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**] ≈ 42 GJ
  - Ton of Coal Equivalent [**tce**] ≈ 29 GJ
    - Czech lignite at 10 to 20 [$GJ.t^{-1}$]
  - British Thermal Unit [**BTU**] ≈ 1.05 kJ
  - **Quad** ≈ 1,055 PJ
    - US Dep. of Energy meaning quadrillion of BTU
    - Czech republic TPES 2014 ≈ 1.7 PJ ≈ 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

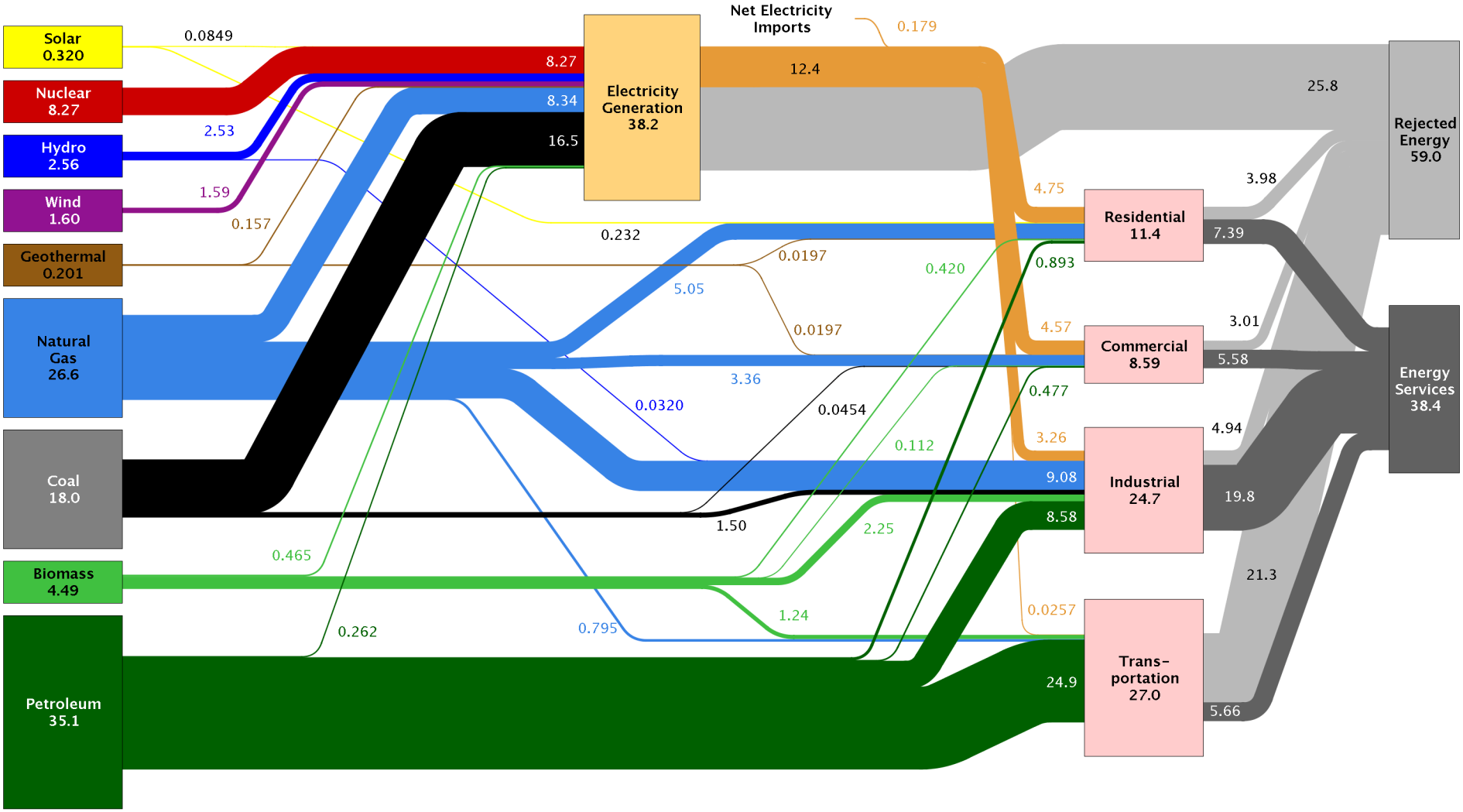
- Other divisions (boundaries change)
  - Renewable x Non-Renewable
  - Commercial x Non-Commercial
  - Modern x Traditional
  - Conventional x Non-Conventional

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

Lawrence Livermore National Laboratory



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			
				TJ	kt	ktce	ktoe
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
Total/mean	**52 271**	**3 004**	**17,40**	**100%**	**100%**	**1 784**	**1 248**

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 measurment
- Conversion factors

Measuring energy

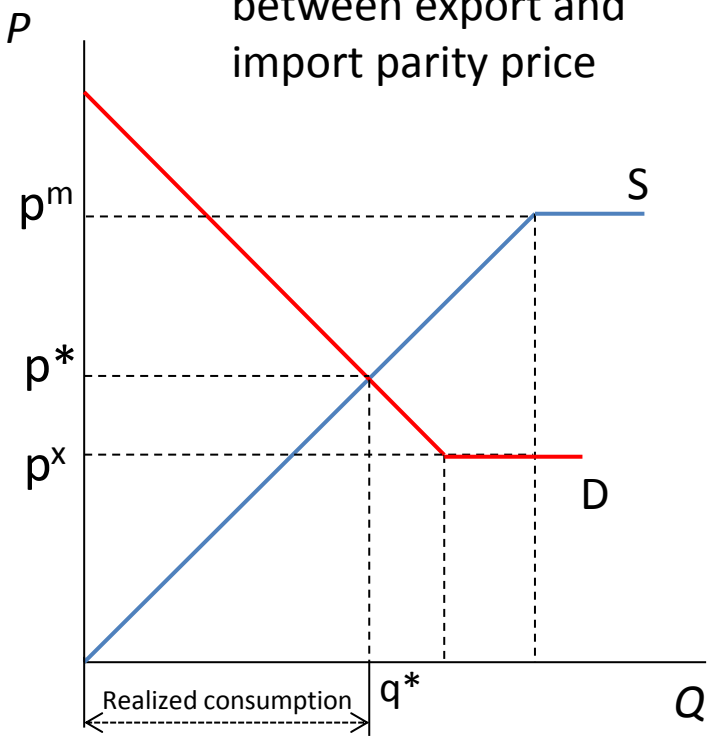
AT WHAT PRICE?

Price - recap

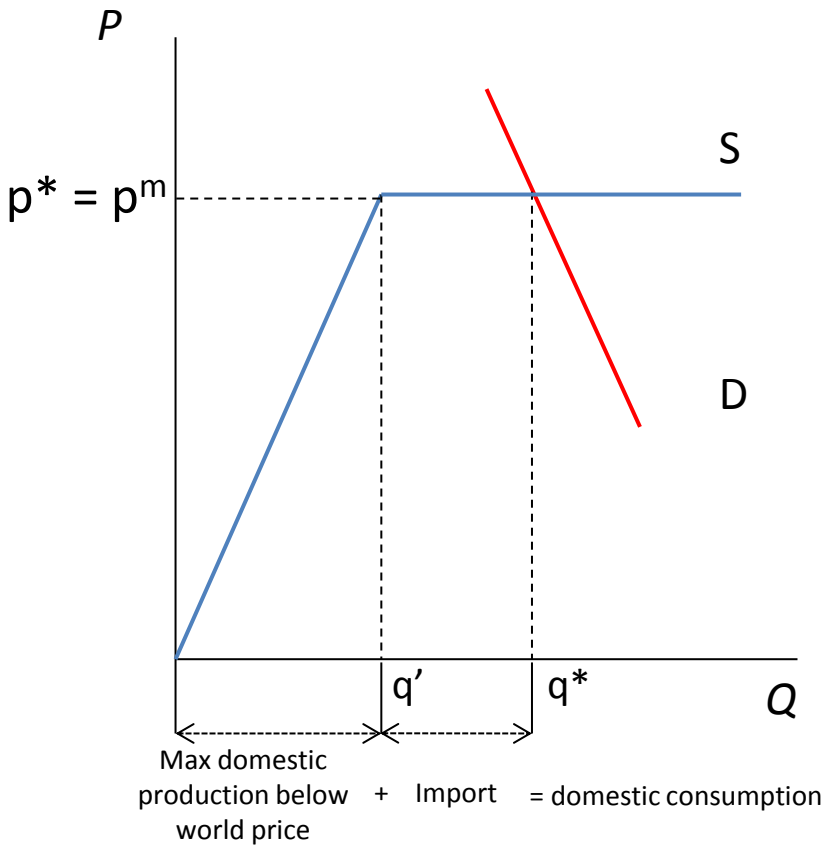
- Price x value
- Price
  - Objective measurable figure
  - Result of supply/demand
  - Denotes *relative scarcity* of a good
- Value
  - Subjective, individual, not measurable
  - Depends on time, place and people
- Value of price is priceless

Energy Pricing

a) Self-sufficient country
- Price set domestically between export and import parity price

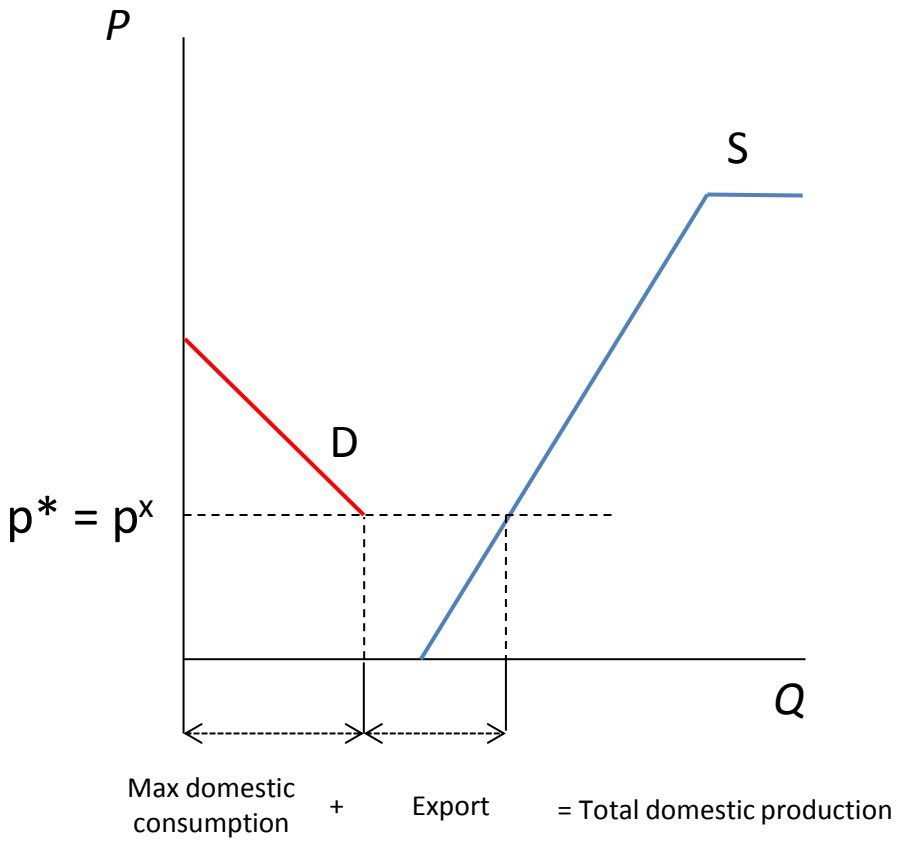


b) Importing country
- Import (world) price

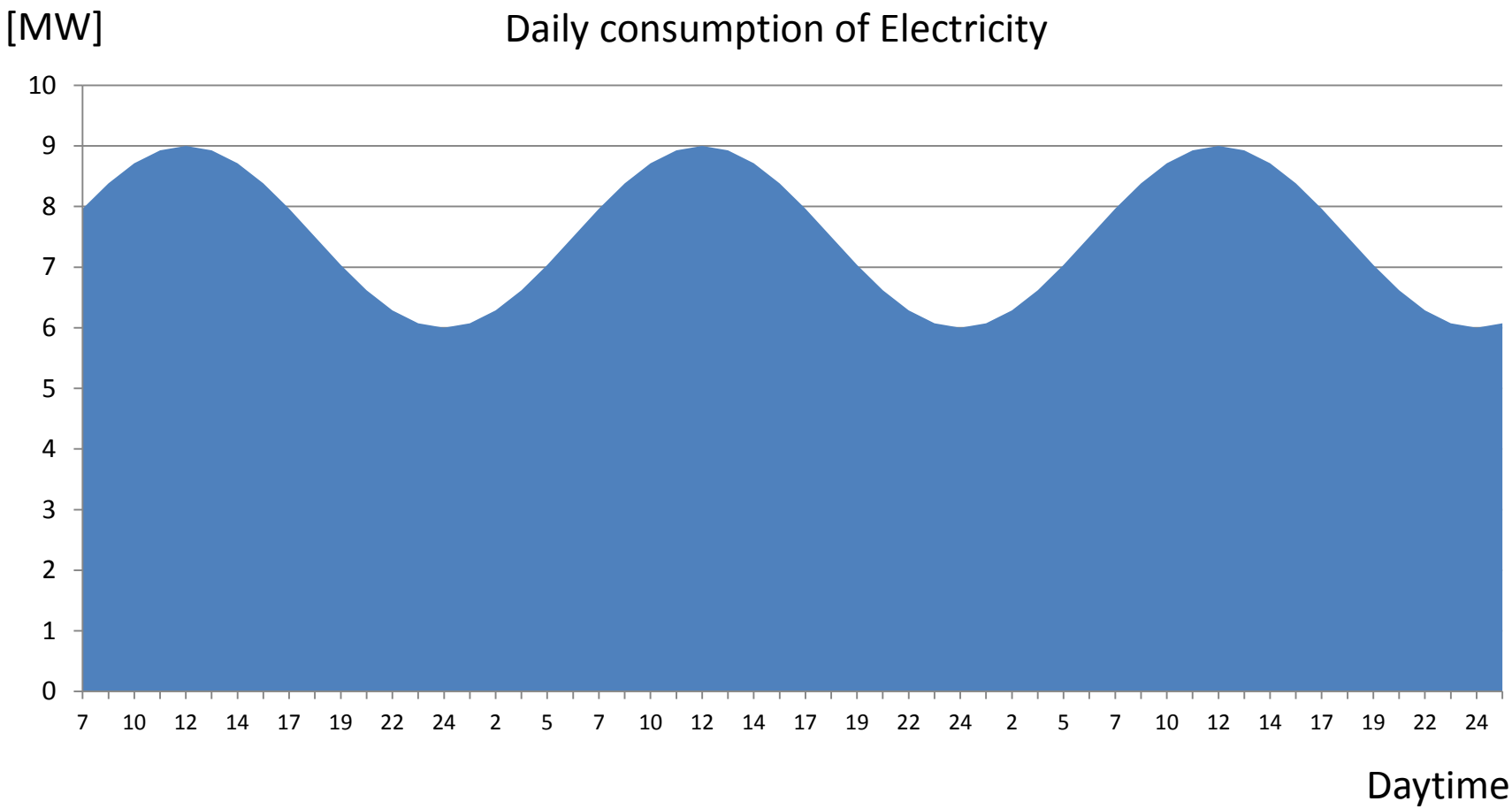


Energy Pricing

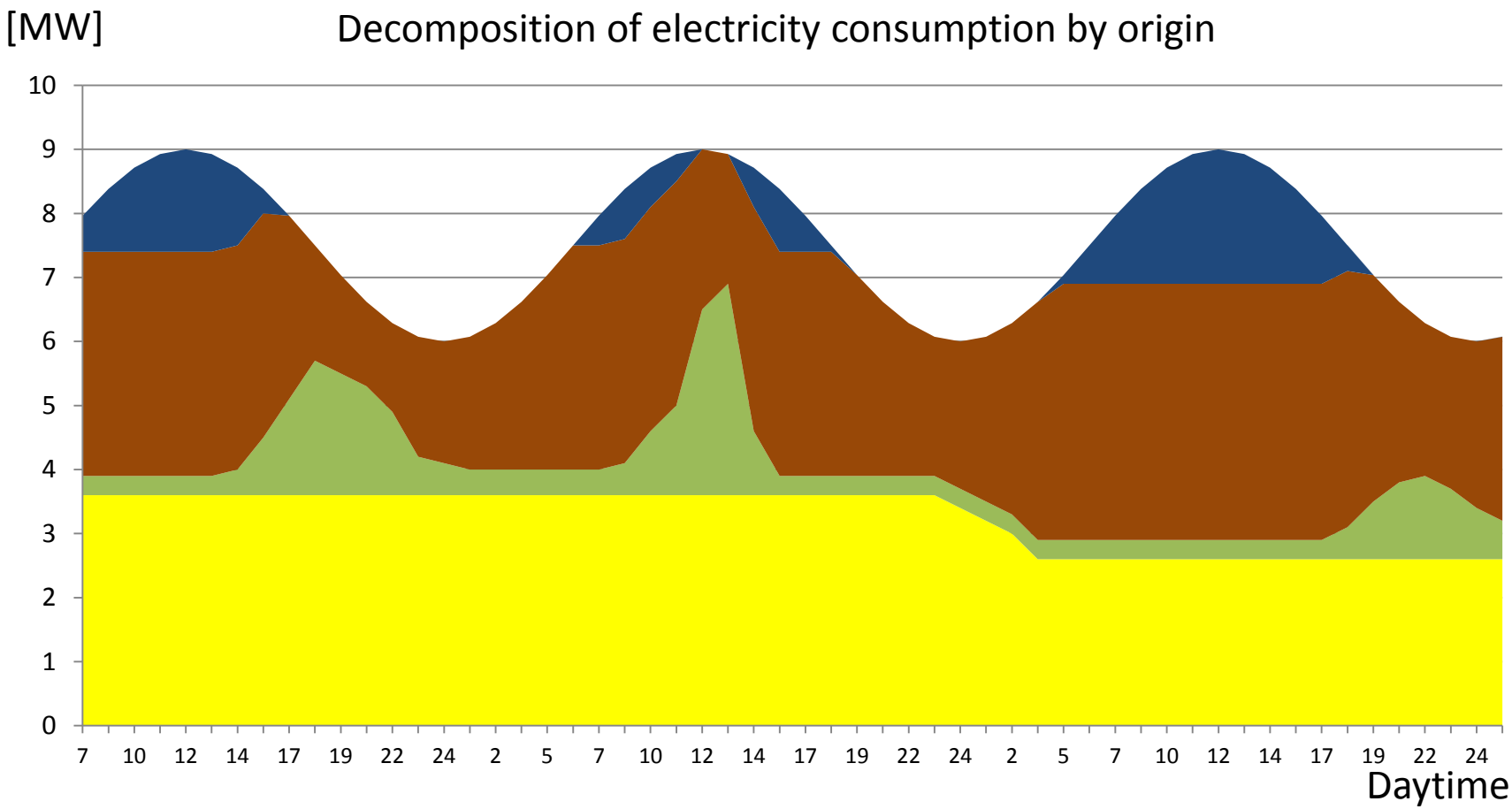
c) Net exporter
- Domestic demand satisfied below world price
- Equilibrium price should be that of world price
- In reality domestic prices of oil exporters significantly lower due subsidies



Peak and Off-Peak Pricing

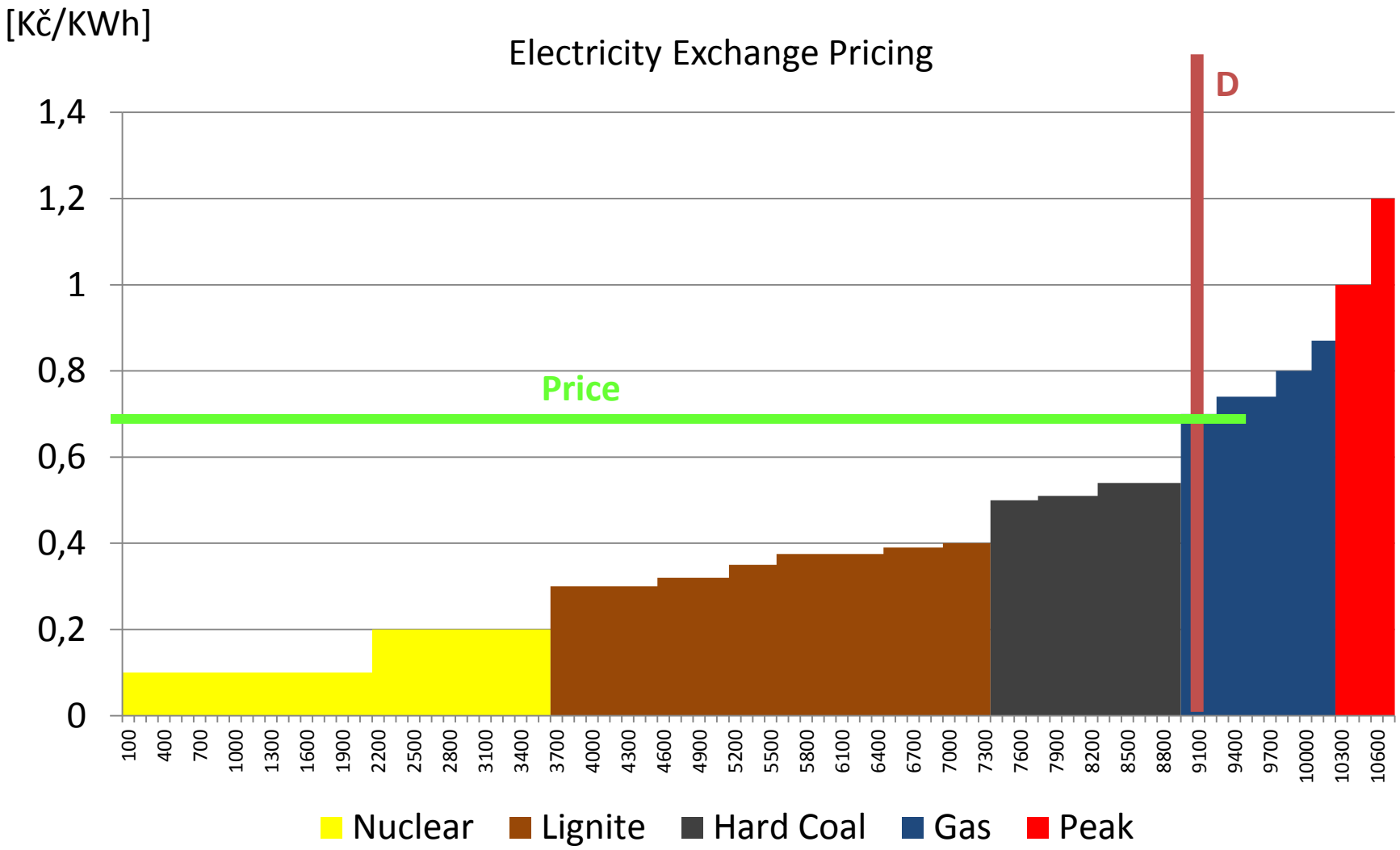


Peak and Off-Peak Pricing

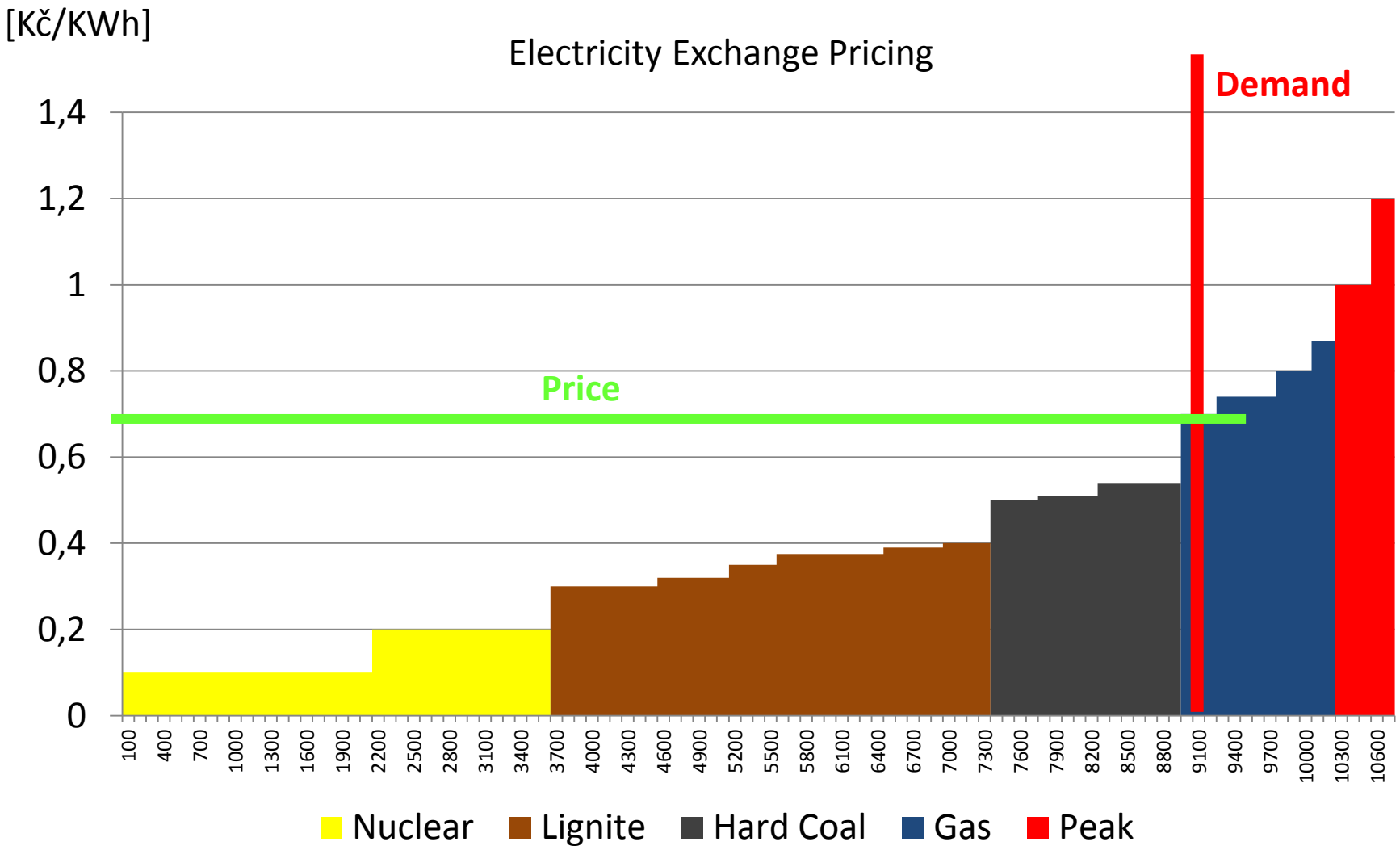


Nuclear (yellow) – Renewables (green) – Coal (brown) – Peak gas (blue)

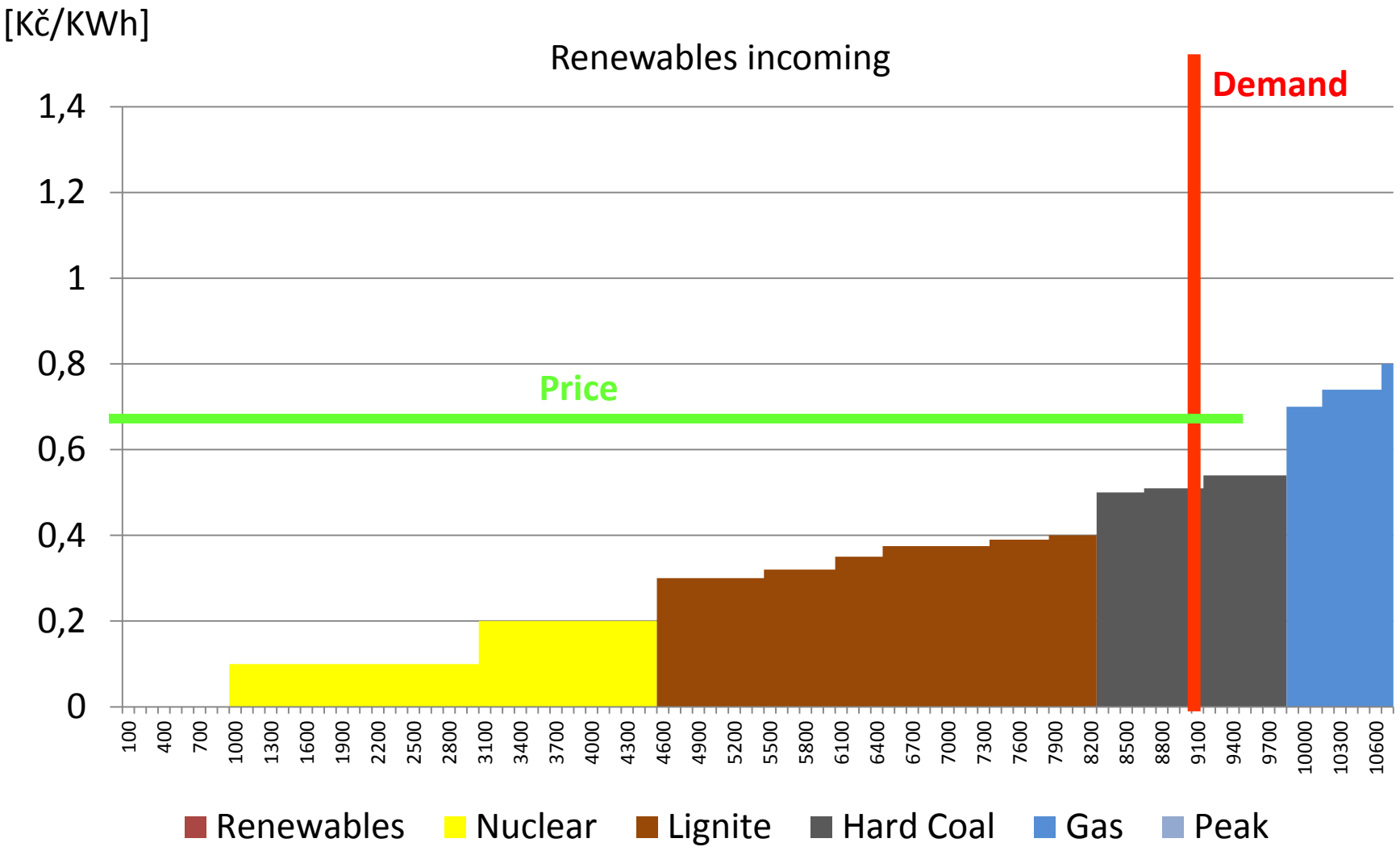
Peak and Off-Peak Pricing



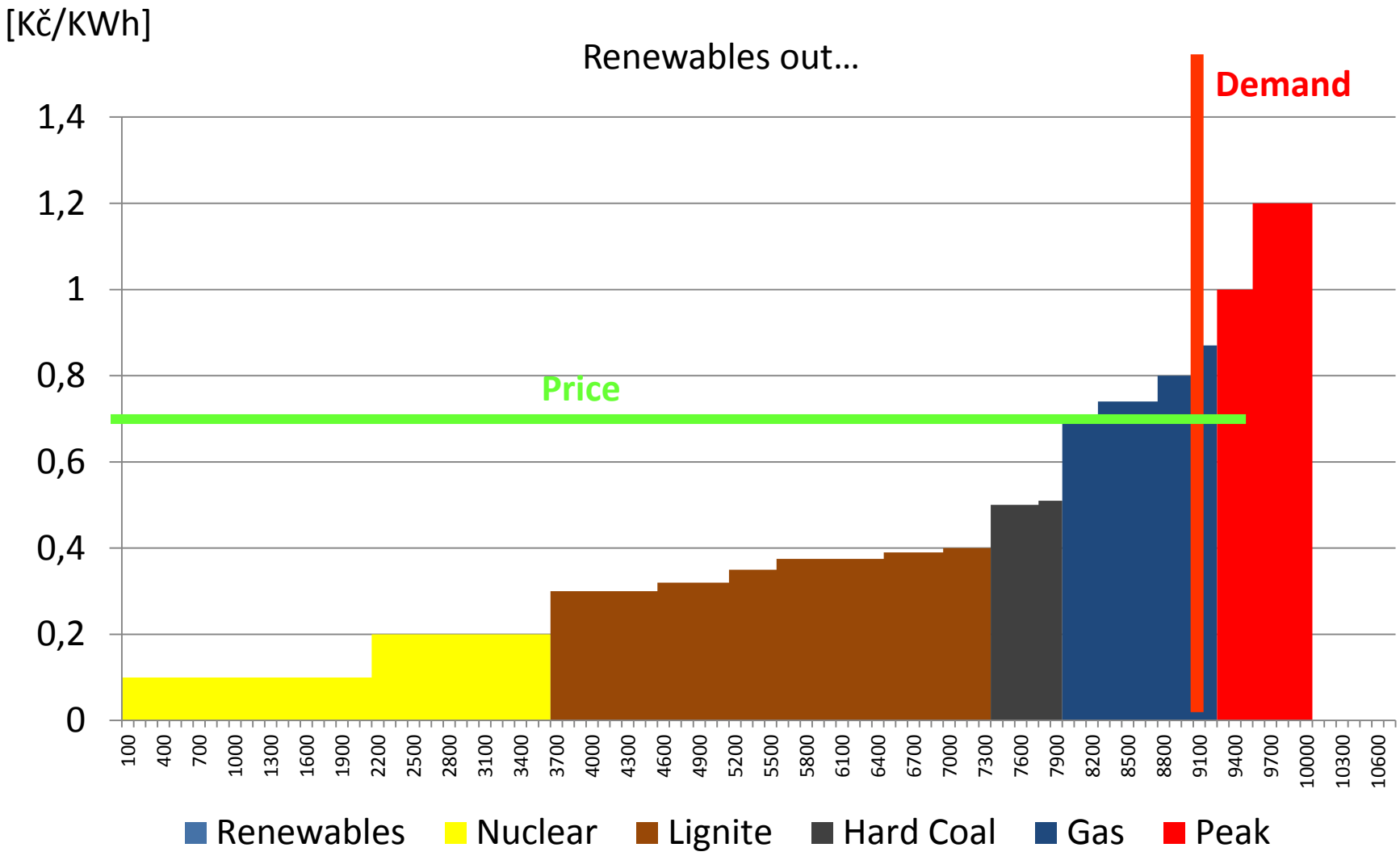
Renewables and Electricity Pricing



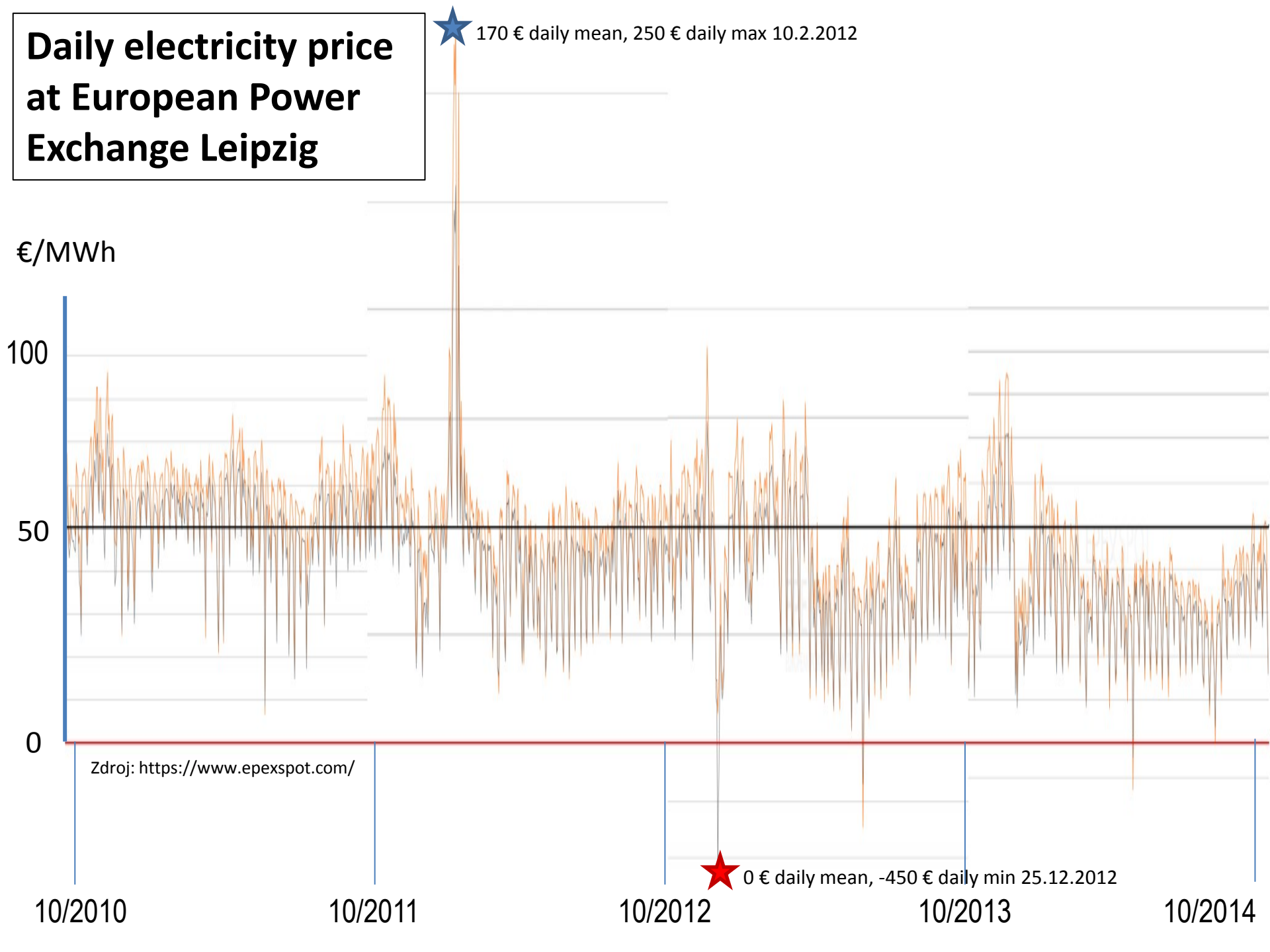
Renewables and Electricity Pricing



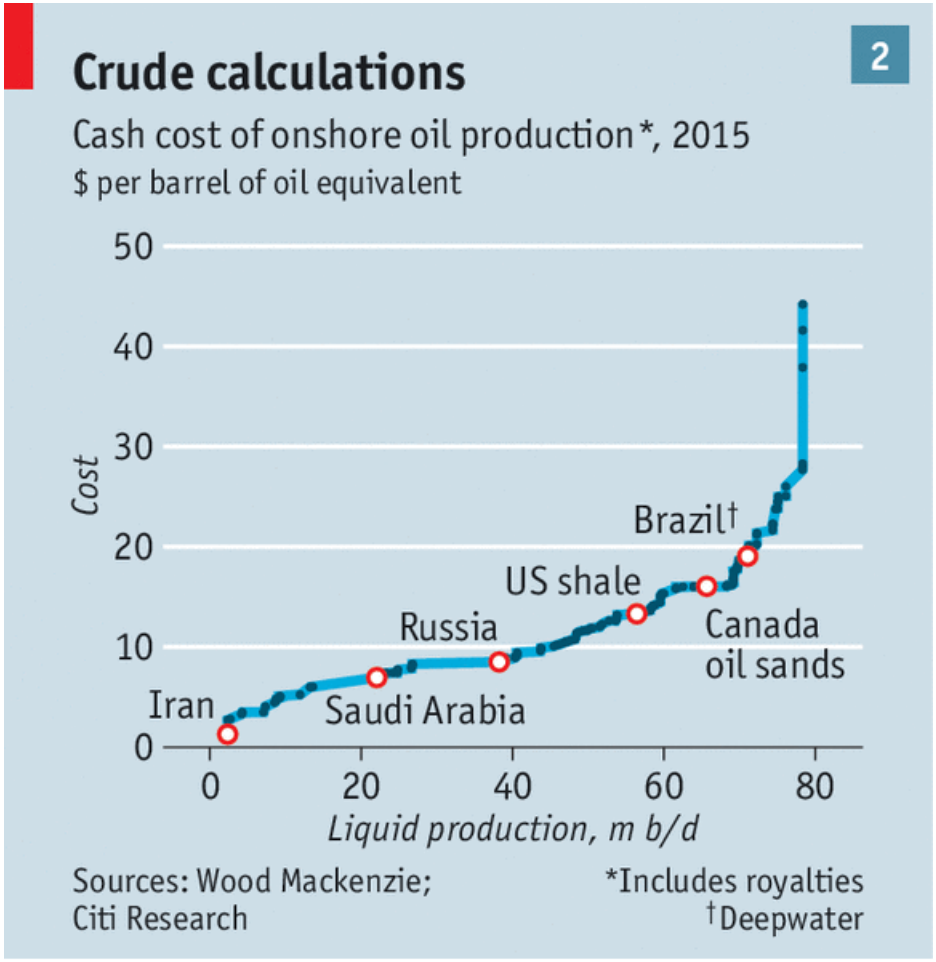
Renewables and Electricity Pricing



Daily electricity price at European Power Exchange Leipzig

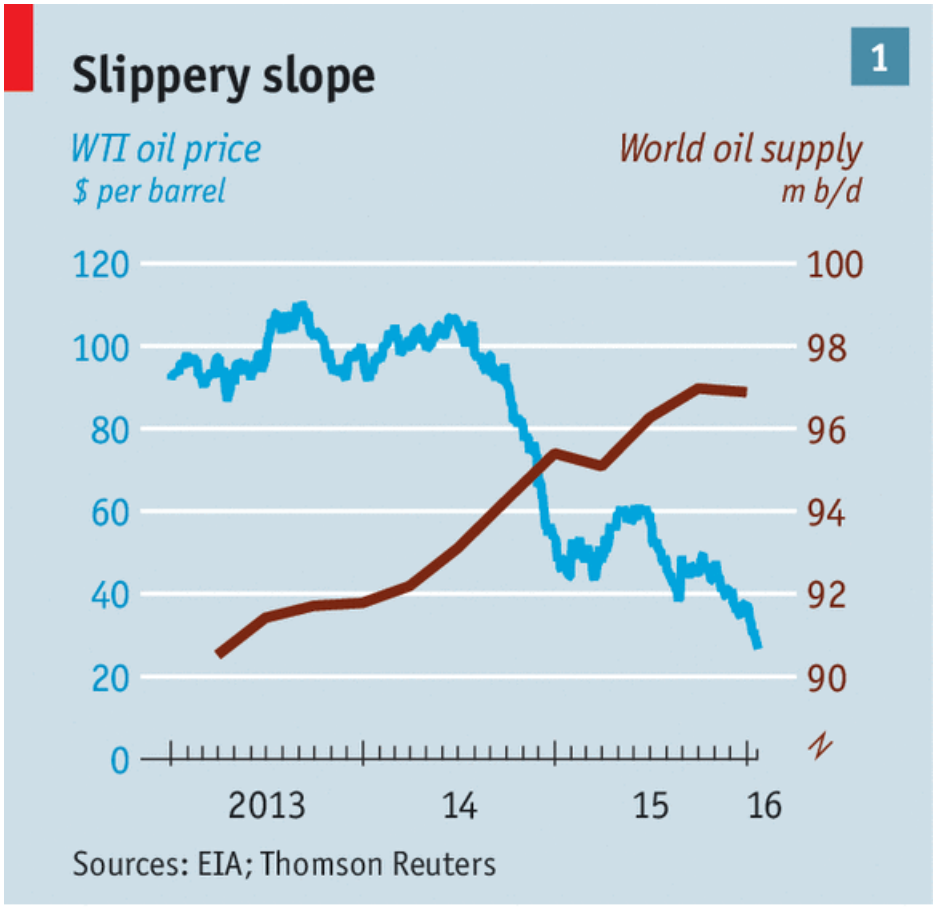


Merit order application - Oil



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

Price *is* vital piece of information



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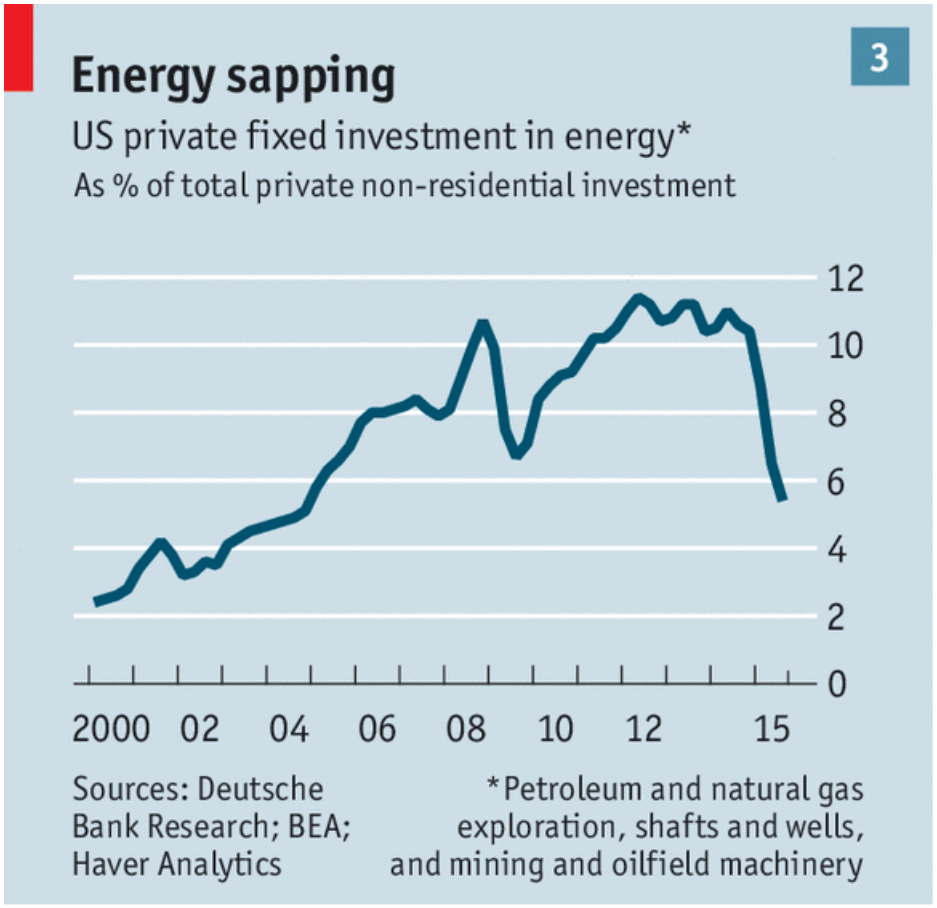


Economist.com

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_2 per year = total 80t/y
- Different emission reduction costs per 10t
  - A = $2,000; B = $4,000
- Government' objective is 60t CO_2 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…16k
   - $2k < T < $4k … 40t of A reduced & C+T = $8k + $8k…16k
   - $4k < T … all emissions reduced & C+T = $16k + $0

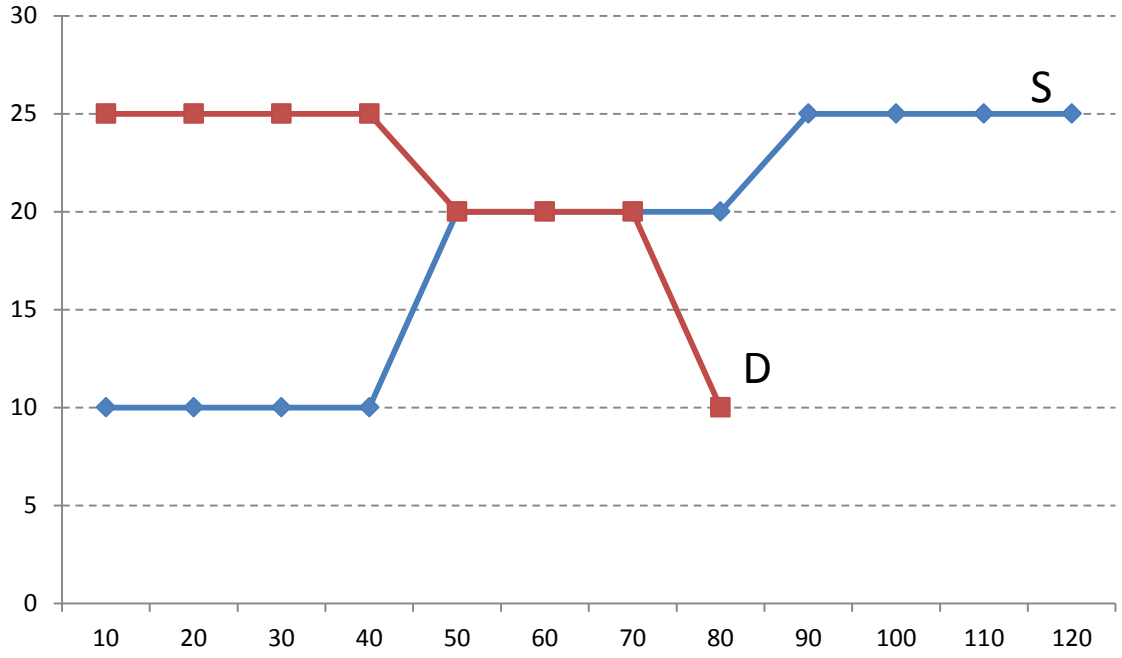
Example 2

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