

# 02 Measuring Energy

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# Measuring Energy

- Literature:
  - Bhattacharyya, S.C., 2011. *Energy Economics: Concepts, Issues, Markets and Governance*. Springer London, London.
  - Chapters 2 and 13

Measuring energy

# **FROM DATA TO INFORMATION**

# *What is energy?* recap

- A *property* of objects meaning capability of doing work or being transferred elsewhere
- Most common heat, electricity, motive
- Units:
  - Energy: 1 [Watt hour] = 3.600 [Joule]
  - Power: 1 [Watt] = 1 [Joule per second]
- **Power** gives you what are you able to do
- **Energy** says what you have done already

# *What is energy?* recap

- Footnote

- Ton of Oil Equivalent [**toe**]  $\approx 42$  GJ

- Ton of Coal Equivalent [**tce**]  $\approx 29$  GJ

- Czech lignite at 10 to 20 [GJ.t<sup>-1</sup>]

- British Thermal Unit [**BTU**]  $\approx 1.05$  kJ

- **Quad**  $\approx 1,055$  PJ

- US Dep. of Energy meaning quadrillion of BTU

- Czech republic TPES 2014  $\approx 1.7$  PJ  $\approx 1.6$  Quads

# *What is energy?* recap

- Heat, light, motive force, chemical transformation etc.
- 2 thermodynamic laws
  - Mass and energy cannot vanish but transform
  - No 100% conversion – losses inevitable
- Primary x Secondary energy
  - Primary – directly from nature (oil, coal, wind, sun, nuclear...)
  - Secondary – derived from Primaries (electricity, gasoline...)

# *What is energy?* recap

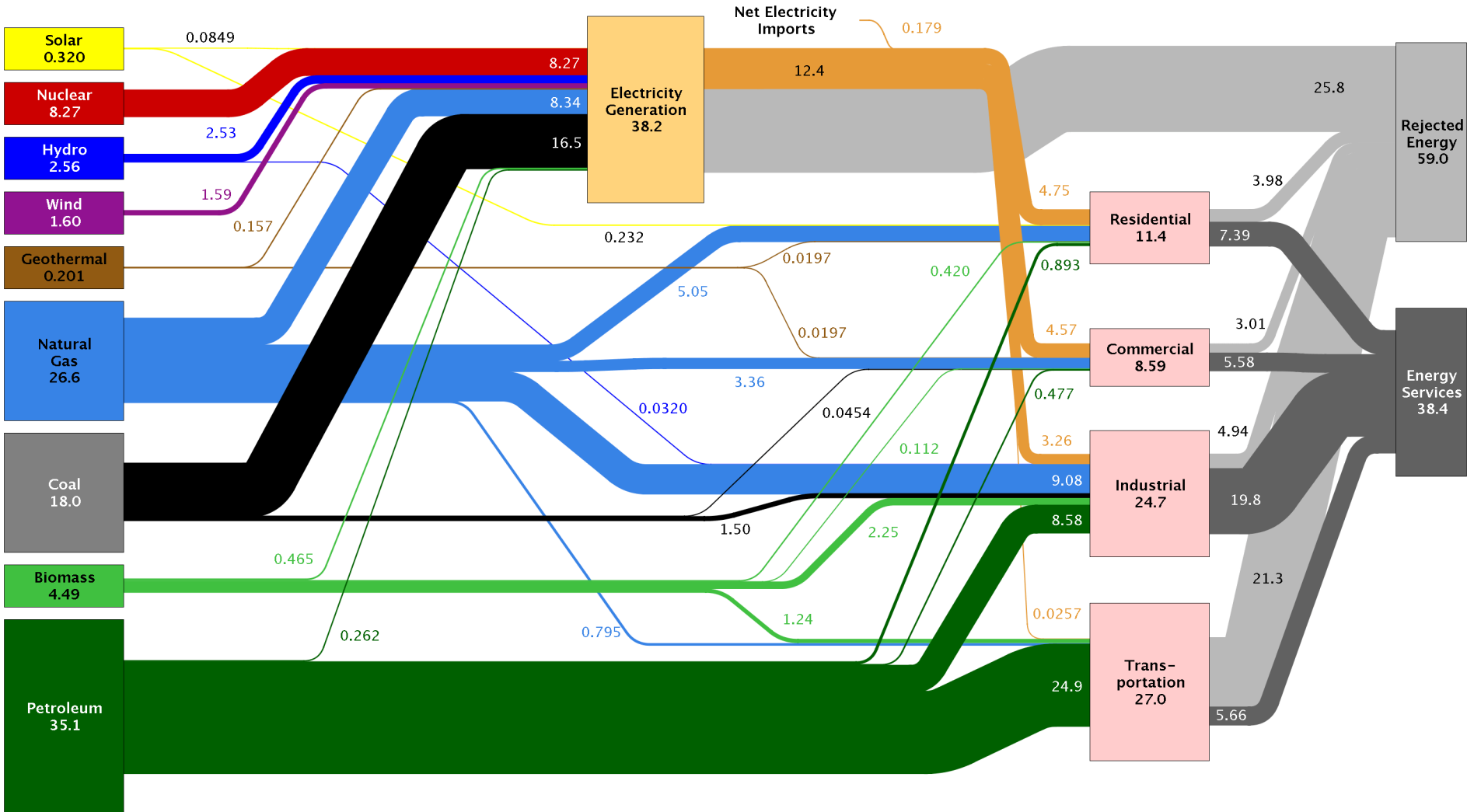
- Other divisions (boundaries change)
  - Renewable x Non-Renewable
  - Commercial x Non-Commercial
  - Modern x Traditional
  - Conventional x Non-Conventional

# Energy System

- Supply – Conversion – Consumption
- Extraction → PES → Transport → Final Energy  
→ End use app → Useful energy
- Losses
- Energy corporations all through the system →  
wide variety of companies



# Estimated U.S. Energy Use in 2013: ~97.4 Quads



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

# Energy Information

- Broadly required **data**:
  - Energy use by various economic activities
  - E production, transformation and delivery to various users
  - „Field“ technical and operating statistics
  - Financial and cost information
  - Macro-economic, social, political information

# Energy Information

- Transform into information about energy...
  - Pricing
  - Investment
  - Research & Development
  - System Management
  - Contingency Plan
  - Long-term Planning

# Energy Accounting Framework

- Comprehensive account of energy flows including losses and any consumption
- See table
  - Production – transformation – consumption
- Accounting units
  - Commodity (physical, tones, barrels...)
  - Overall **Energy** Balance (common unit, eg BTU, GJ, TOE...) – easier comparison

# Energy Accounting Framework

## Supply-side

Production (+)

Trade (import/export) (+/-)

Bunkers (transport costs, e.g. Tankers) (-)

Stock change (+/-)

Primary energy requirement (PER)

## Conversion

Statistical difference (+/-)

Transformation input (-)

Energy sectors' own use (-)

Transmission and Distribution losses (-)

Net supply available

## Net domestic consumption

Final energy consumption

↳ Agriculture

↳ Industry

↳ Transport

↳ Residential

↳ Commercial

↳ Non-energy uses

- Total energy needed to satisfy country's demand and transformation requirements
- Primary need (shown in TPES)
- Efficiency indicator
- Sectorial situation may be analyzed

# Energy Accounting Units - Example

**Tab – A lignite surface mine yearly consumption decomposition**

Consumer	TJ	kt	GJ/t	Share		ktce	ktoe
				TJ	kt		
PP Chvaletice	16 631	978	17,00	32%	33%	567	397
Refinery Litvínov	7 072	530	13,35	14%	18%	241	169
HP Otrokovice	4 523	274	16,51	9%	9%	154	108
Paperworks Mondi Štětí	4 358	180	16,70	8%	6%	149	104
HP Strakonice, a.s.	1 754	112	15,66	3%	4%	60	42
HP Třinec	1 698	106	16,00	3%	4%	58	41
HP Poříčí	789	47	16,79	2%	2%	27	19
PP Hodonín	446	27	16,63	1%	1%	15	11
Export	6 640	332	20,00	13%	11%	227	159
Retail	8 360	418	20,00	16%	14%	285	200
<b>Total/mean</b>	<b>52 271</b>	<b>3 004</b>	<b>17,40</b>	<b>100%</b>	<b>100%</b>	<b>1 784</b>	<b>1 248</b>

All units above are scientific – commercial units (eg TCE) might be not



# Lignite Surface Mine



# Useful Ratios

- Energy supply mix
  - Share of various sources on primary supply
- Self-reliance
  - What portion of energy is of domestic origin
- Share of renewables
- Power generation mix
- Efficiency
  - Electricity production
  - Refining
  - Overall
- Per capita consumption (primary and final)
- Energy intensity



# Some energy data issues

- Availability
  - lags, various sources, imprecision, confidentiality
- Quality
  - Different standards and methodologies, deliberate changes, trade and balance discrepancies
- Cross border comparison
  - Traditional fuels, terminologies, sectors definition, accounting
- Common measurement
- Conversion factors

Measuring energy

**AT WHAT PRICE?**

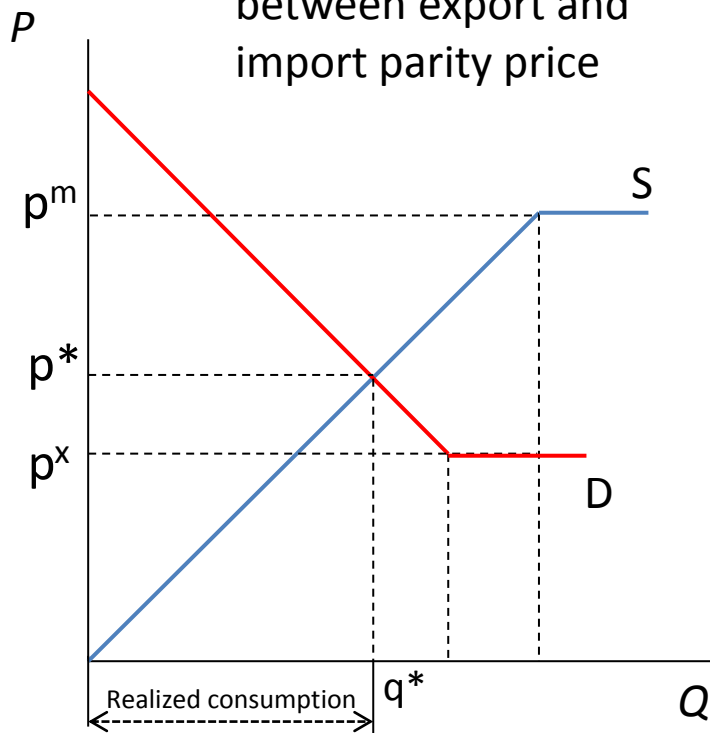
# Price - recap

- Price x value
- Price
  - Objective measurable figure
  - Result of supply/demand
  - Denotes *relative scarcity* of a good
- Value
  - Subjective, individual, not measurable
  - Depends on time, place and people
- Value of price is priceless

# Energy Pricing

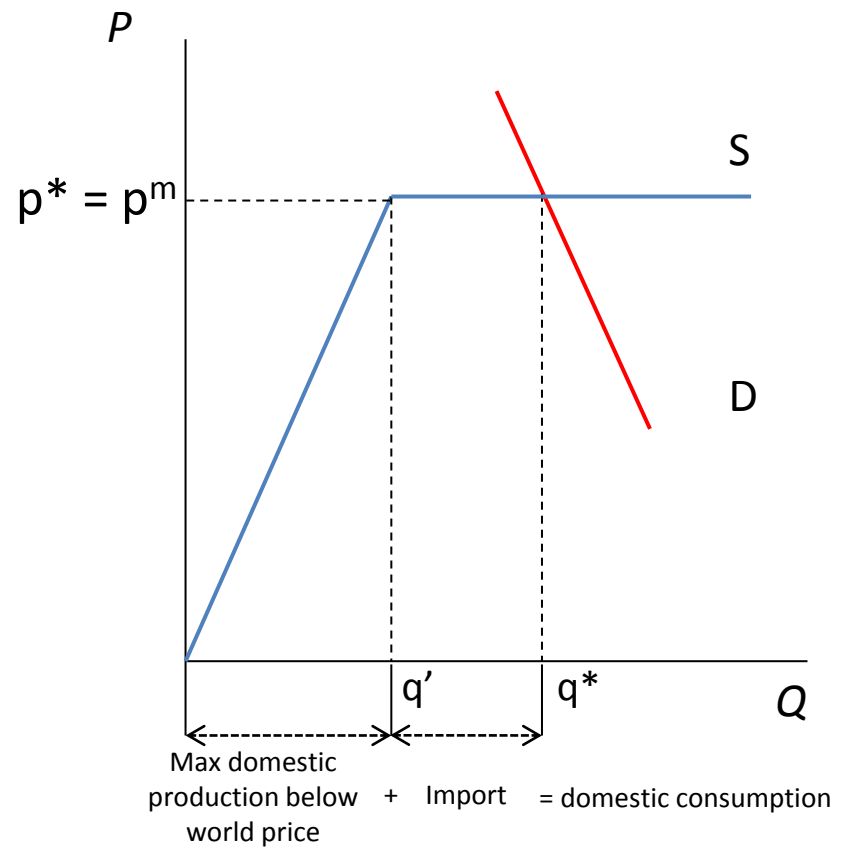
a) Self-sufficient country

- Price set domestically between export and import parity price



b) Importing country

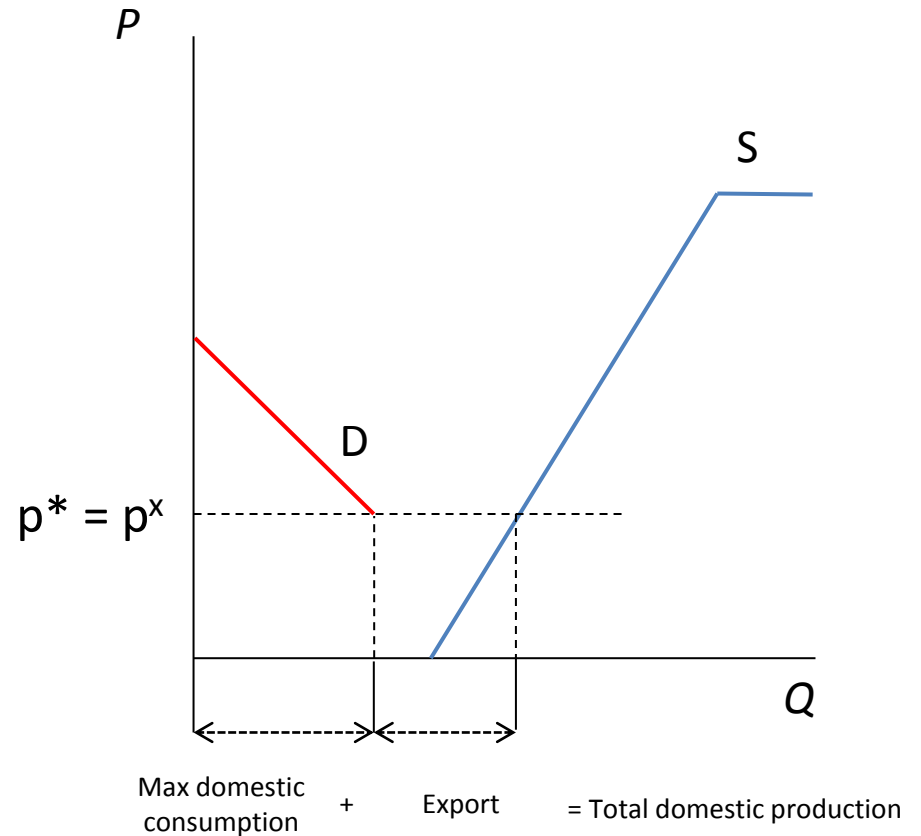
- Import (world) price



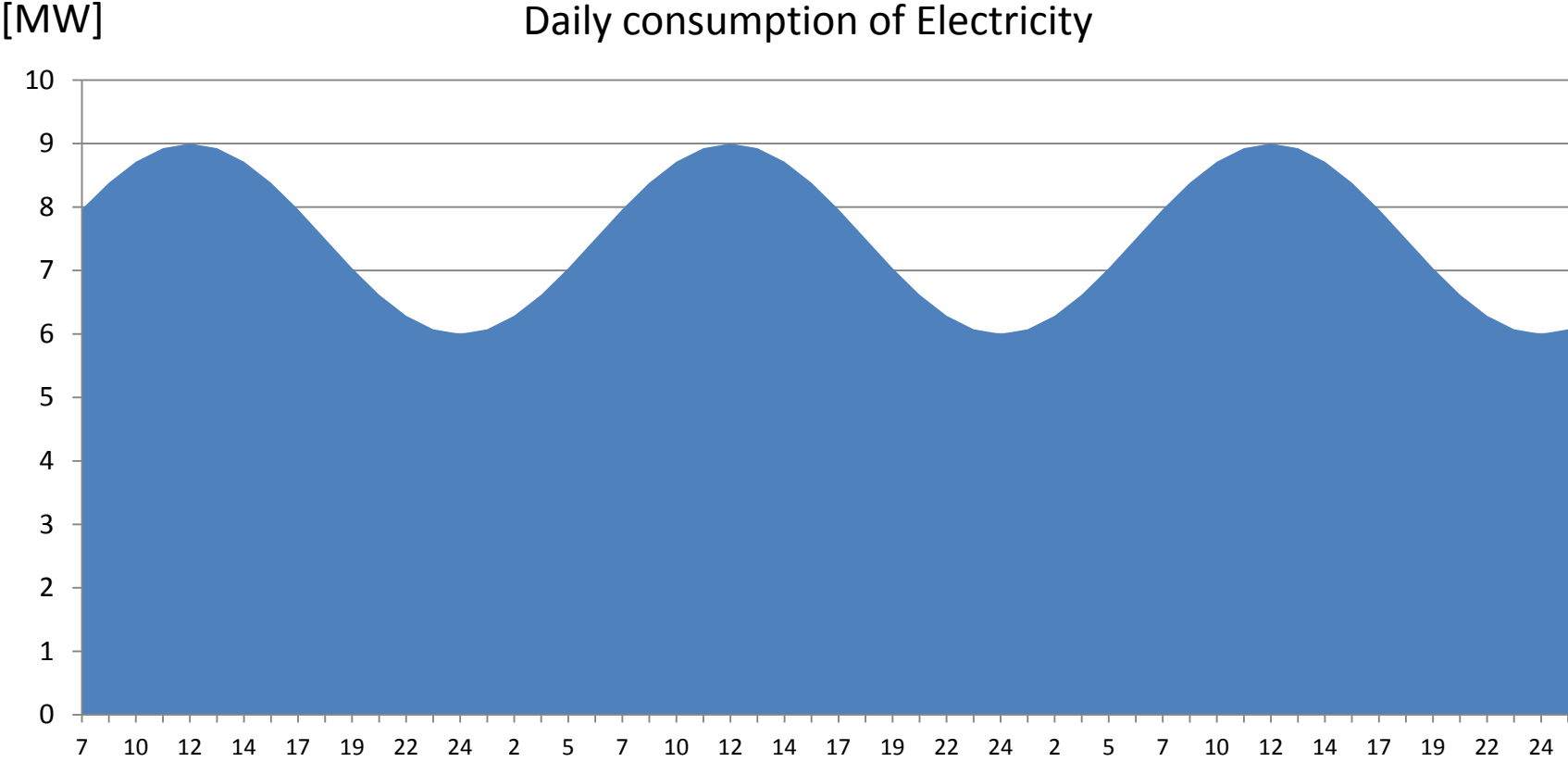
# Energy Pricing

## c) Net exporter

- Domestic demand satisfied below world price
- Equilibrium price should be that of world price
- In reality domestic prices of oil exporters significantly lower due subsidies

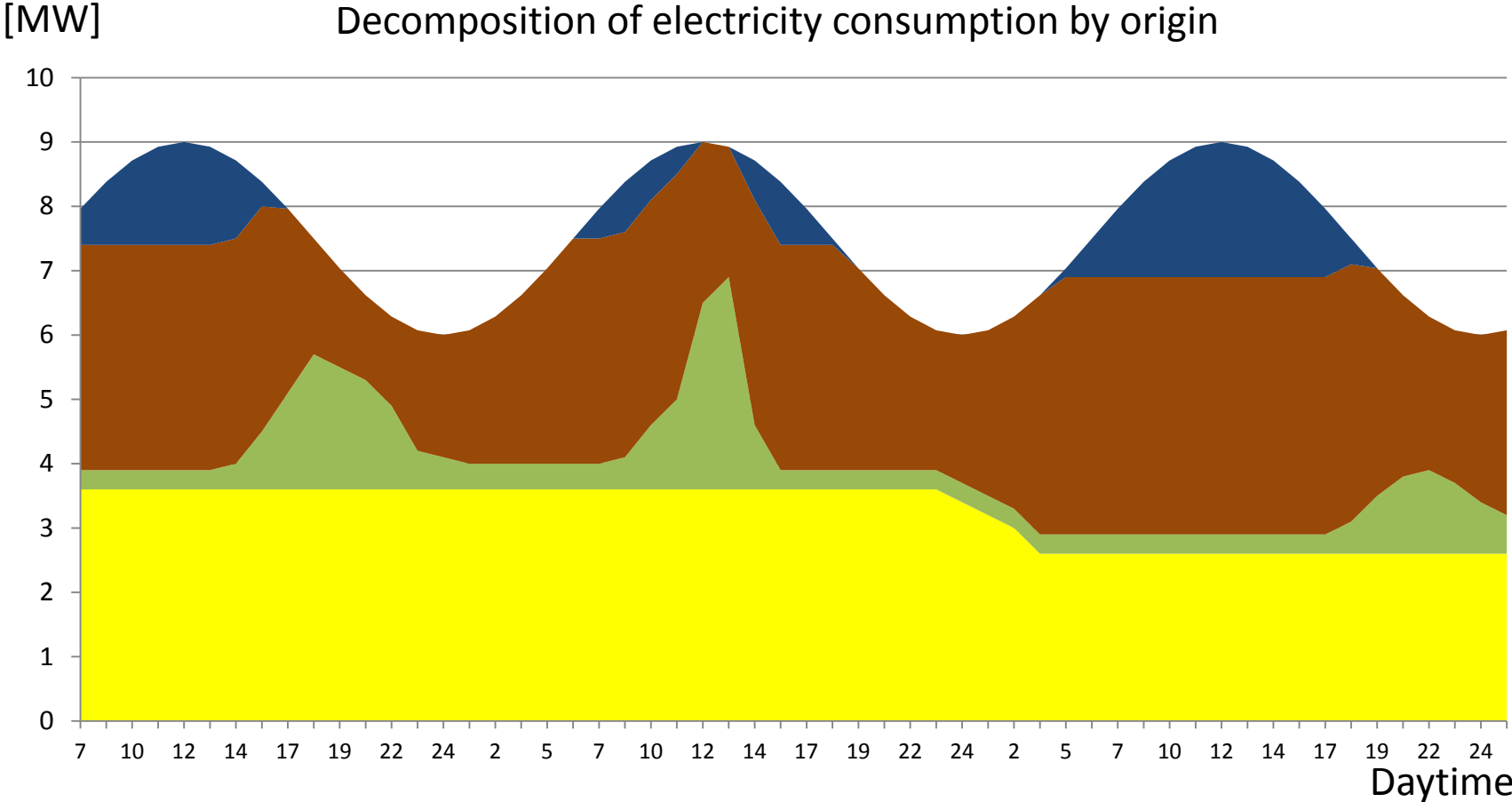


# Peak and Off-Peak Pricing



Daytime

# Peak and Off-Peak Pricing

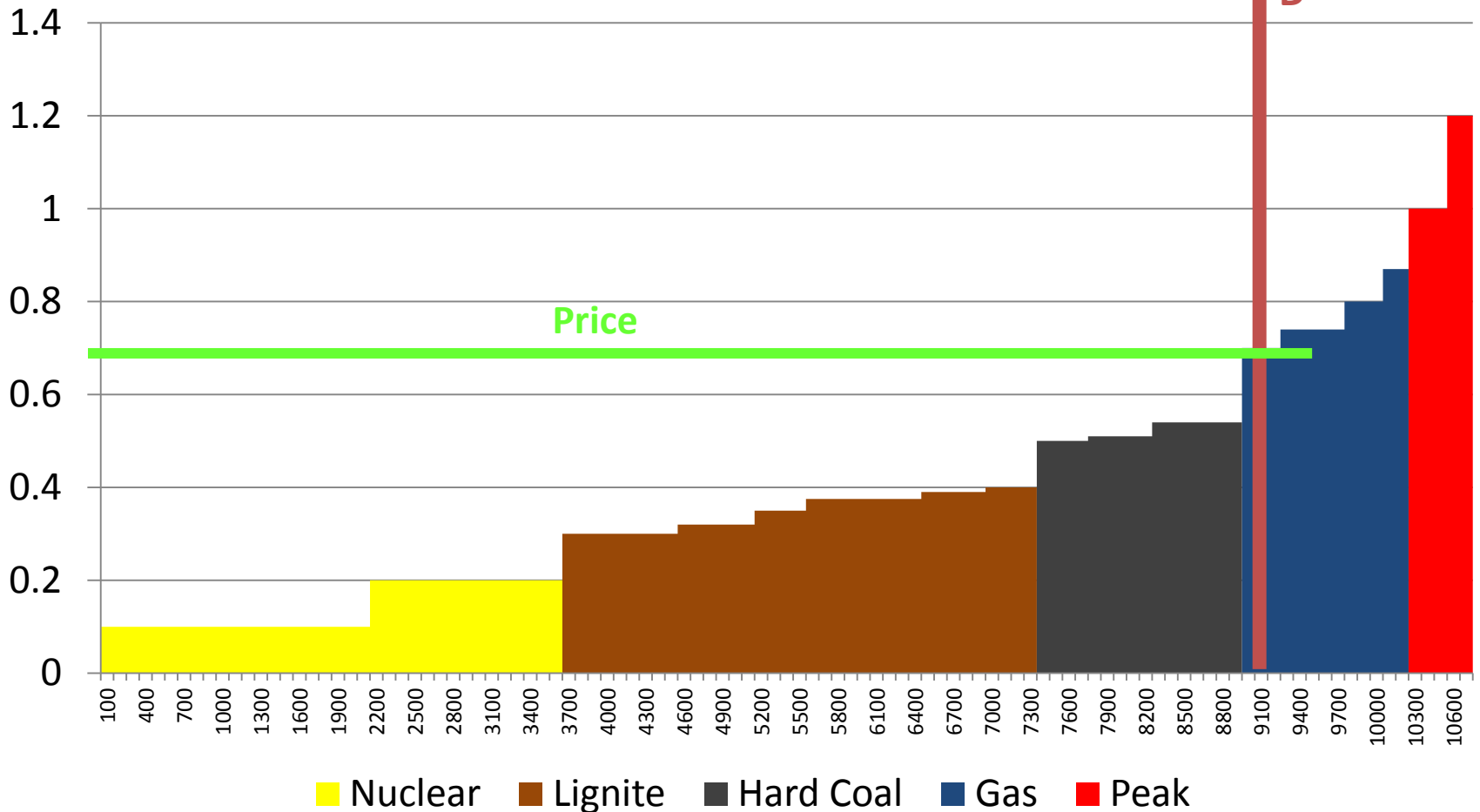


Nuclear (yellow) – Renewables (green) – Coal (brown) – Peak gas (blue)

# Peak and Off-Peak Pricing

[Kč/KWh]

Electricity Exchange Pricing

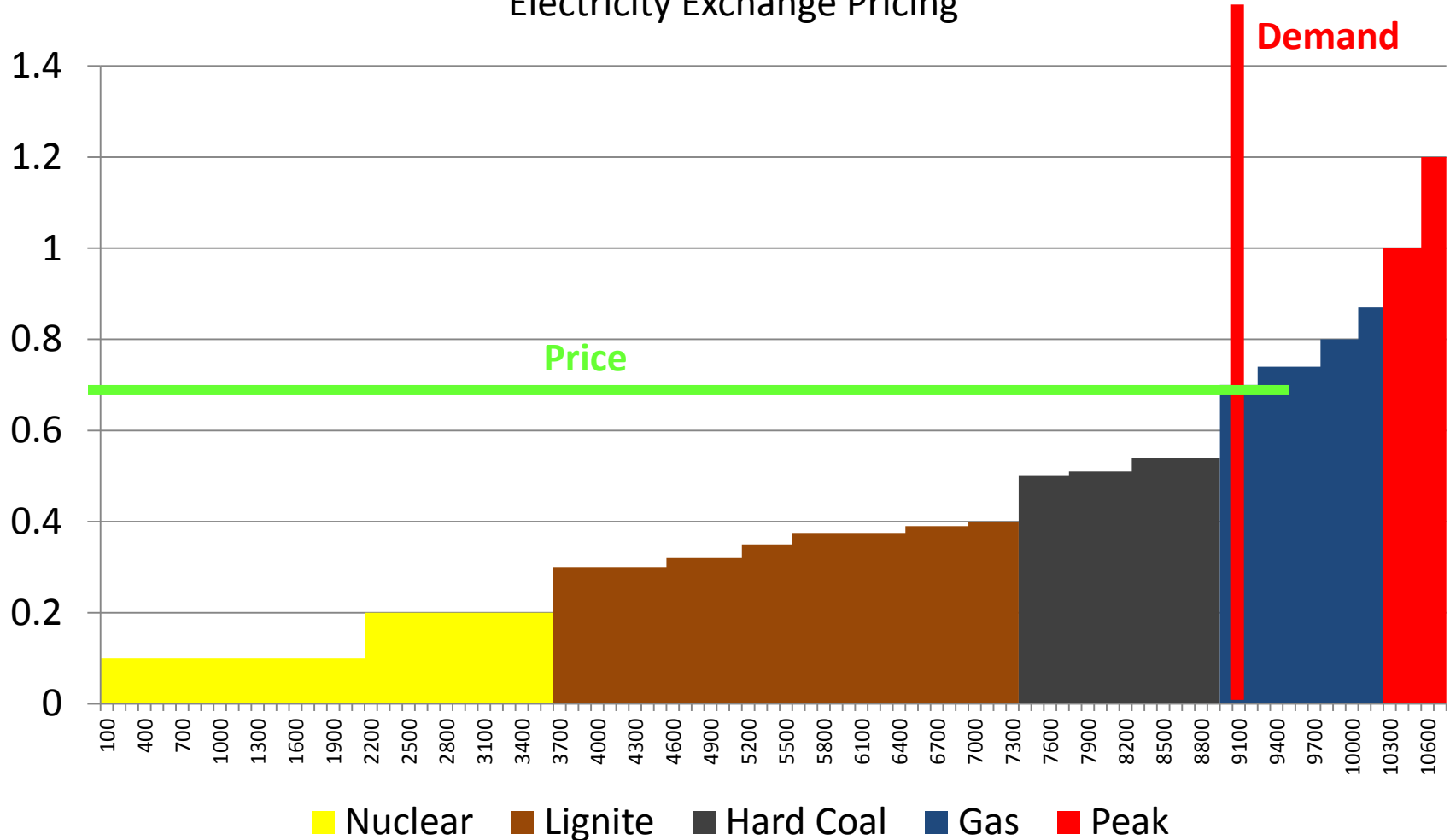




# Renewables and Electricity Pricing

[Kč/KWh]

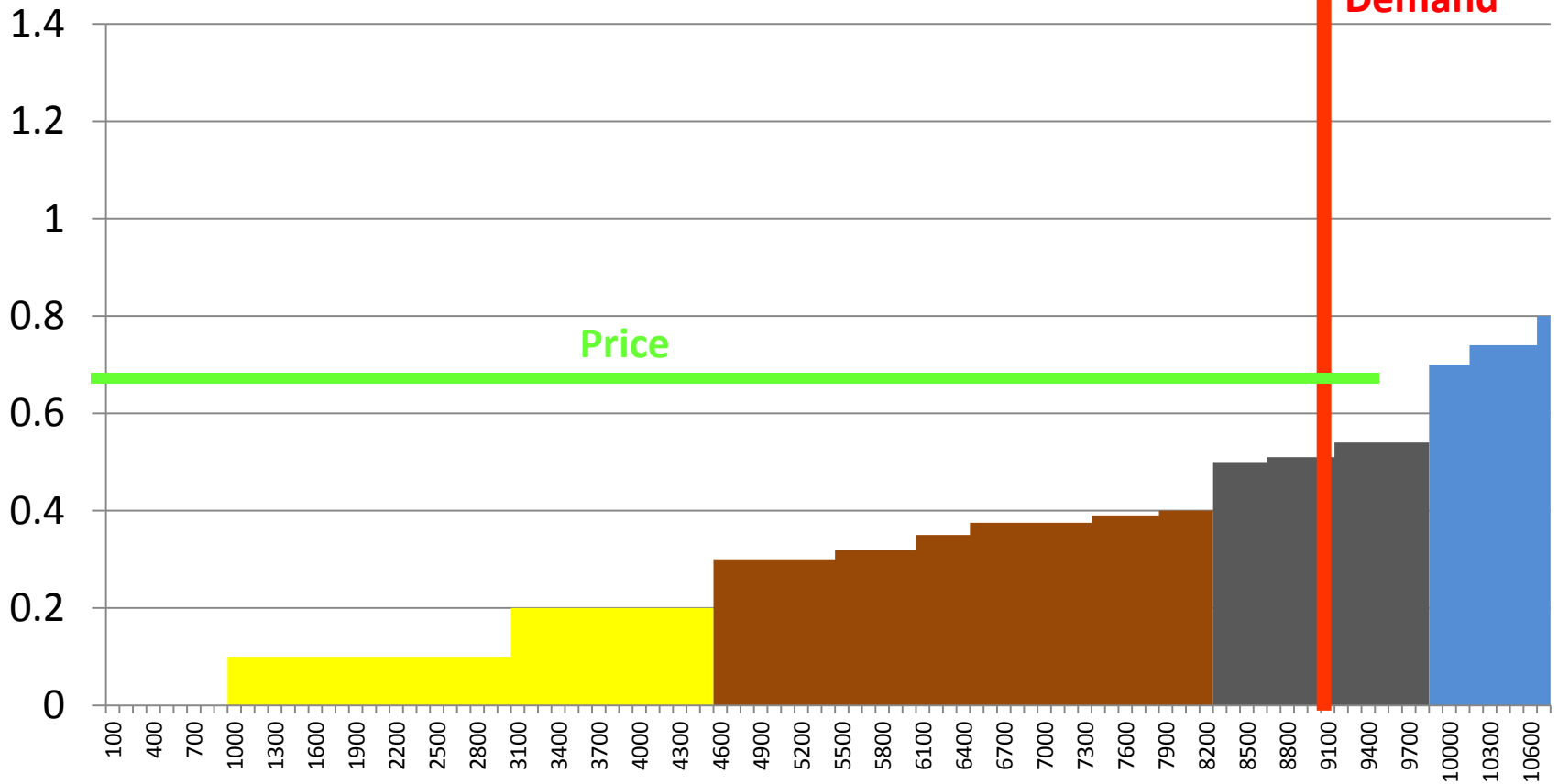
Electricity Exchange Pricing



# Renewables and Electricity Pricing

[Kč/KWh]

Renewables incoming

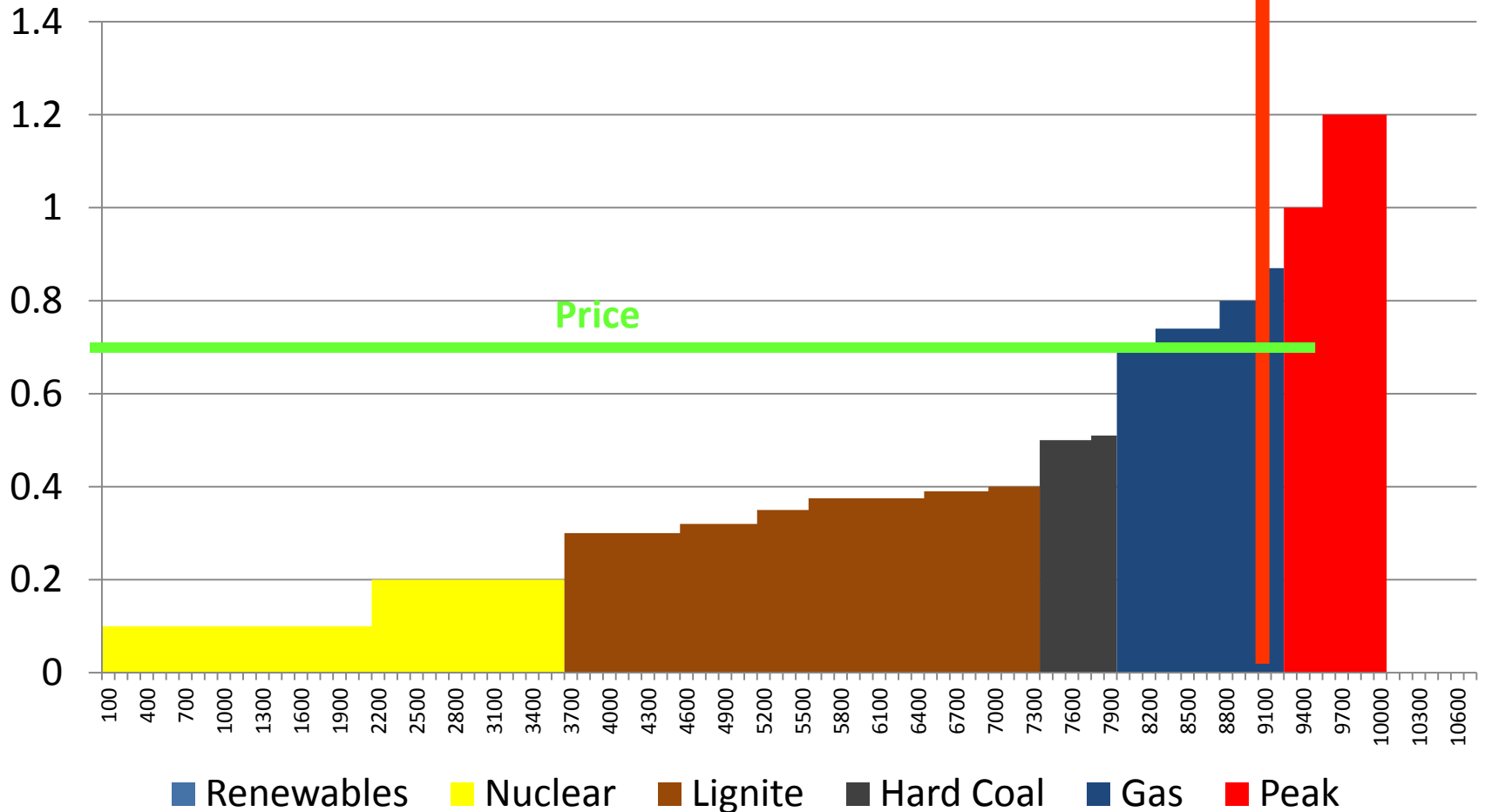


Renewables Nuclear Lignite Hard Coal Gas Peak

# Renewables and Electricity Pricing

[Kč/KWh]

Renewables out...



# Daily electricity price at European Power Exchange Leipzig

★ 170 € daily mean, 250 € daily max 10.2.2012

€/MWh

100

50

0

Zdroj: <https://www.epexspot.com/>

10/2010

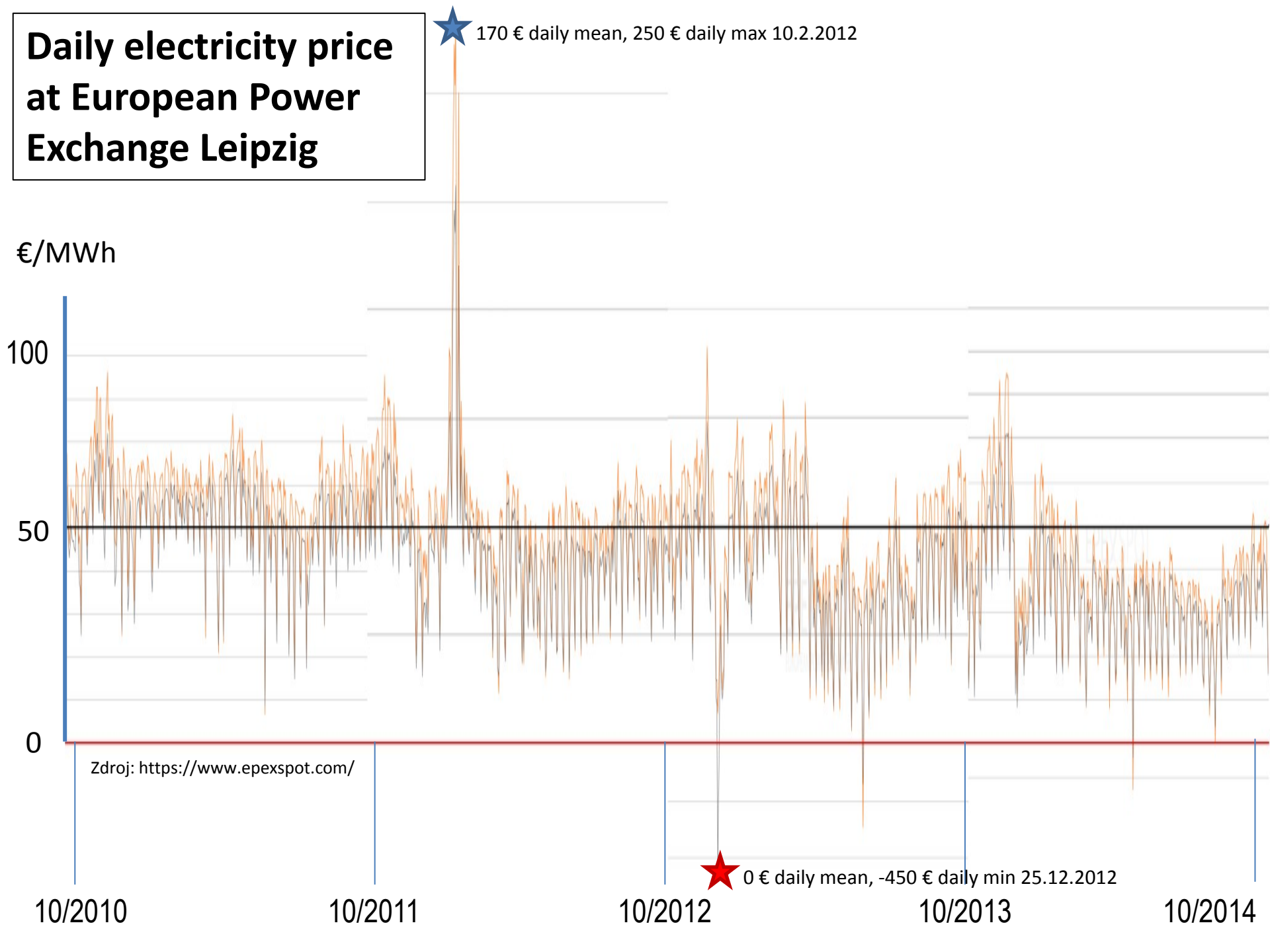
10/2011

10/2012

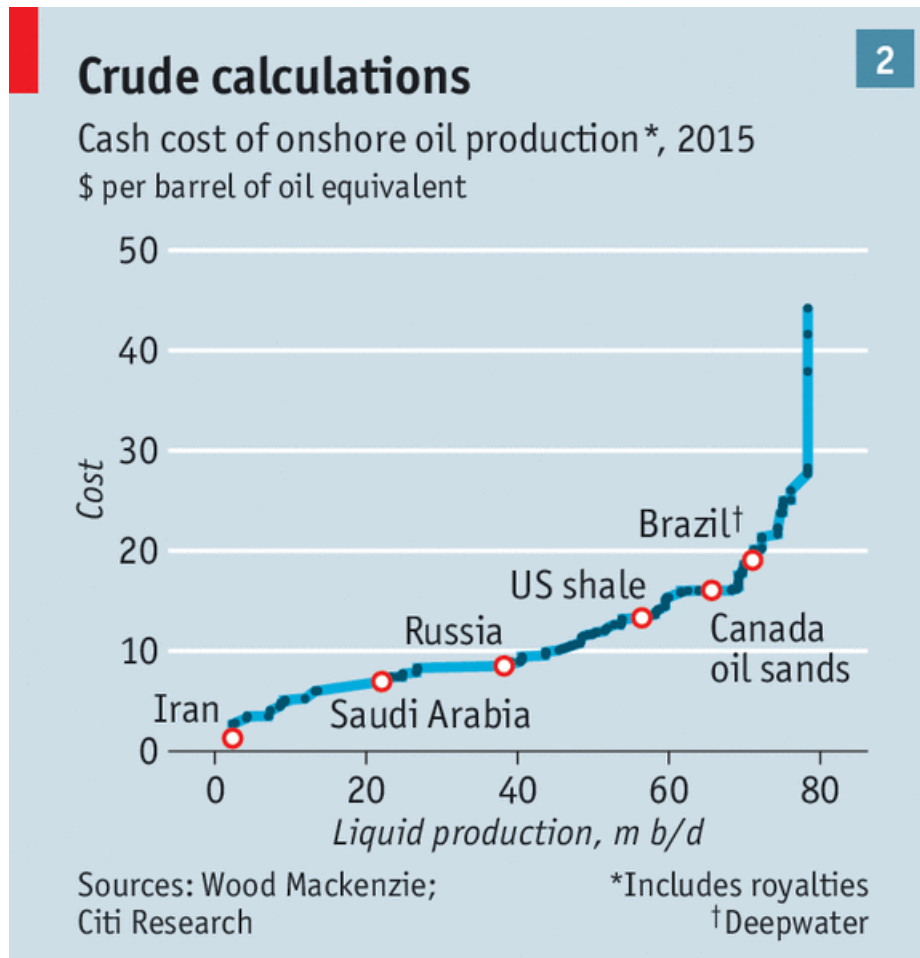
10/2013

10/2014

★ 0 € daily mean, -450 € daily min 25.12.2012



# Merit order application - Oil



Economist.com

See: <http://www.economist.com/blogs/graphicdetail/2016/01/daily-chart-6>

# Price *is* vital piece of information

## Slippery slope

1

WTI oil price  
\$ per barrel

World oil supply  
m b/d



Sources: EIA; Thomson Reuters

## Energy sapping

3

US private fixed investment in energy\*  
As % of total private non-residential investment



Sources: Deutsche Bank Research; BEA; Haver Analytics

\* Petroleum and natural gas exploration, shafts and wells, and mining and oilfield machinery

Measuring energy

**HOW TO REGULATE?**

# Allowances v Taxes

- Government aims to decrease CO2 emissions
- Two ways of achieving that:
  - Tax – payment for each ton of CO2 emitted
  - Tradable allowances – permission to emit particular volume of CO2
- Different parameters
  - Tax – maximum price for decarbonisation is set
  - Allowances – maximum volume is set



# Example 1

- Two types of PP in a Country – A and B
- Both emit 40t CO<sub>2</sub> per year = total 80t/y
- Different emission reduction costs per 10t
  - A = \$2,000; B = \$4,000
- Government' objective is 60t CO<sub>2</sub> per year
  - Regulation
  - Tax
  - Allowances

# Example 1

## 1. Regulation

- Each PP must decrease emissions by 10t/y
- Costs = 2,000 + 4,000 = **\$6,000**

## 2. Allowances

- 60t allowances issued, both A and B get 30t
- B buys 10t allowances from A and emits 40t
- A emit 20t ... total emissions 60t
- Costs = 2 \* 2,000 = **\$4,000**
- Price of allowance between \$2k and \$4k

## 3. Taxation

- $T < \$2k$  ... no emission reduction &  $C+T = \$0 + \$0 \dots 16k$
- $\$2k < T < \$4k$  ... 40t of A reduced &  $C+T = \$8k + \$8k \dots 16k$
- $\$4k < T$  ... all emissions reduced &  $C+T = \$16k + \$0$

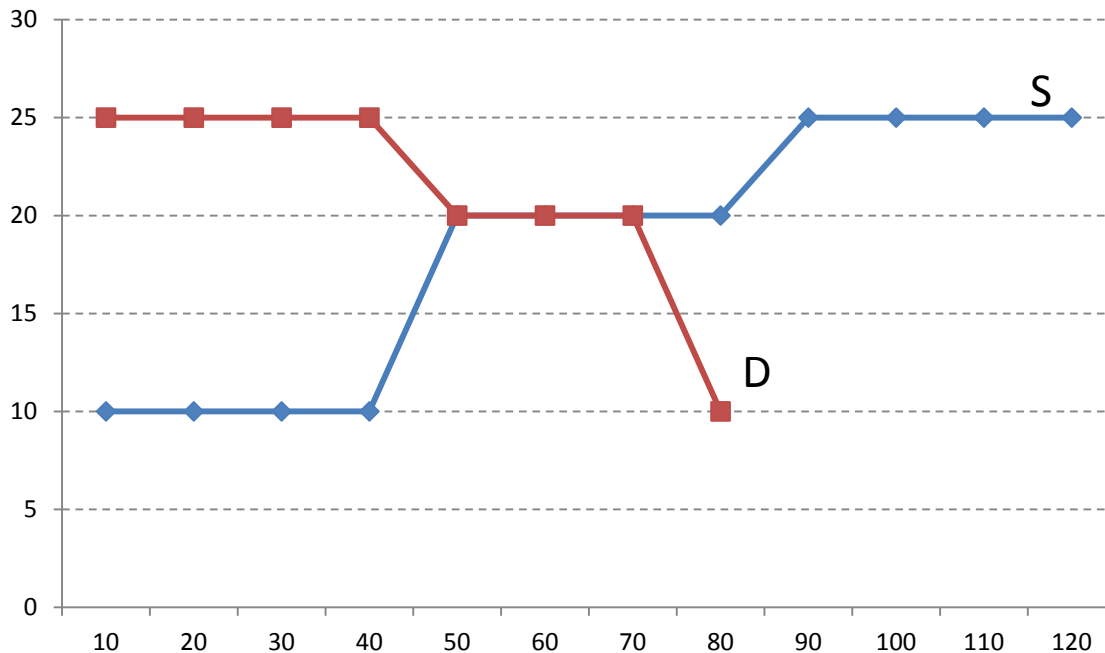
# Example 2

Company	Emissions [t]	Costs reducing 1 t
A	70	20
B	80	25
C	50	10
Total	200	

- Government objective: 120 t
- Method: Allowances
- Who will sell at what price?
- What will be final cost of reducing emissions?

# Example 2

Company	Emissions [t]	Costs reducing 1 t
A	70	\$20
B	80	\$25
C	50	\$10
Total	200 (120 allowances issued)	



- C sells 40t allowances to B at price of \$20
- Total costs = \$1,100
  - A reduces 30t at \$20
  - B doesn't reduce
  - C reduces 50 at \$10
- Costs w/o trade
  - \$1,700