost renewable energy investments

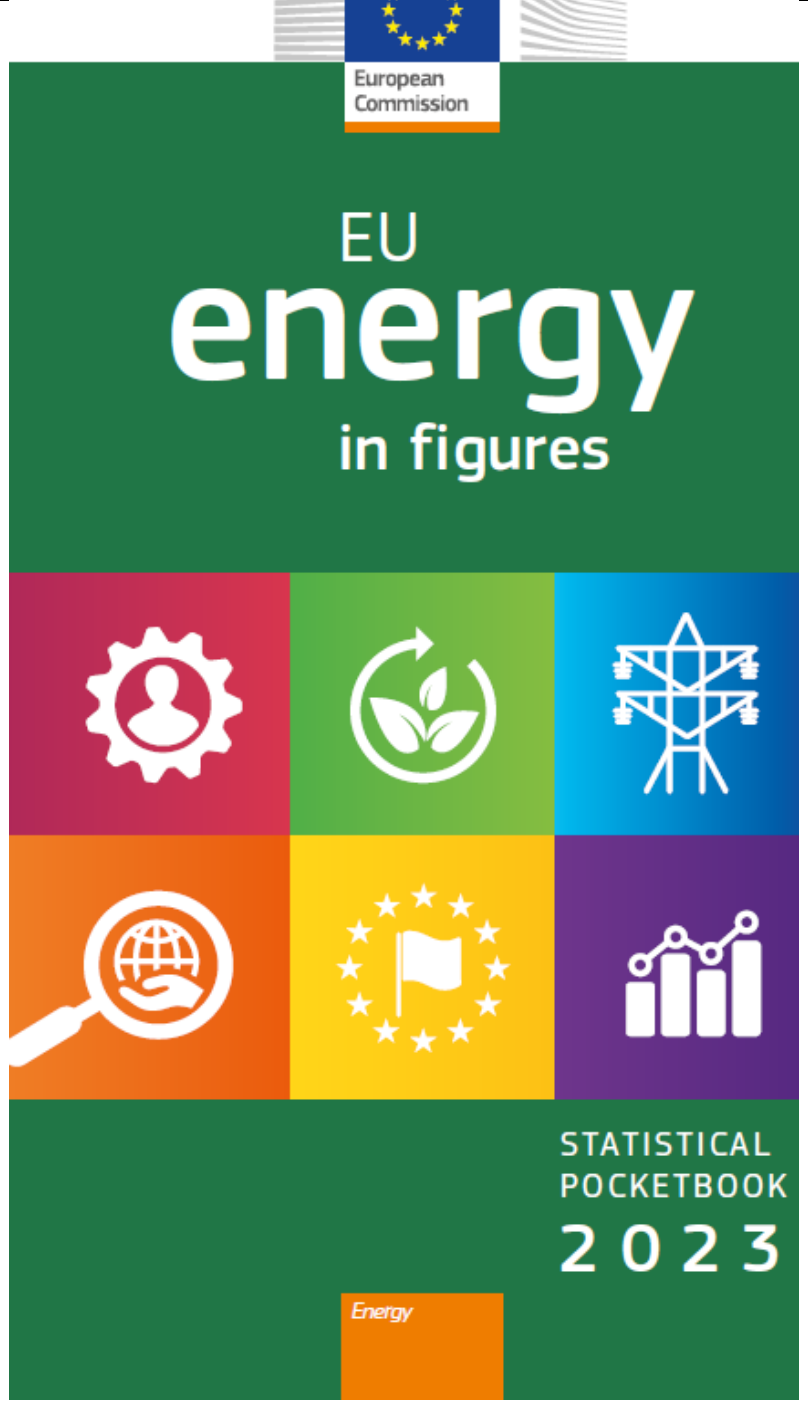
Better protect and empower EU consumers

Enhance the competitiveness of EU industry

European Commission

Electricity generation EU-28




European Commission
EU
energy
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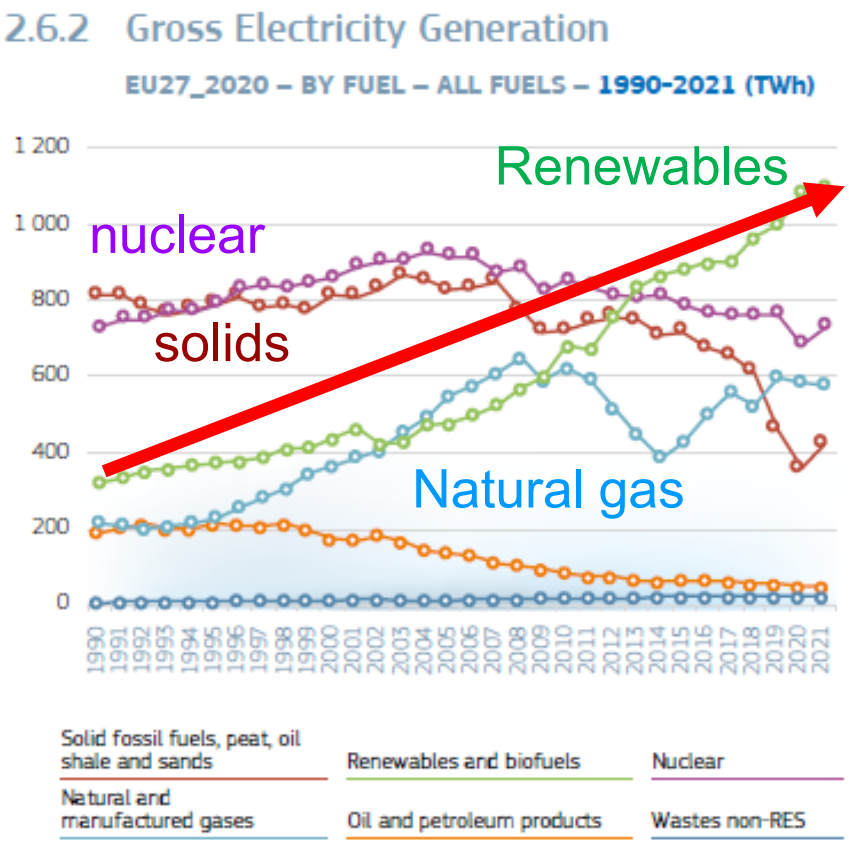
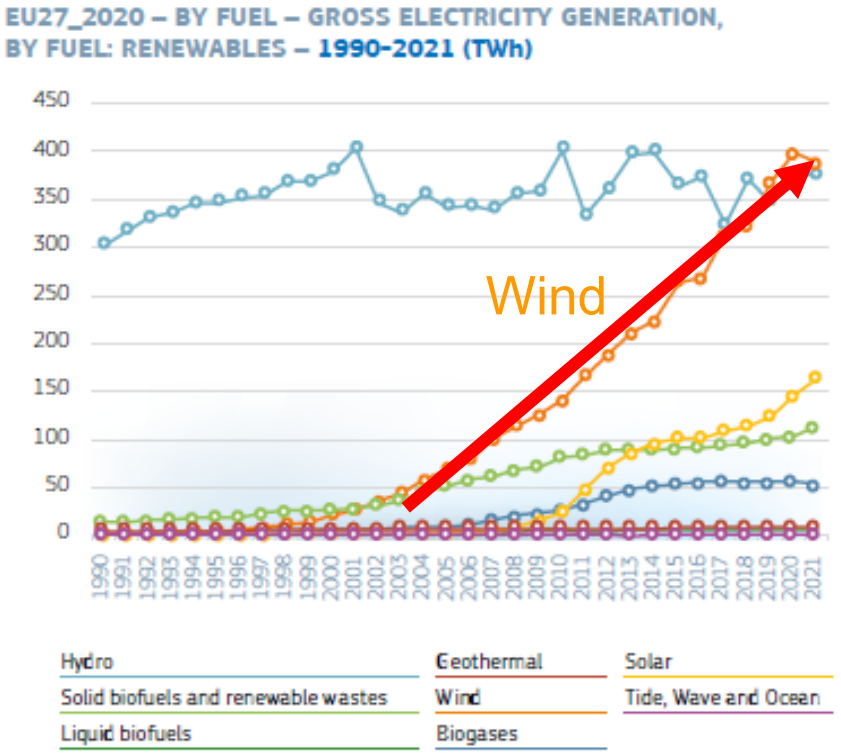
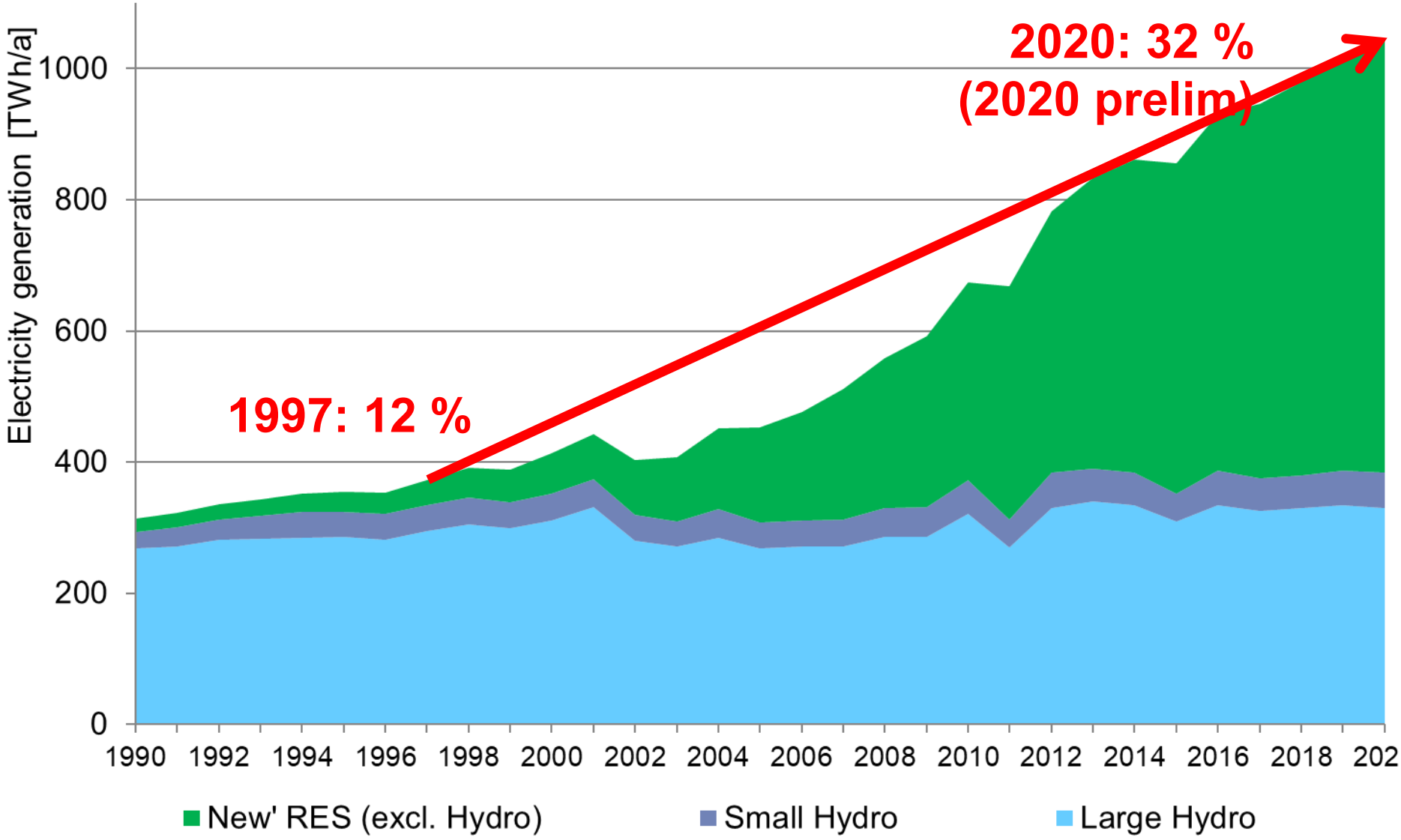
STATISTICAL
POCKETBOOK
2023
Energy

Electricity generation EU-27





Electricity generation RES EU-28

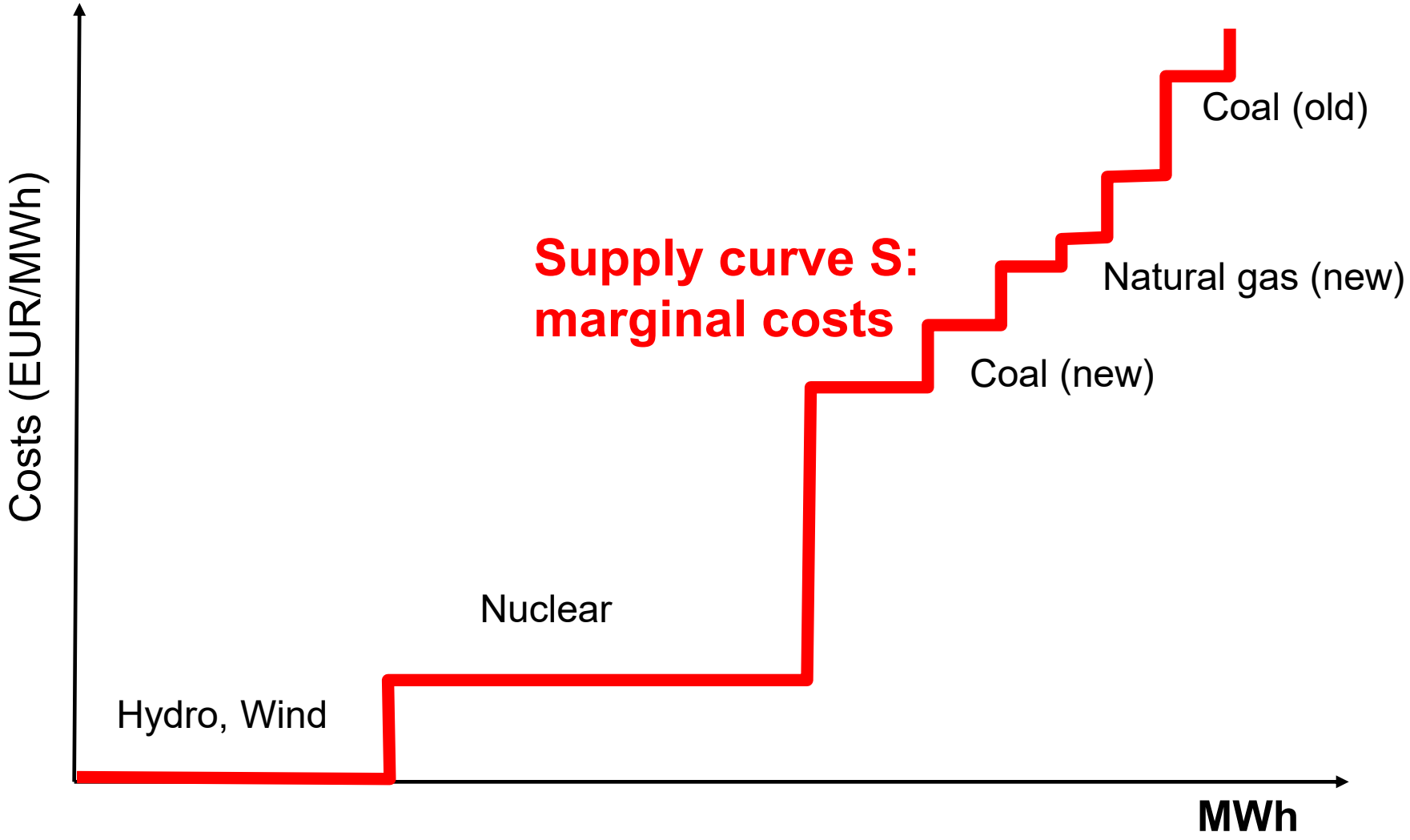


Source: EUROSTAT, own estimations

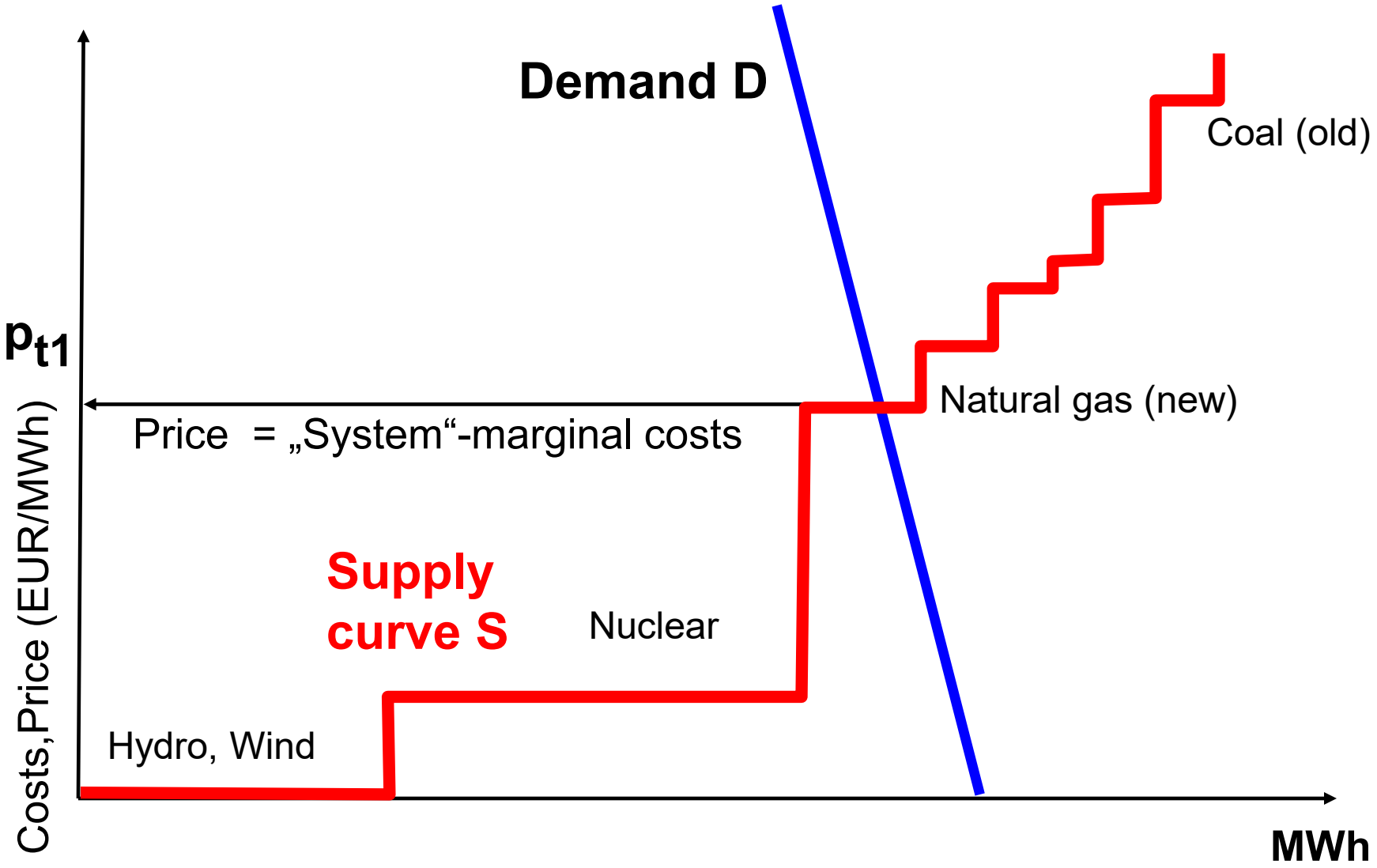
2. How prices come about

THE *MERIT-ORDER* CURVE OF SUPPLY

based on short-term marginal costs (MC)



BASIC PRINCIPLE OF COMPETITION: PRICE = MARGINAL COSTS



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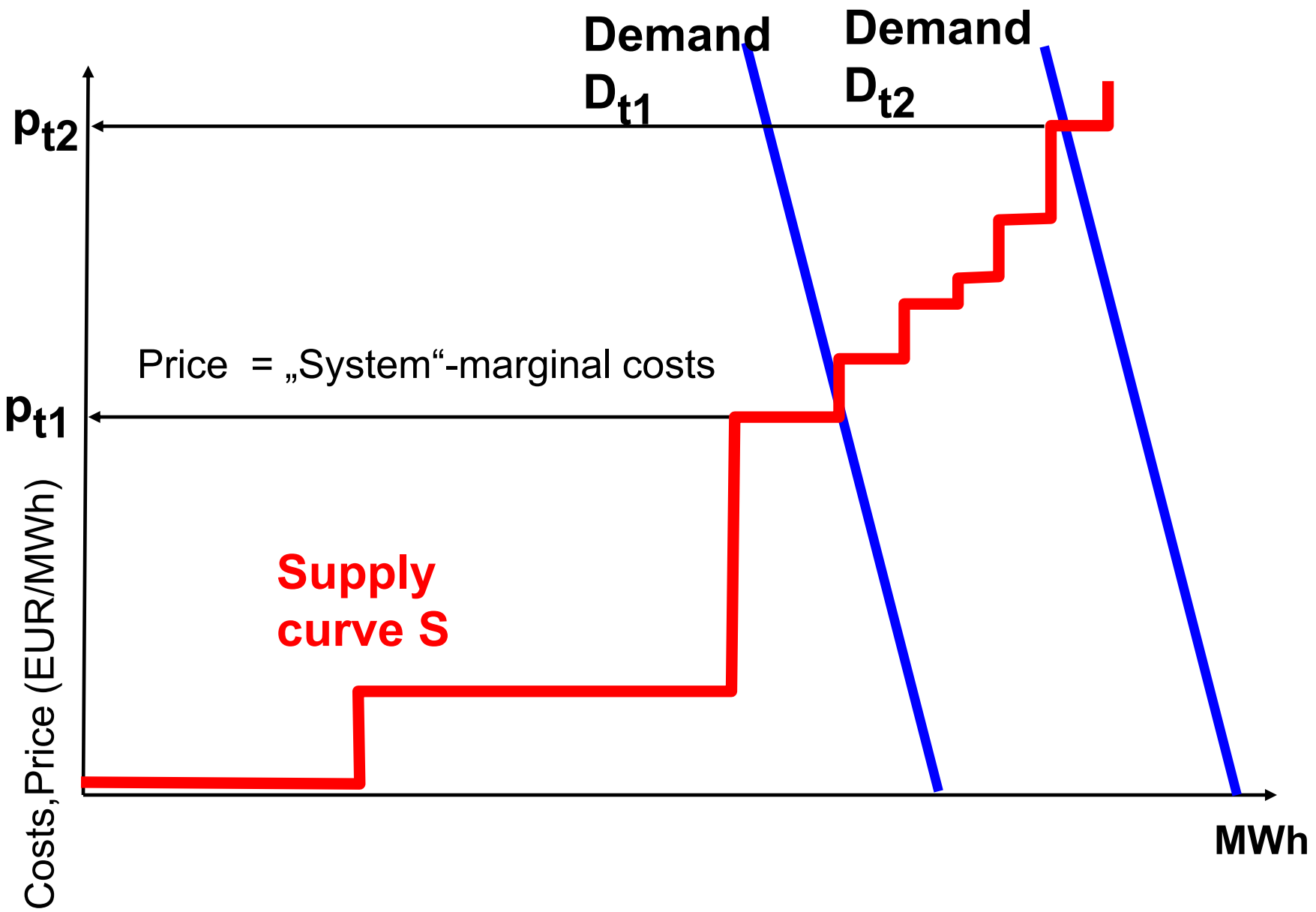
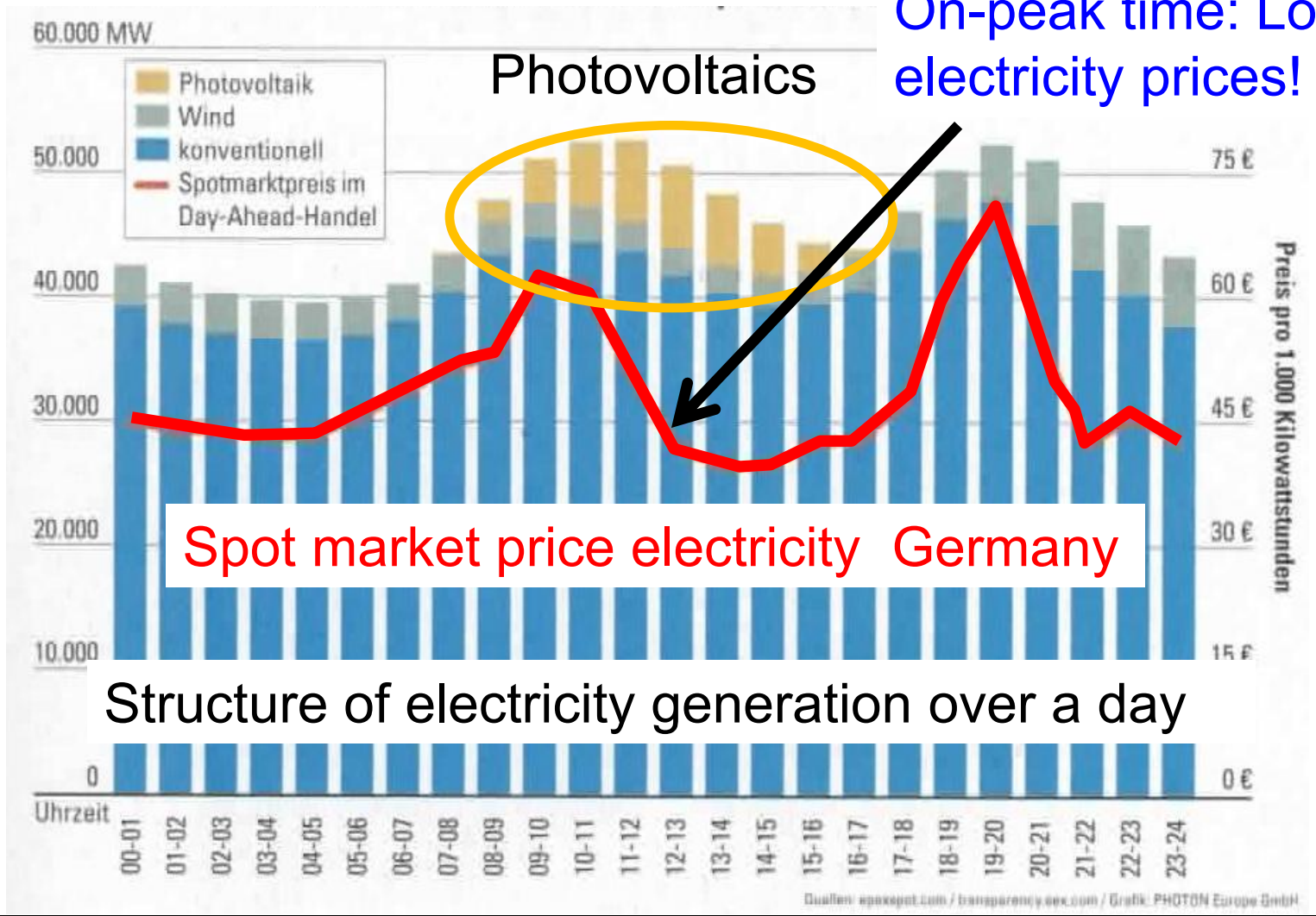


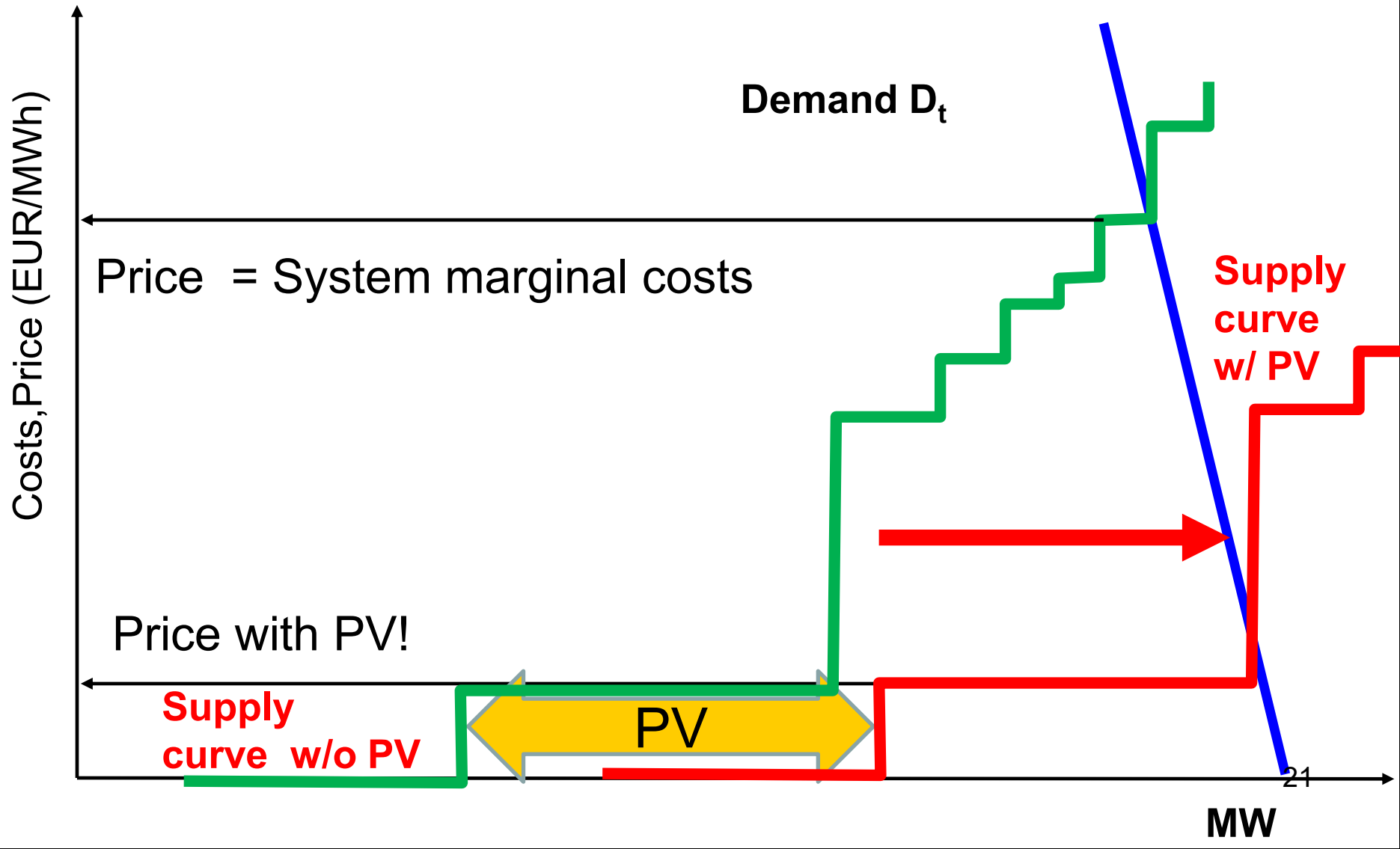
PV AFFECTS THE ELECTRICITY MARKET PRICE IN GERMANY



WHY?

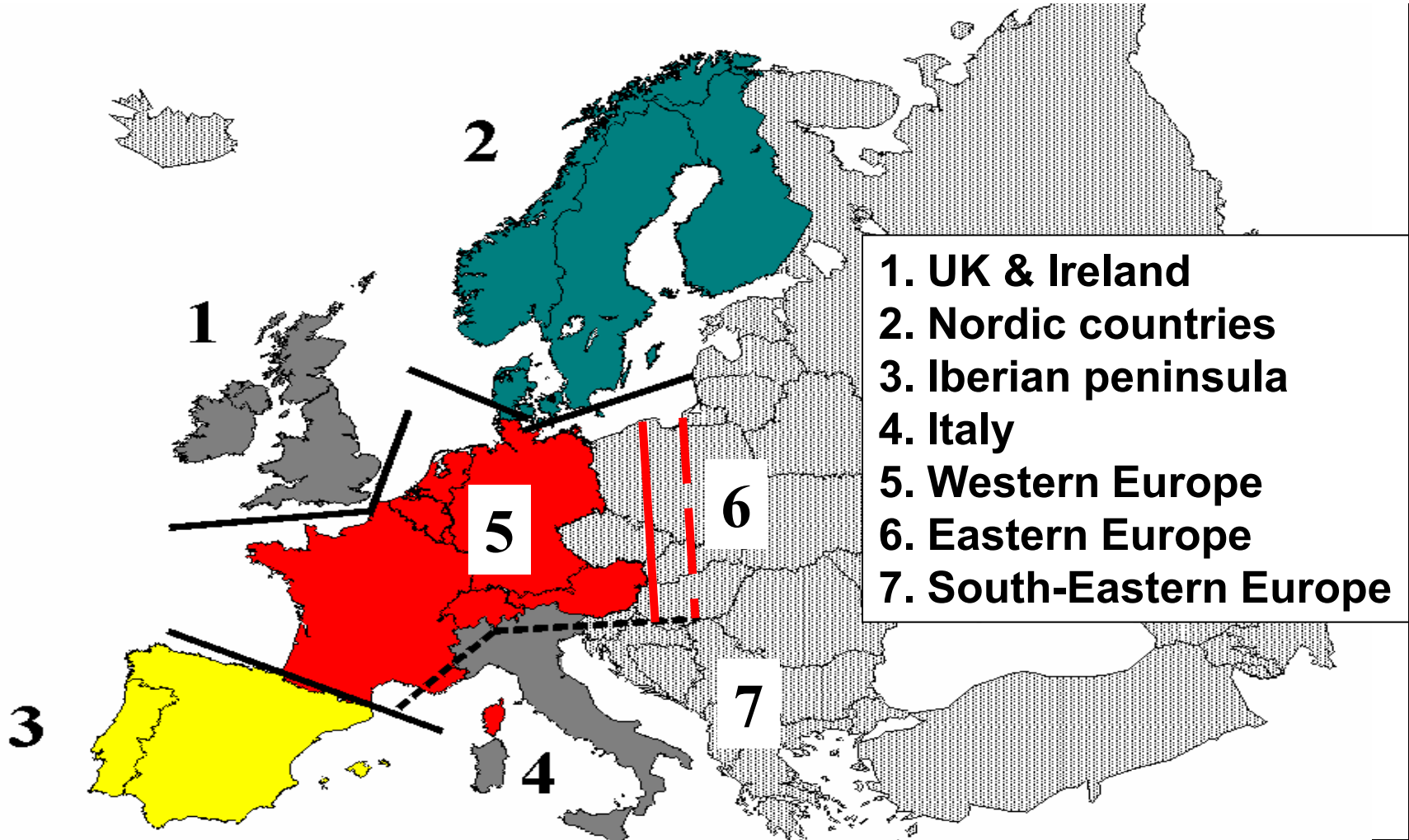
STMC = 0!

Example: prices without and with PV

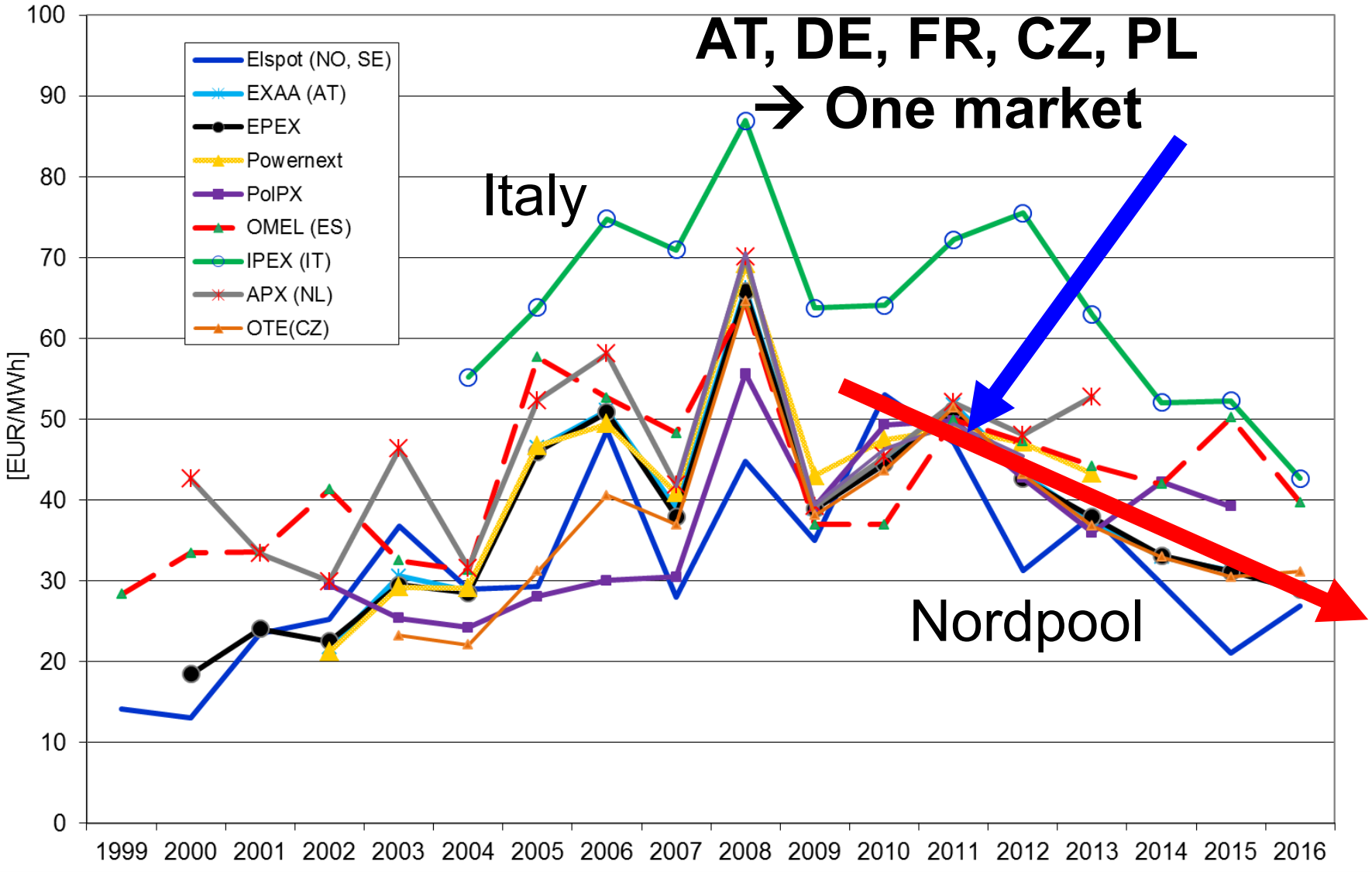


3 HOW PRICES DEVELOPED IN EUROPE

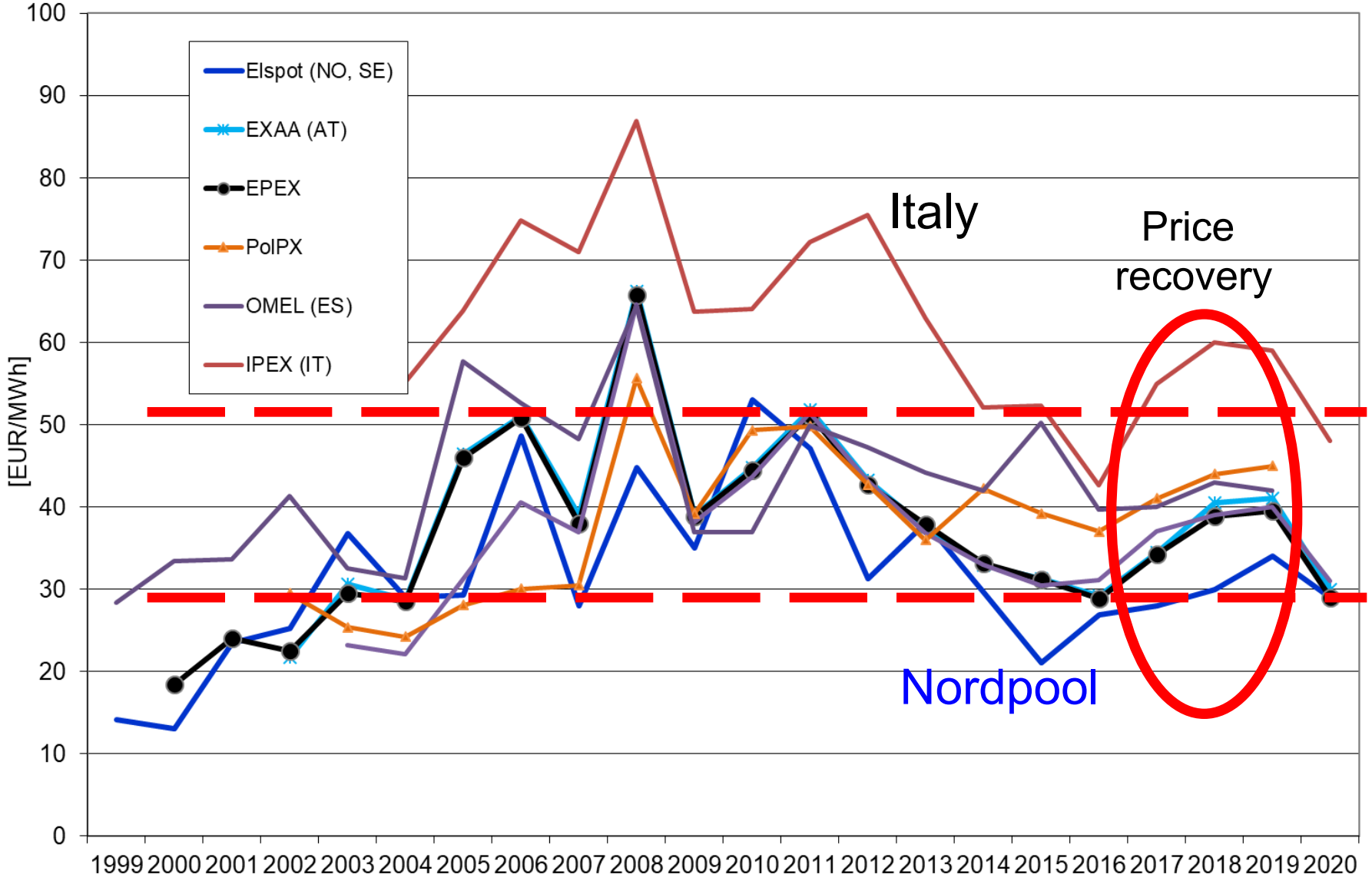
EUROPEAN ELECTRICITY SUB-MARKETS

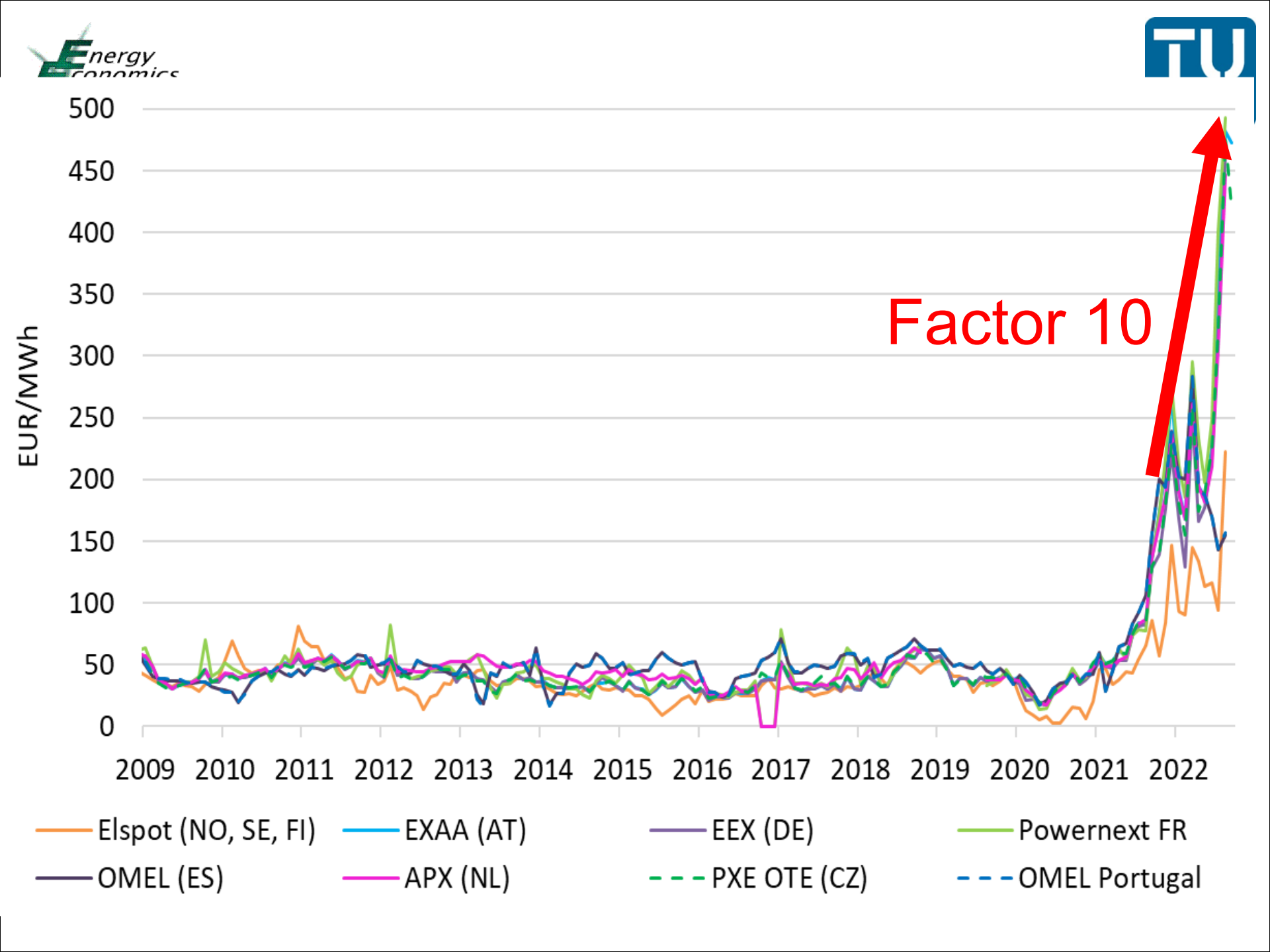


Development of day-ahead electricity prices in Europe per year (1)



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



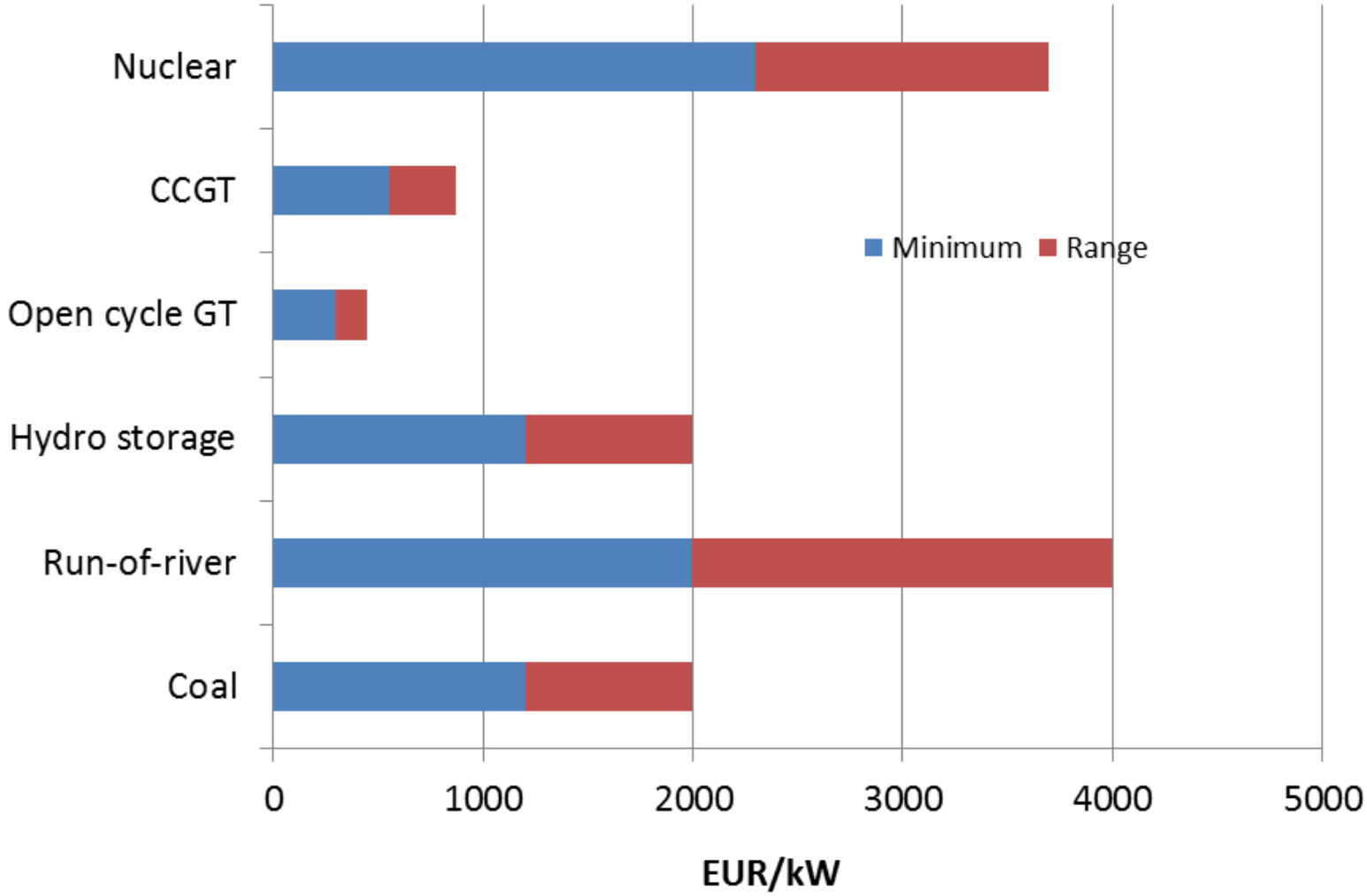

Energy Economics
500
450
400
350
300
250
200
150
100
50
0
EUR/MWh
Factor 10
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Elspot (NO, SE, FI)
EXAA (AT)
EEX (DE)
Powernext FR
OMEL (ES)
APX (NL)
PXE OTE (CZ)
OMEL Portugal

Day-ahead electricity prices in Europe

WHAT ARE IMPORTANT IMPACT PARAMETERS ON ELECTRICITY PRICES AND COSTS?

Investment costs

Electricity generation Conventional 2018



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.

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346 €/MWh !!!

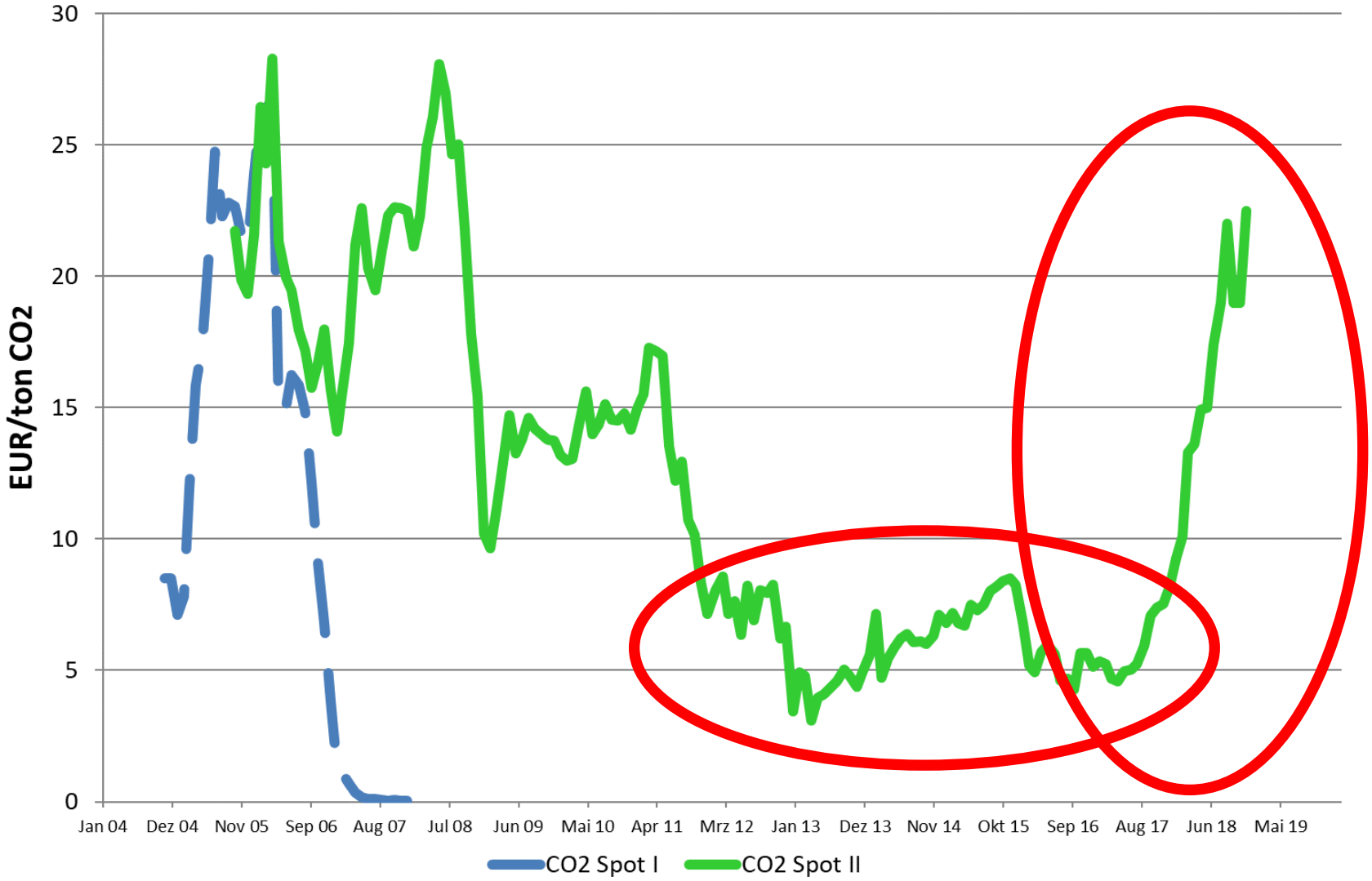
Price of Dutch T.T.F. natural gas, the European benchmark

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

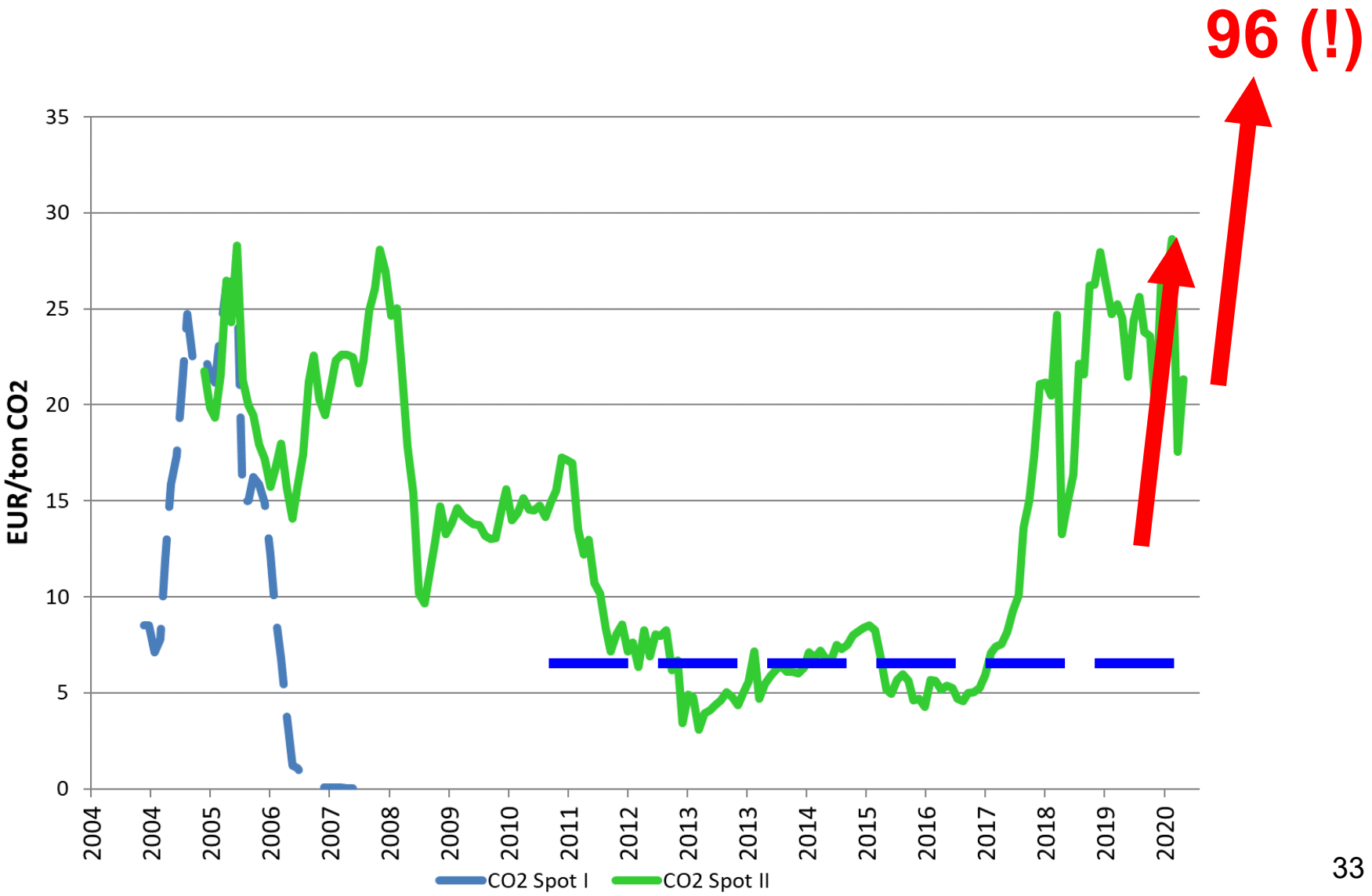
- NATURAL GAS;
- ELECTRICITY PRICES
- CO2 CERTIFICATES

4 ENVIRONMENTAL ASPECTS – THE CO2-PRICE

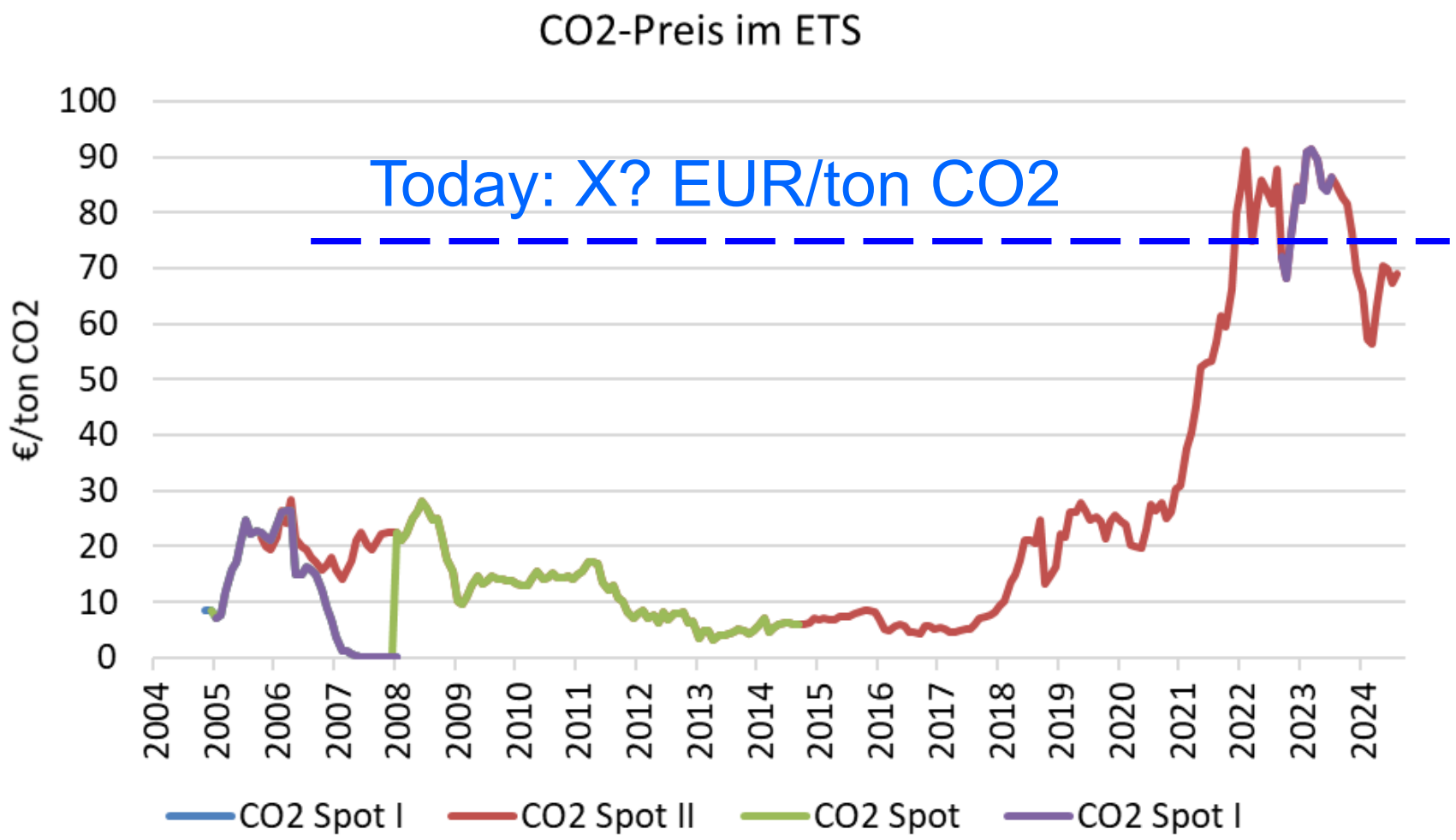
The CO2-Price



Development of CO2 prices in Europe



The CO2-Price



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)

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

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

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

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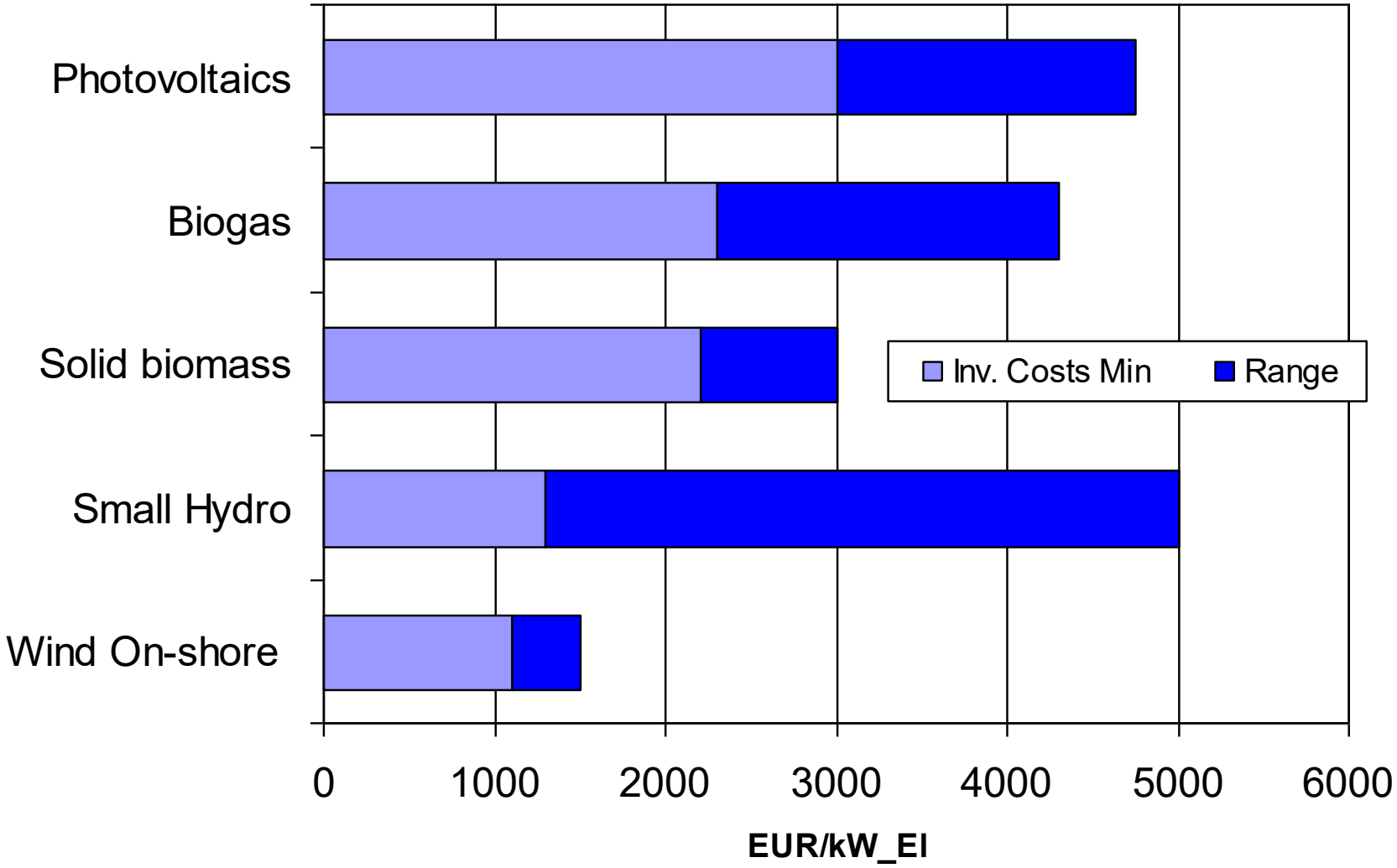
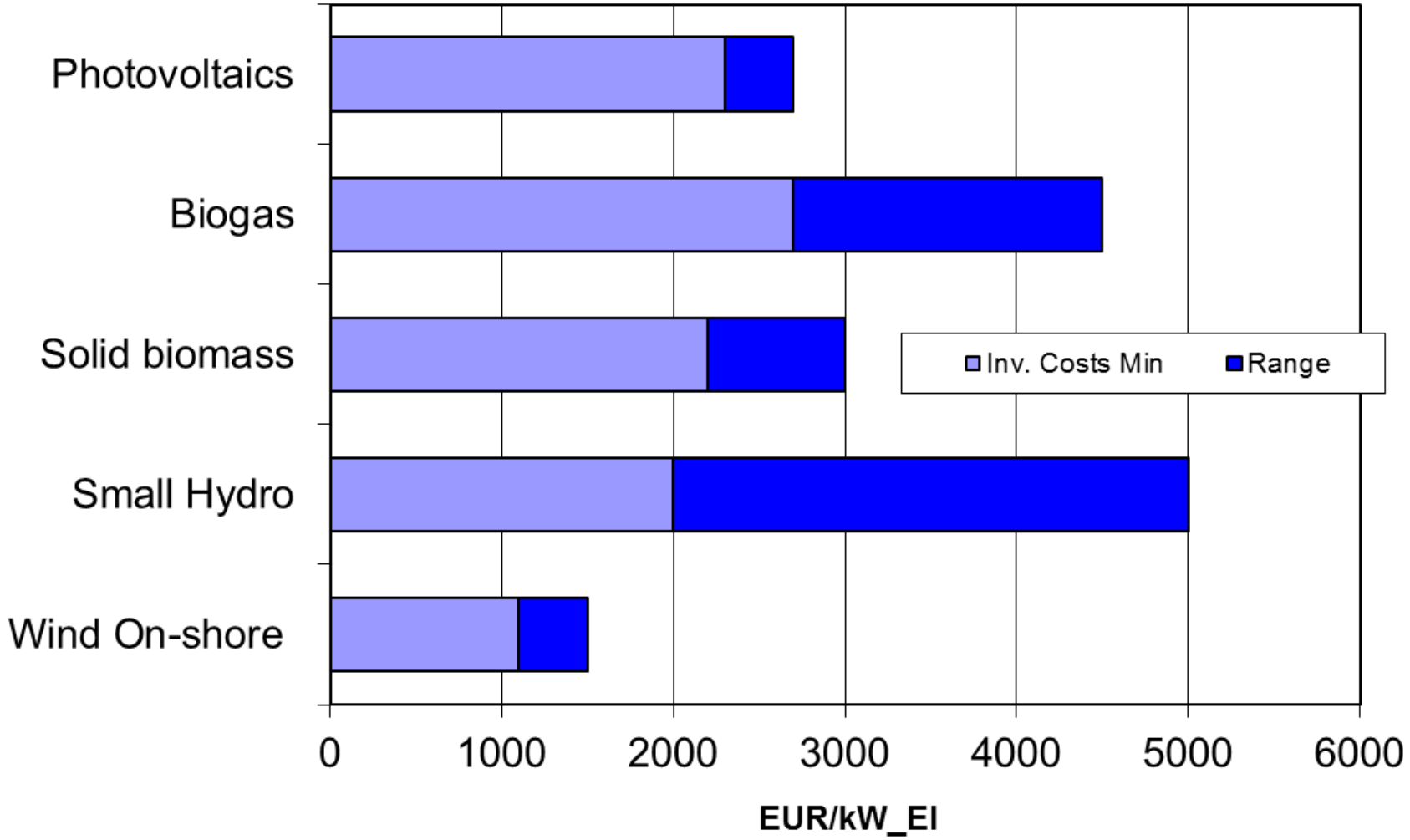
Investment costs

Electricity from new renewables 2010



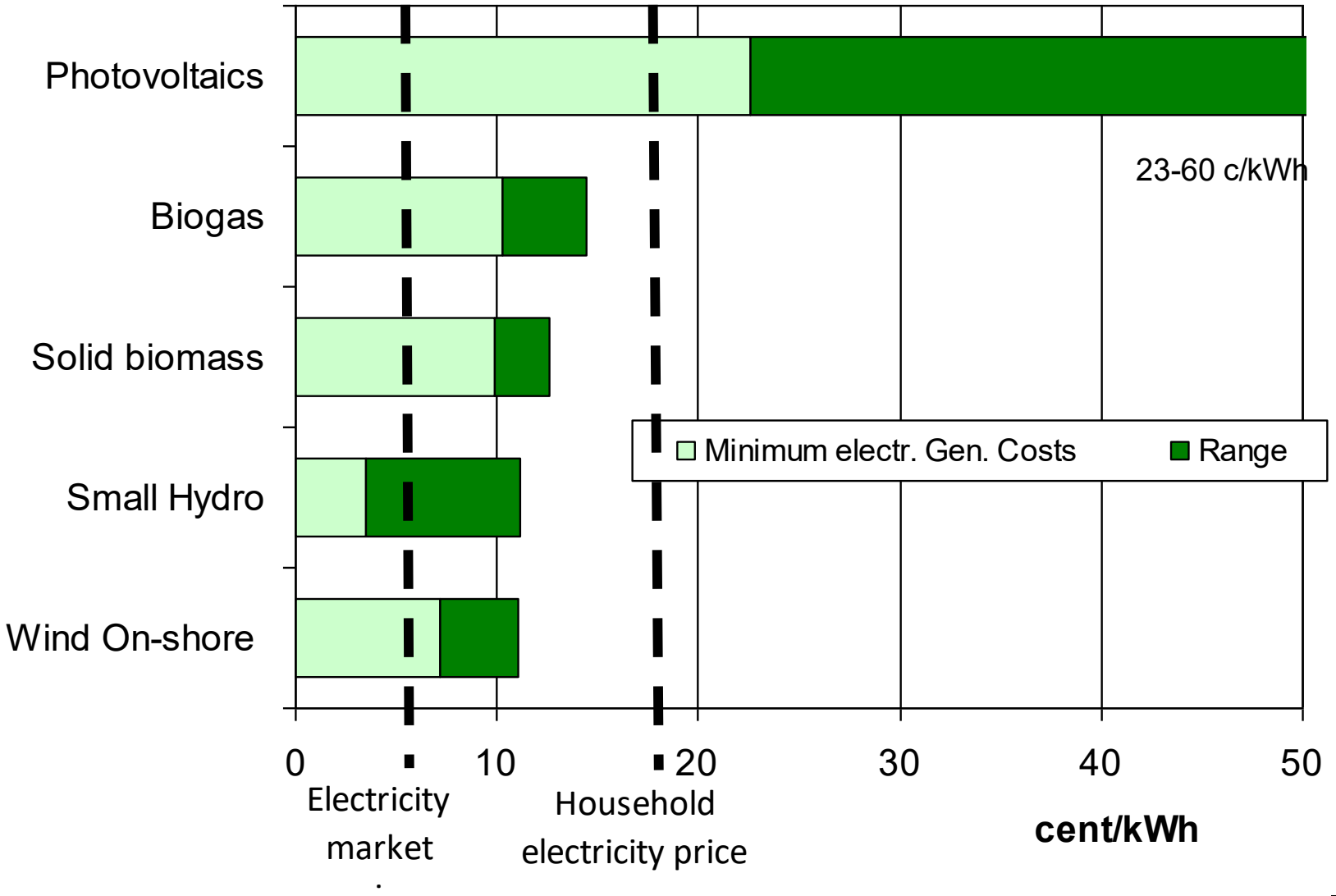
Investment costs

Electricity from new renewables 2020



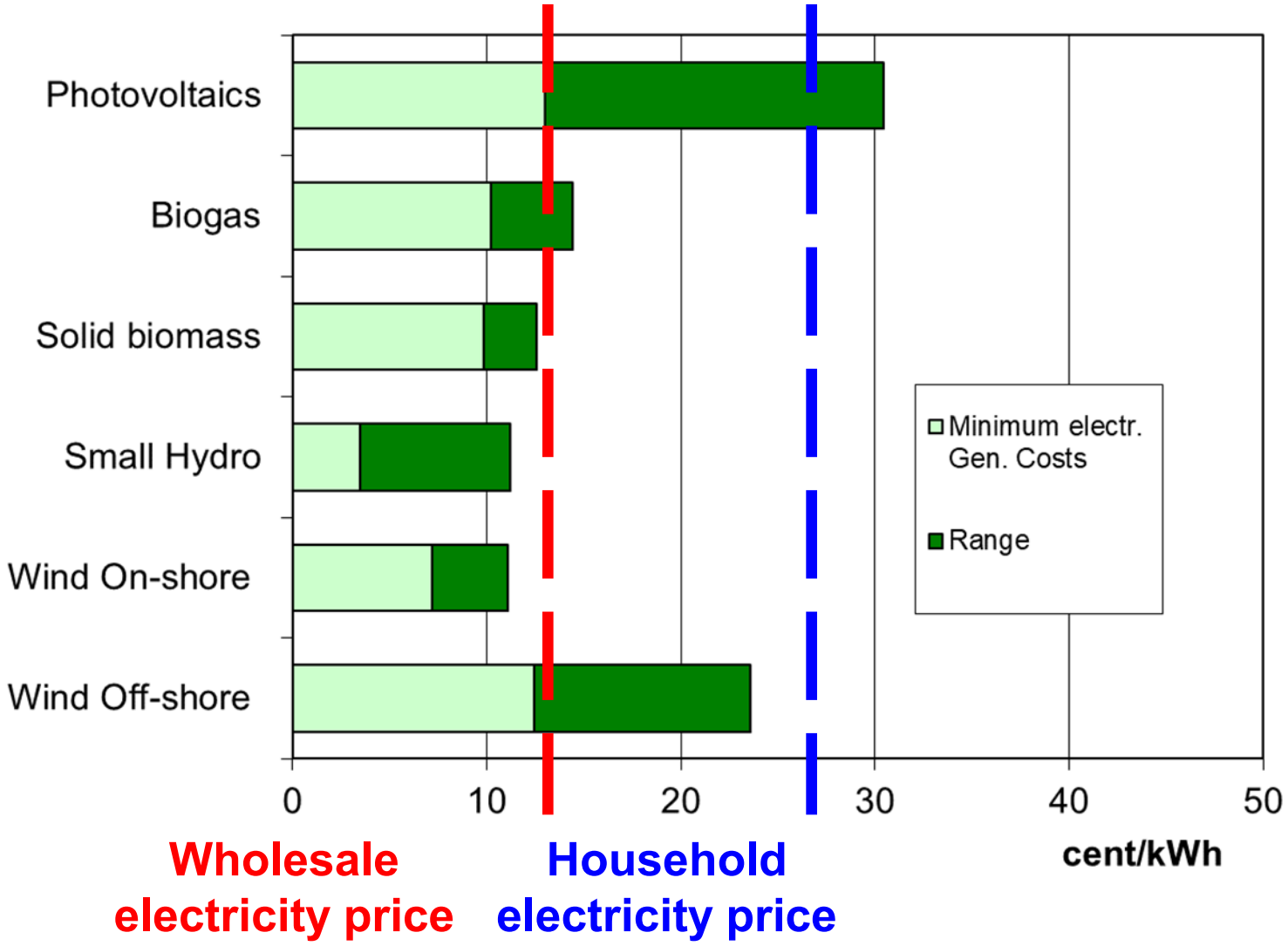
Generation costs

Electricity from new renewables 2010

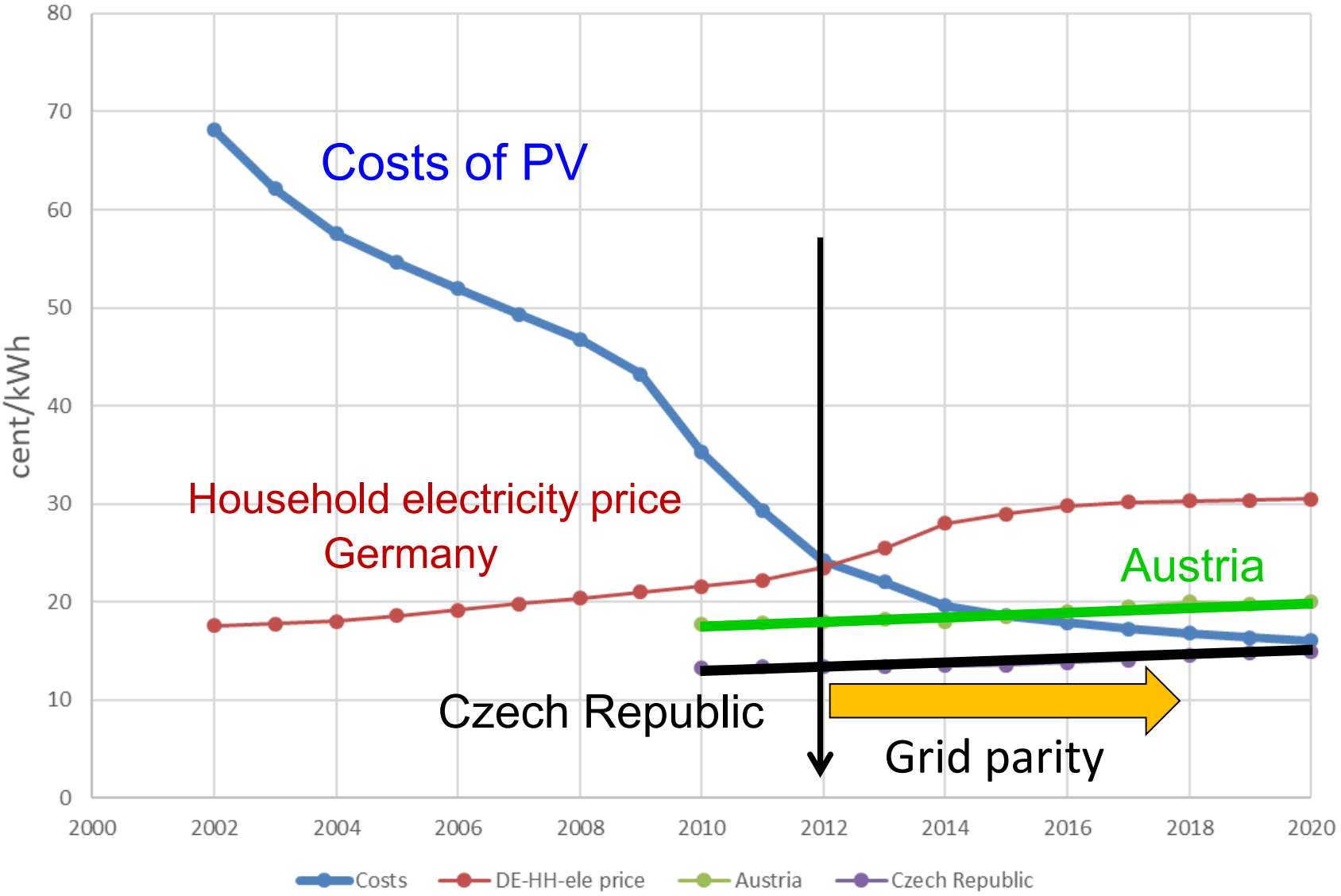


Generation costs

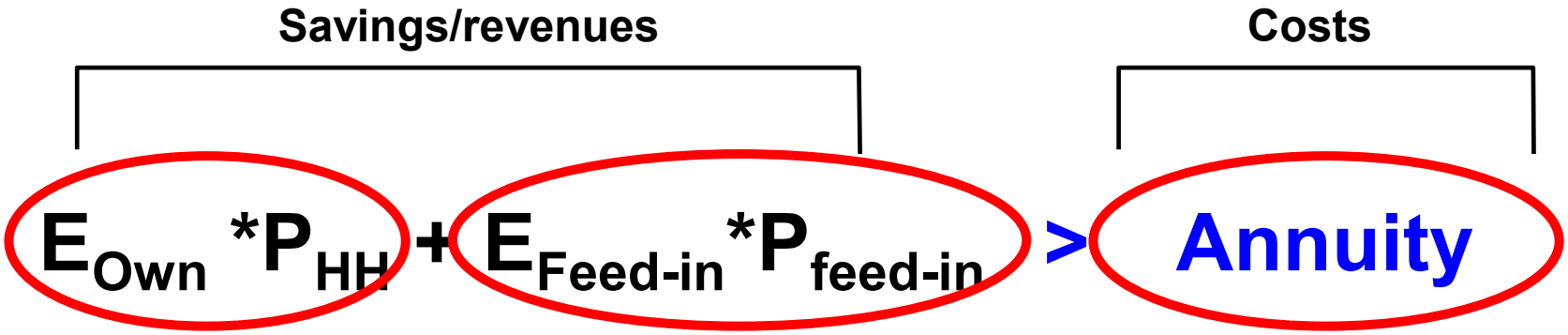
Electricity from new renewables 2023



Grid parity: PV-costs and household electricity prices



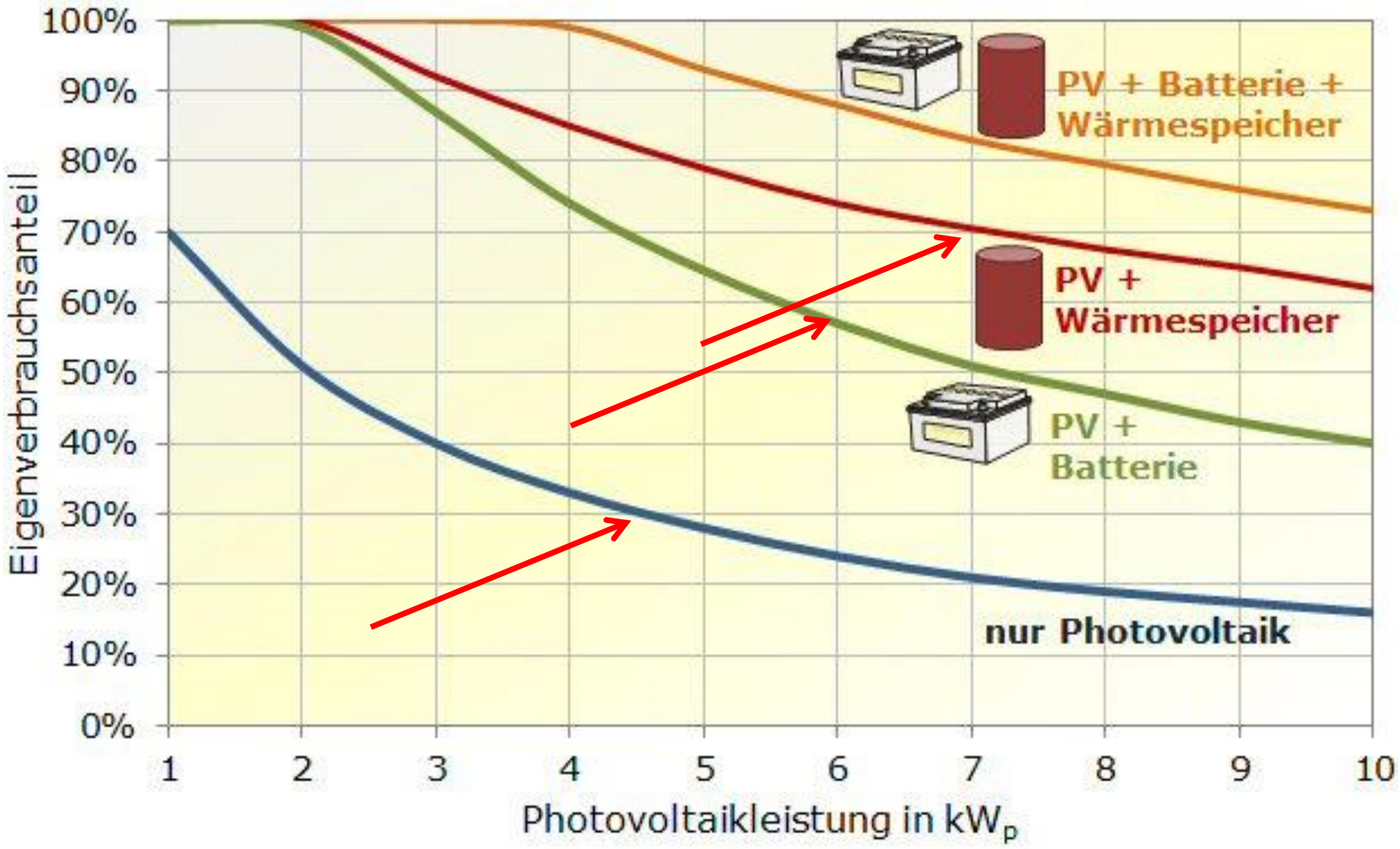
Assessment of Grid Parity



Grid parity term

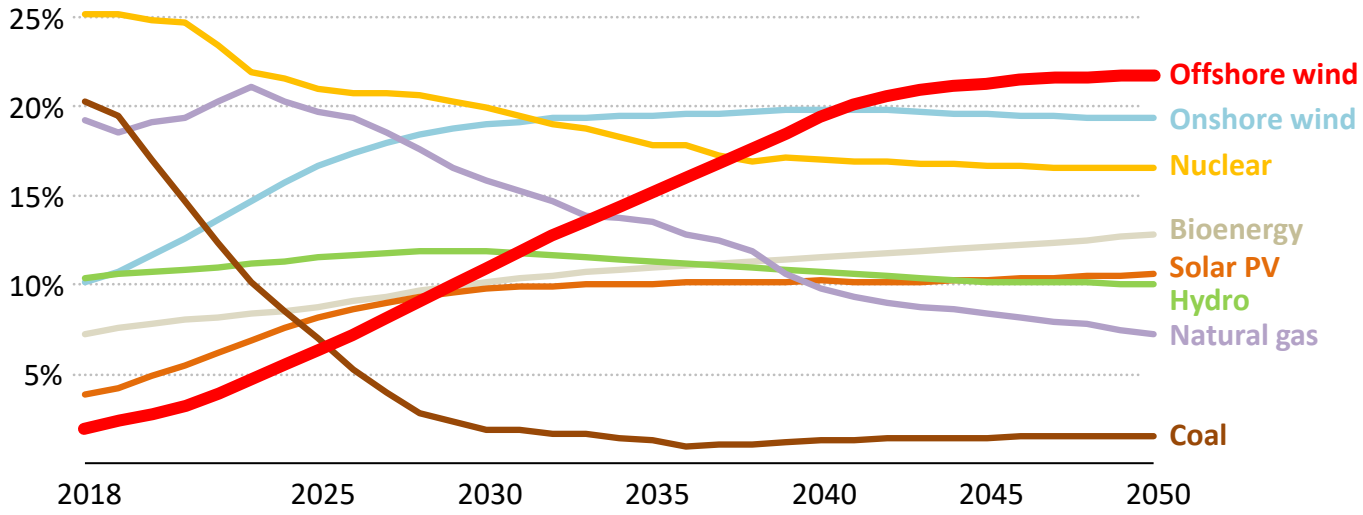
Subsidy still necessary?

Share of own consumption



A carbon neutral Europe puts offshore wind in front

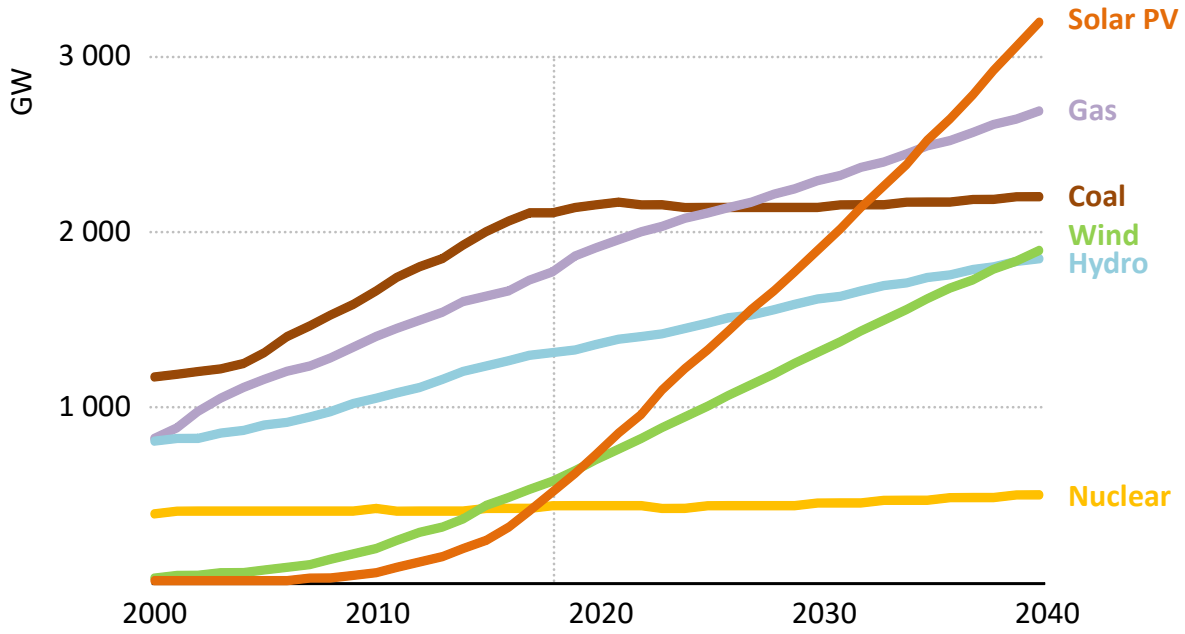
Shares of electricity generation by technology in the European Union, Sustainable Development Scenario



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.