The EU-ETS: Observations and thoughts about the first half of the 2005-2007 compliance period

Yves Smeers
CORE, Universite Catholique de Louvain

Andreas Ehrenmann
Electrabel*

*The opinions expressed in this presentation are not necessarily the ones of Electrabel

Agenda

- Some basic design features of the EU-ETS
- The first 18 months of the first compliance period
- The dispute over "windfall profits"
- The long term in the power sector: granting free allowances
  - investment when there is no market power
  - free allowances and the missing money
  - free allowances and uncertainty

The EU-ETS

- Cap and trade system

- Operating over an horizon decomposed in compliance periods

  - 2005-2007 Pre Kyoto

    * Covering CO2 emissions by the power and heat, pulp and paper, metals, oil and gas, cement line glass sectors in EU-25

- – 2008-2012 Kyoto phase 1
    - ∗ Possibly covering other sectors and other GHG
    - ∗ Allowing for contributions of CER[1] from CDM[2] and ERU[3] from JI[4]
  - – 2013- post Kyoto decomposed in 5 years periods
    - ∗ Of which one knows essentially nothing

[1] Cerfitied Emission Reduction

[2] Clean Development Mechanisms projects

[3] Emission Reduction Units

[4] Joint Implementation projects

A key debate

The allocation of allowances under subsidiarity:

- Different rules for allocation of free allowances to existing units (use of auctioning) in different member states: Germany no auctioning, Netherlands 10%

- Different quantities (benchmarks, running hours) for new entrants.

- Different guaranteed durations: Germany 14 years, Netherlands until the end of the trading period.

The first 18 months of the first compliance period

What we expected before January 2005

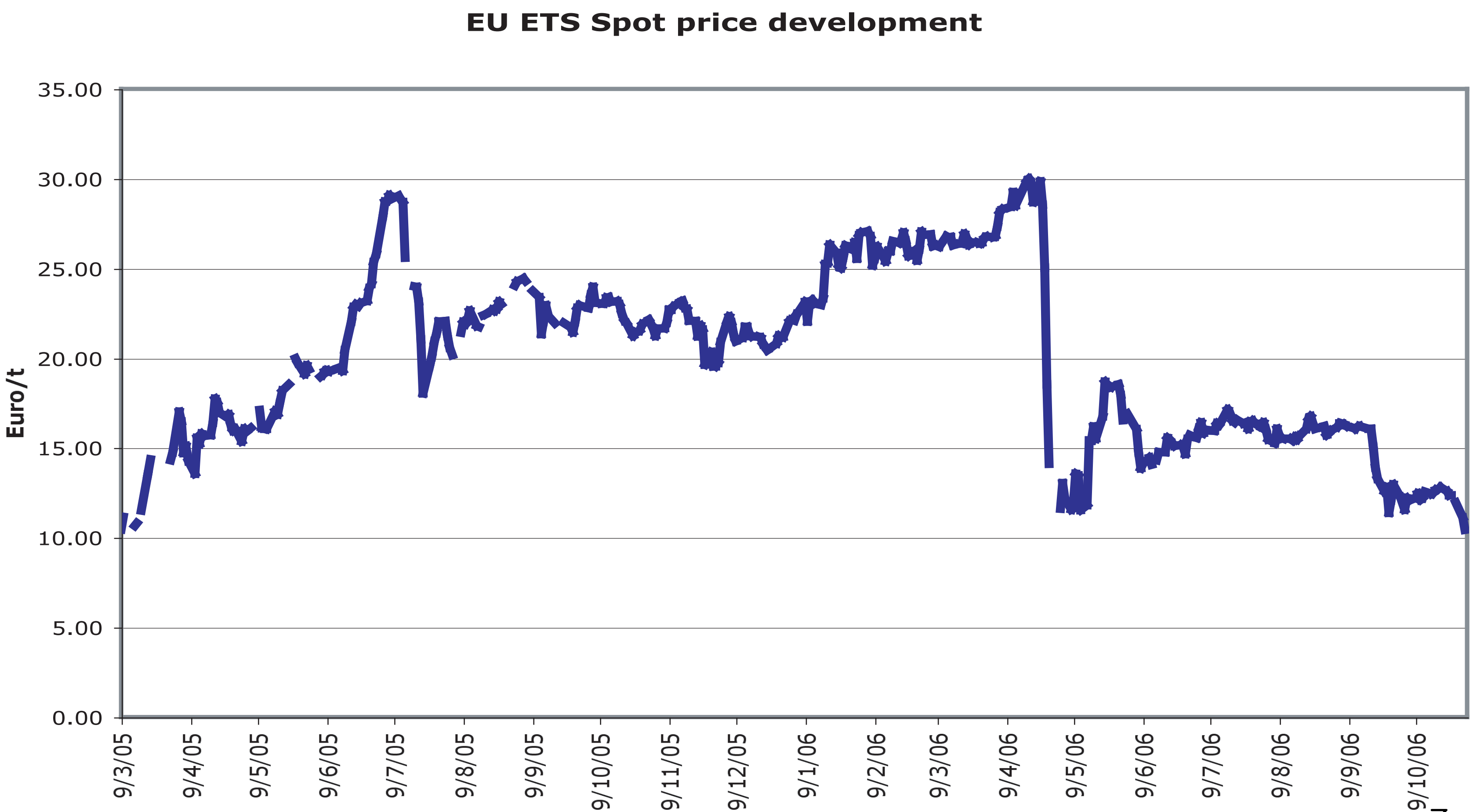
CO_2 prices will be low in the first compliance period because

- Allocances will be granted as a small reduction of a BAU[1] scenario
- MS[2] will construct these scenarios and will inflate them
- The total constraints will thus be mildly binding, and hence the CO_2 price will be low
- This environmentally ineffective outcome does not matter: the objective of the first compliance period is to get the system in place
- And we will have a long horizon of more restrictive emission constraints to adapt

[1] Business as usual

[2] Member States

What happened ?



- What we understand well
  - short run substitution in the power sector

- We do not know much about
  - short run substitution in the other sectors

- We do not understand well
  - the intertemporal arbitrage between compliance periods (there should be none) when banking is not permitted (or at least ex ante)

Short run substitution in the power sector

Let

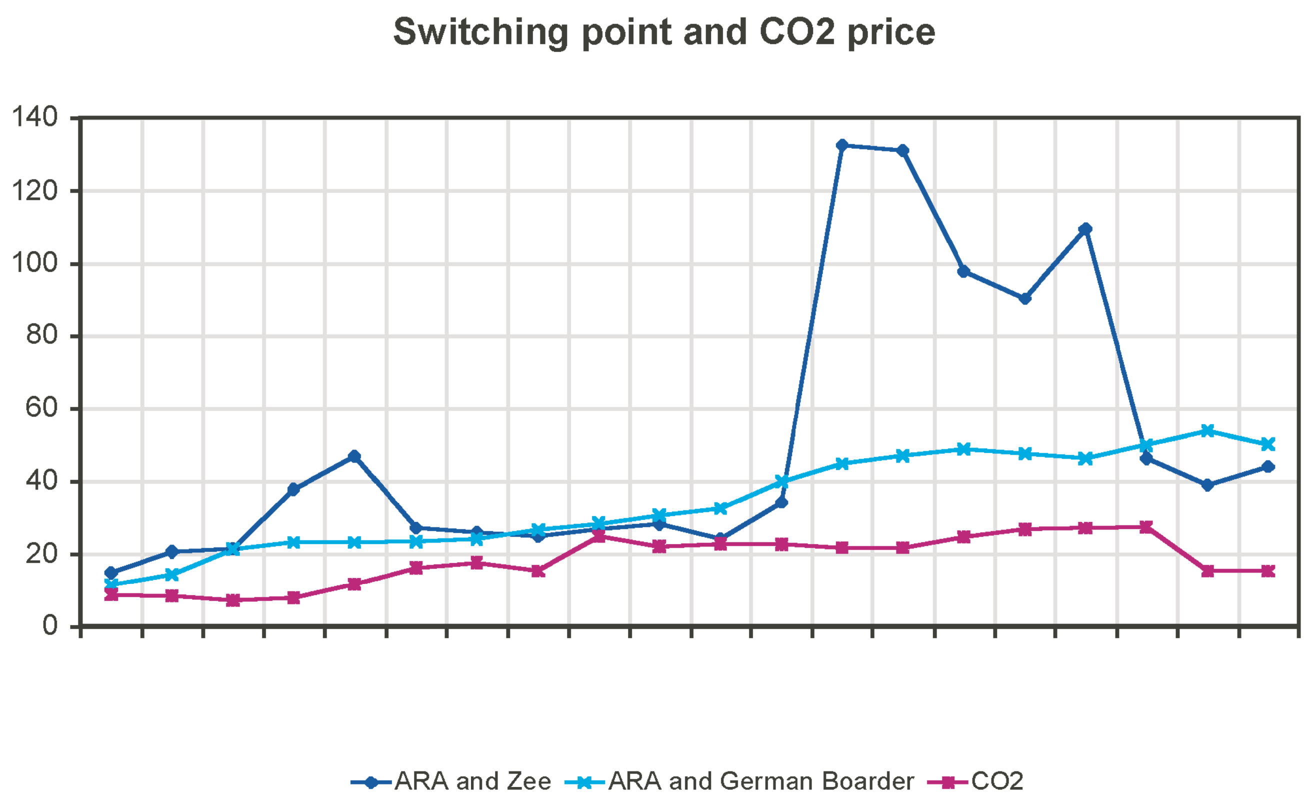
c_c and c_g be the prices of coal and natural gas (€/GJ~$/MMBtu)
h_c and h_g be the heat rates of coal and gas plants (GJ/MWh)
e_c and e_g be the emission rates of coal and gas plants (in t CO_2/MWh)
λ be the price of a CO_2 allowance (€/t CO_2)

Then one compares

$$h_c c_c + e_c \lambda \text{ with } h_g c_g + e_g \lambda$$

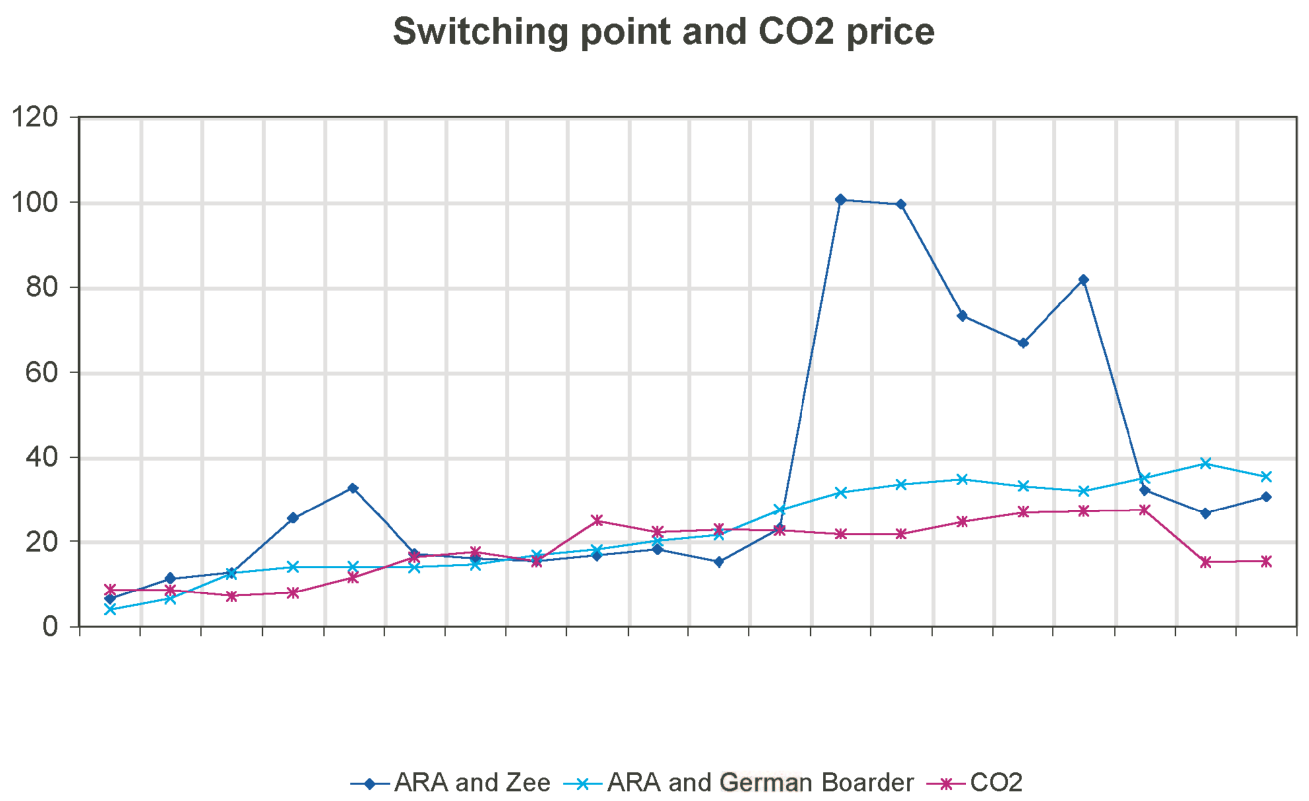
to get the "meritorder" or optimal dispatch

Did we see a lot of substitution during the first phase ? (1)



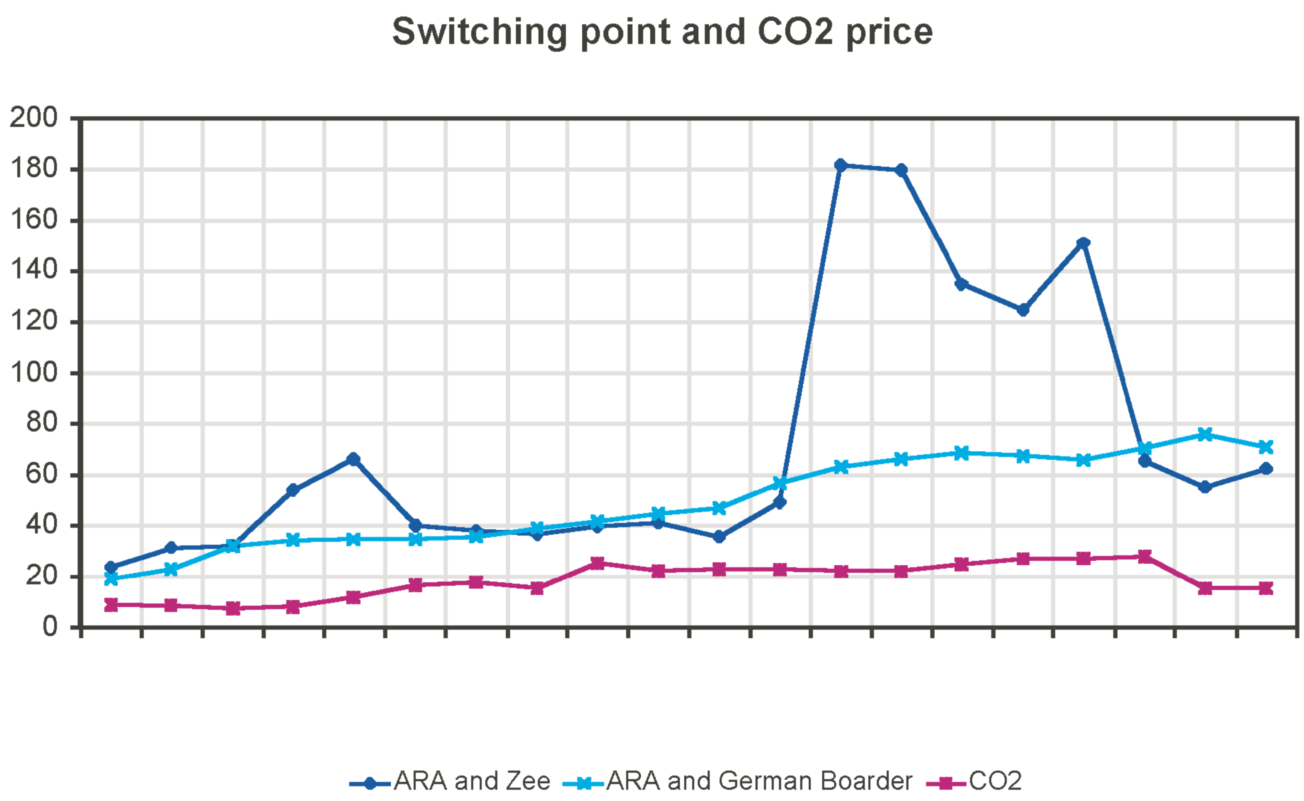
CCGT@49/coal@37 and CO_2

Did we see a lot of substitution during the first phase ? (2)



CCGT@57/coal@37 and CO_2

Did we see a lot of substitution during the first phase ? (3)



CCGT@57/coal@46 and CO_2

Did we see a lot of substitution during the first phase ? (4)

- Not clear
  - Most of time, CO_2 prices did not reach the level necessary to induce a substitution to gas that would have reduced emissions
  - This is undoubtedly due to high gas prices that were not foreseen when the EU-ETS was conceived

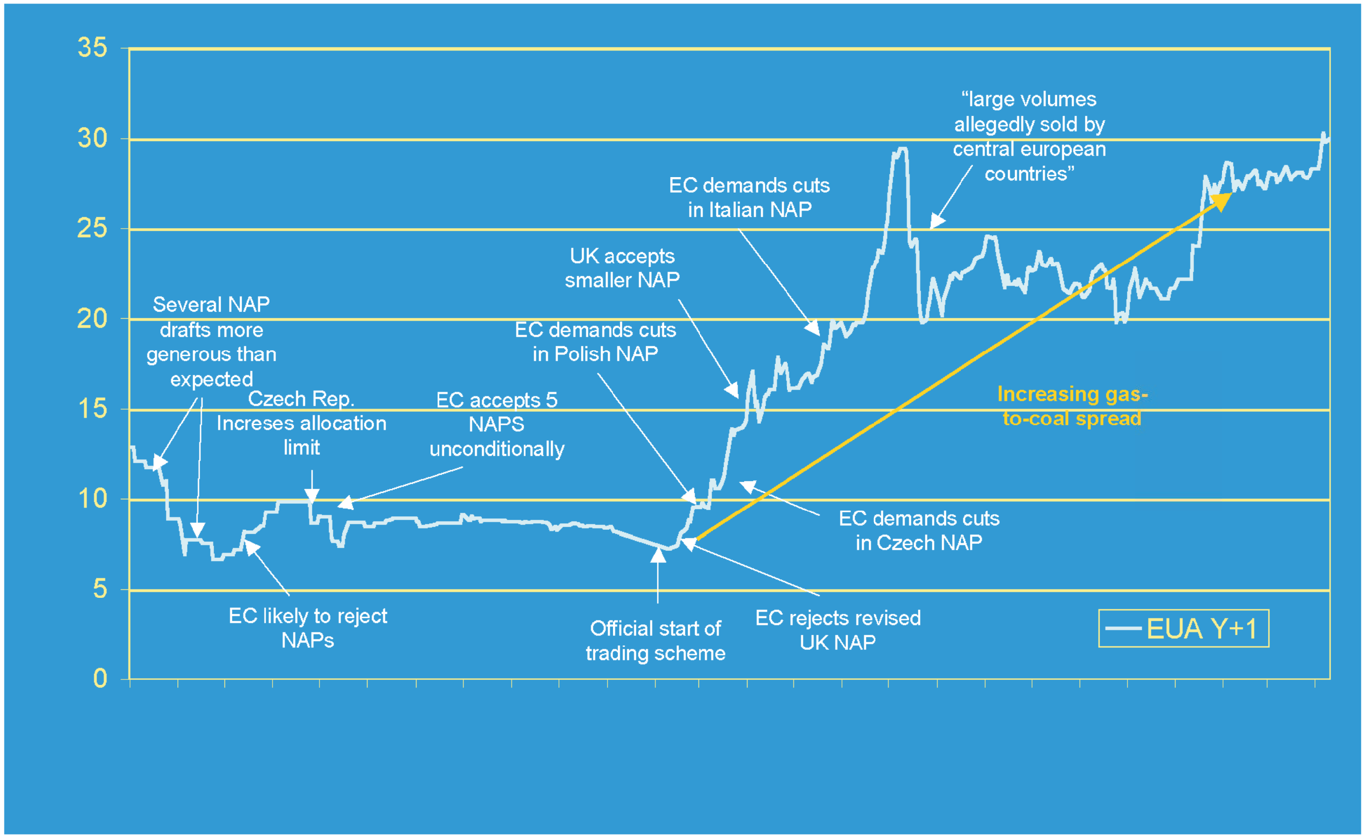
- Still CO_2 prices were high
  In any case much higher than expected

What we don't fully understand but can make sense of

- Why are CO2 prices high ? (even though switching points are higher)

- Why were these so variable (before the crash of April 2006)?

We saw a lot of volatility



Evolution before April 24th

The crash of April 24th

- Figures on consumption of allowances started to leak out

- One realized that there would be more allowances available than expected

- And even after April/May, there remains considerable uncertainty as to whether this first period will be long or short allowances

The impact of uncertainty on the price: counter productive limitation of arbitrage (1)

- Emission allowances are a finite resource traded in a very short compliance period (almost non storable)

- At some period of time, new information on quantities can drastically modify the expectation of the market on remaining allowances to be traded in the rest of the compliance period
  - Granting of allowances in some MS
  - Consumption of allowances to substitute hydro in dry years
  - Impact of economic growth on demand
  - Availability of registries

- As we saw in April of this year

The impact of uncertainty on the price: counter productive limitation of arbitrage (2)

- If information indicates that there remain little allowances, prices might jump; they may fall otherwise
  - This is exacerbated when the end of the horizon of the trading period is close.
- Because of the exclusion of inter compliance period arbitrage, this increases the forward price of allowances:
  the lower bound is zero, but the upper bound can go up a VOLL related value in case of market failure
- In expectation (intra compliance period arbitrage) the price can be
  - High
  - Even though not sufficient to induce a gas to coal substitution

The dispute over windfall profits

Why do generators benefit from the EU-ETS

- Assume generators do not exert market power

- Then they sell at marginal cost

- Marginal cost includes the value of the allowances (an opportunity cost) whether these were obtained free or had to be purchased

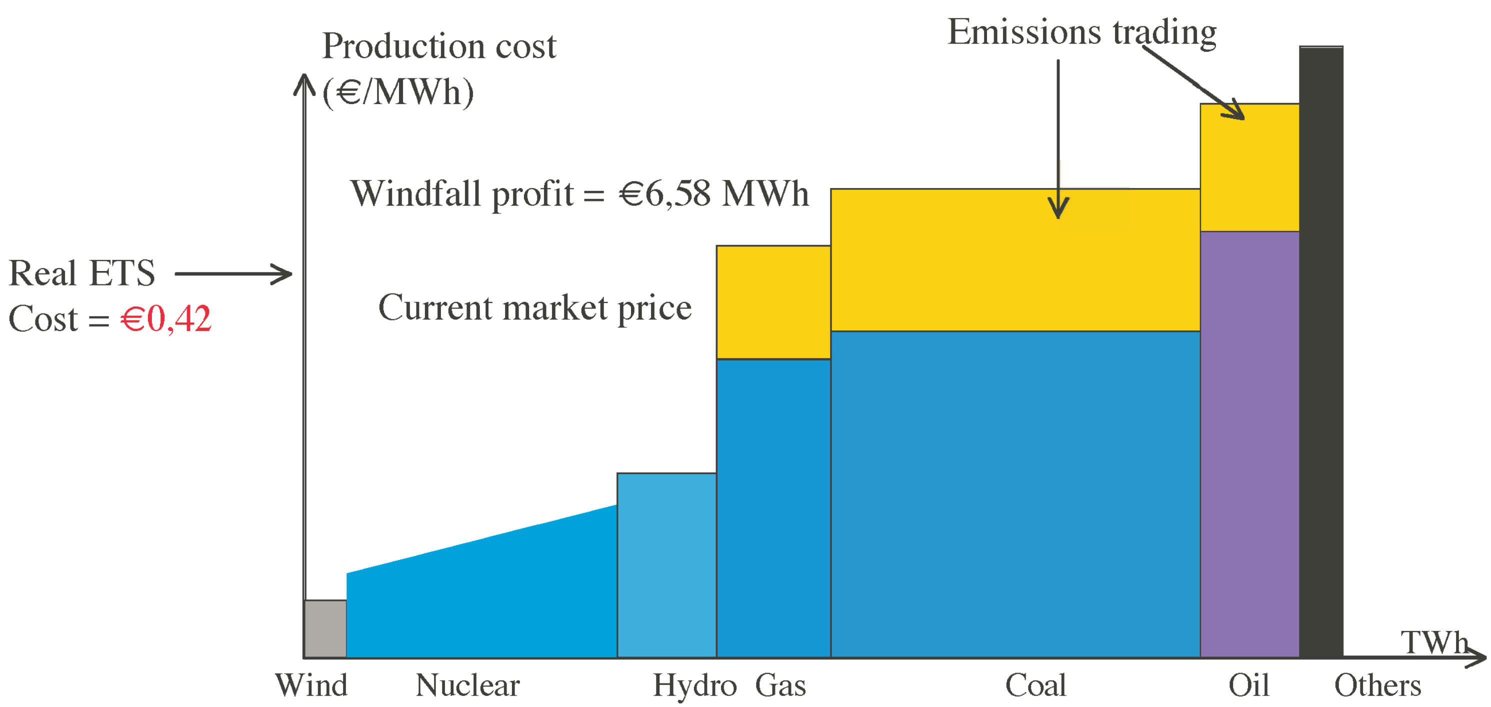
- Therefore the price should move like the fuel cost of the marginal plant in this case gas
  + the opportunity cost of CO_2 for that plant.

This is the result of the *merit order*

And this is what is seen on the market to the dismay of politicians and large industrial consumers (who have foreseen this well before January 2005)

From "Environmental Finance", April 2004)

The merit order and the demand in a single node



On the windfall profits

- We have a theory that explains what happens in practice
- Given the high gas prices, notwithstanding the current CO2 price
  - Coal operates in base load
  - The marginal cost of electricity increases
  - And hence the price of electricity (assuming no exercise of market power)
  - This increases the profits of some plants but may decrease the profit of others
  - This might not have been intended, but is an unavoidable consequence of the ETS

- The major policy questions: do we understand
  - That the pass through of $CO2$ price in electricity price is normal in a competitive market?
  - The different components of the windfall profits?
  - And why some of those windfall profits are necessary in order to induce investments? (see later)
- The usual debate between fairness and efficiency

The longer term in the power sector granting free allowances

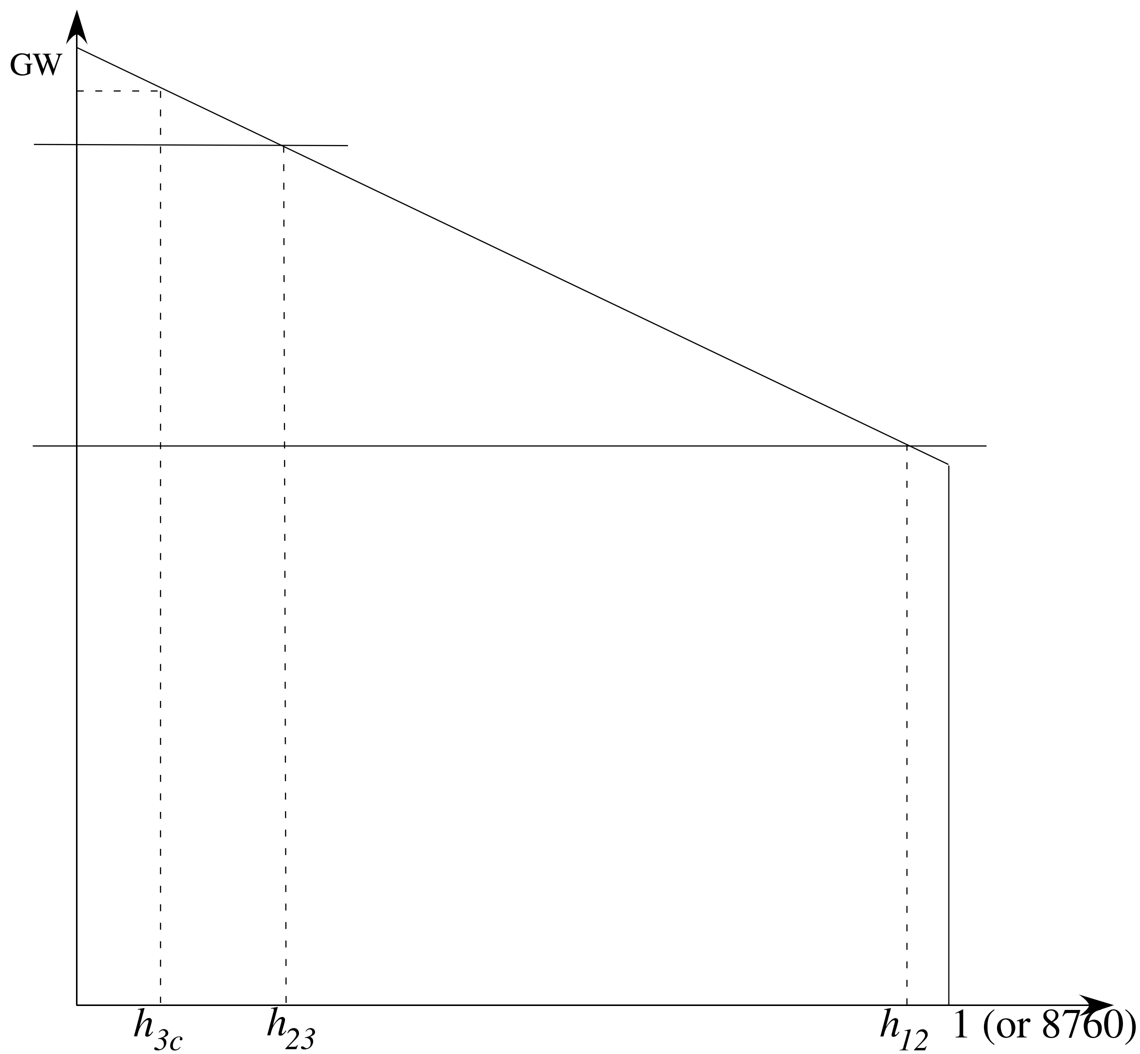
The investment situation

- Reserve margins are decreasing
  - is this good (the elimination of excess capacity by competition ?)
  - or bad (a shortage of investments because of market or policy failure ?)
- A lot of “paper projects”
  and less “real projects”
- And a question
  - what could be the additional impact of the EU-ETS ?

A simple analysis

Starting point : Joskow (2006) on investments

- three technologies (base, intermediate, peak)
- a price inelastic load duration curve
- remuneration of plants at short run marginal cost as long as capacity is not tight
- VOLL vs. price cap
- the introduction of the missing money


GW
h3c
h23
h12
1 (or 8760)

The reference case: the perfectly informed and benevolent social planner

Utilization of the different plants

- $K_1 + h_{12}c_1 = K_2 + h_{12}c_2 \qquad h_{12} = \dfrac{K_1 - K_2}{c_2 - c_1}$

- $K_2 + h_{23}c_2 = K_3 + h_{23}c_3 \qquad h_{23} = \dfrac{K_2 - K_3}{c_3 - c_2}$

- Demand $D = p_{\text{peak}} - \beta \star h$

- $z_1 = p_{\text{peak}} - \beta h_{12}; \quad z_2 = \beta(h_{12} - h_{23}); \quad z_3 = \beta h_{23}$

This gives the least cost system

The missing money (from Joskow (2006))

Plant 1 makes a	0	margin during	$[h_{12}, 1]$
	$(c_2 - c_1)$		$[h_{23}, h_{12}]$
	$(c_3 - c_1)$		$[0, h_{23}]$
Plant 2 makes a	0	margin during	$[h_{12}, 1]$
	0		$[h_{23}, h_{12}]$
	$(c_3 - c_2)$		$[0, h_{12}]$
Plant 3 makes a	0	margin during	$[h_{12}, 1]$
	0		$[h_{23}, h_{12}]$
	0		$[0, h_{12}]$

Plant 3 will thus not be constructed

Equilibrium with missing money

Suppose plant 3 receives $\overline{p}$ when at capacity (that is during a curtailment). We define

$[h_{12}, 1]$	duration when plant 1 is marginal
$[h_{23}, h_{12}]$	duration when plant 2 is marginal
$[h_{3c}, h_{23}]$	duration when plant 3 is marginal
$[0, h_{3c}]$	duration when there is a curtailment.

Plant 1 makes a	0	margin during	$[h_{12}, 1]$
	$(c_2 - c_1)$		$[h_{23}, h_{12}]$
	$(c_3 - c_1)$		$[h_{3c}, h_{23}]$
	$(\overline{p} - c_1)$		$[0, h_{3c}]$
Plant 2 makes a	0	margin during	$[h_{23}, h_{12}] \cup [h_{12}, 1]$
	$(c_3 - c_2)$		$[h_{3c}, h_{23}]$
	$(\overline{p} - c_2)$		$[0, h_{3c}]$
Plant 3 makes a	0	margin during	$[h_{3c}, h_{23}] \cup [h_{23}, h_{12}] \cup [h_{12}, 1]$
	$(\overline{p} - c_3)$		$[0, h_{3c}]$

The equilibrium is given by

$$
\begin{aligned}
K_1 &= (h_{12} - h_{23})(c_2 - c_1) + (h_{23} - h_{3c})(c_3 - c_1) + h_{3c}(\overline{p} - c_1) \\
K_2 &= (h_{23} - h_{3c})(c_3 - c_2) + h_{3c}(\overline{p} - c_2) \\
K_3 &= h_{3c}(\overline{p} - c_3)
\end{aligned}
$$

Note

h_{3c} (curtailment) increases when $\overline{p}$ decreases

h_{12} and h_{23} remain unchanged (in some interval)

The reference case with emission constraint

Let λ be the value of an emission allowance. Assume that we retain

$$c_1 + e_1\lambda < c_2 + e_2\lambda < c_3 + e_3\lambda$$

Alternatively, we can write

$$\begin{array}{rcl} K_1 & = & (h_{12} - h_{23})[(c_2 - c_1) + \lambda(e_2 - e_1)] + (h_{23} - h_{3c})[(c_3 - c_1) \\ & + & \lambda(e_3 - e_1)] + h_{3c}[\overline{p} - (c_1 + e_1\lambda)] \\ \\ K_2 & = & (h_{23} - h_{3c})[(c_3 - c_1) + \lambda(e_3 - e_1)] + h_{3c}[\overline{p} - (c_2 + e_2\lambda)] \\ \\ K_3 & = & h_{3c}[\overline{p} - (c3 + e_3\lambda)] \end{array}$$

Emissions are

- Plant 1 in base

$$e_1(p_{\text{peak}} - \beta\,1) = e_1\,p_{\text{base}}$$

- Plant 1 in intermediate load

$$\begin{aligned} & e_1\Big[(p_{\text{peak}} - \beta h_{12}) - (p_{\text{peak}} - \beta\,1)\Big]\frac{1+h_{12}}{2} \\ = \;& e_1\beta(1-h_{12})\left(\frac{1+h_{12}}{2}\right) \\ = \;& \frac{e_1\beta}{2}[1^2 - h_{12}^2] \end{aligned}$$

In total

$$e_1\Big[(p_{\text{peak}} - \beta\,1) + \frac{\beta}{2}(1^2 - h_{12}^2)\Big]$$

- Plant 2 in intermediate load

$$e_2\beta(h_{12} - h_{23})\frac{h_{12} + h_{23}}{2} = \frac{e_2\beta}{2}(h_{12}^2 - h_{23}^2)$$

- Plant 3 in peak

$$e_3\beta h_{23}\frac{h_{23}}{2} = \frac{e_3\beta}{2}h_{23}^2$$

Total emissions are

$$\begin{aligned} & e_1\left[\left(p_{\text{peak}} - \beta\,1\right) + \frac{\beta}{2}\left(1^2 - h_{12}^2\right)\right] \\ + \; & \frac{e_2\beta}{2}(h_{12}^2 - h_{23}^2) + \frac{e_3\beta}{2}h_{23}^2 = E \end{aligned}$$

Equilibrium with VOLL($\overline{p}$) when there is an emission constraint

Let "cap" be the cap on emissions and "pcap" the cap on prices ($\overline{p}$)
Combine

$$
\begin{aligned}
K_1 &= (h_{12} - h_{23})[(c_2 - c_1) + \lambda(e_2 - e_1)] \\
&+ (h_{23} - h_{3c})[(c_3 - c_1) + \lambda(e_3 - e_1)] \\
&+ h_{3c}[\overline{p} - (c_1 + e_1\lambda)] \\
\\
K_2 &= (h_{23} - h_{3c})[(c_3 - c_2) + \lambda(e_3 - e_2)] + h_{3c}[\overline{p} - (c_2 + e_2\lambda)] \\
\\
K_3 &= h_{3c}[\overline{p} - (c_3 + e_3\lambda)]
\end{aligned}
$$

with

$$e\,m_1 + e\,m_2 + e\,m_3 \leq \text{cap}$$

As before (and provide we check that the solution is compatible with the assumptions)

Emissions are

- for plant 1

$$e\,m_1 = e_1\Big[\Big(p_{\text{peak}} - \beta\,1\Big) + \frac{\beta}{2}\Big(1^2 - h_{12}^2\Big)\Big] \text{ (see before)}$$

- for plant 2

$$e\,m_2 = \frac{e_2\beta}{2}(h_{12}^2 - h_{23}^2) \text{ (see before)}$$

- for plant 3

$$e\,m_3 = \frac{e_3\beta}{2}(h_{23}^2 - h_{3c}^2) \text{ (see before)}$$

and hence

$$
\begin{aligned}
\text{cap} &= e_1\left[\left(p_{\text{peak}} - \beta\,1\right) + \frac{\beta}{2}(1^2 - h_{12}^2\right)\right] \\
&+ \frac{e_2\beta}{2}\left(h_{12}^2 - h_{23}^2\right) + \frac{e_3\beta}{2}\Big)(h_{23}^2 - h_{3c}^2\Big)
\end{aligned}
$$

Check

$$0 \leq h_{3c} \leq h_{23} \leq h_{12} \leq 1$$

Equilibrium with VOLL($\overline{p}$) when there is an emission constraint and free allowances

Let a_1, a_2 and a_3 be the free quantities of allowances per MWh of invested capacity. One writes

$$\begin{aligned}
K_1 - a_1\lambda &= (h_{12} - h_{23})[(c_2 - c_1) + \lambda(e_2 - e_1)] \\
&+ (h_{23} - h_{3c})[(c_3 - c_1) + \lambda(e_3 - e_1)] \\
&+ h_{3c}[\overline{p} - (c_1 + e_1\lambda)]
\end{aligned}$$

$$K_2 - a_2\lambda = (h_{23} - h_{3c})[(c_3 - c_2) + \lambda(e_3 - e_2)] + h_{3c}[\overline{p} - (c_2 + e_2\lambda)]$$

$$K_3 - a_3\lambda = h_{3c}[\overline{p} - (c_3 + e_3\lambda)]$$

with

$$
\begin{aligned}
\text{cap} &= e_1\left[\left(p_{\text{peak}} - \beta\,1\right) + \frac{\beta}{2}(1^2 - h_{12}^2\right)\Big] \\
&+ \frac{e_2\beta}{2}\left(h_{12}^2 - h_{23}^2\right) + \frac{e_3\beta}{2}\Big)(h_{23}^2 - h_{3c}^2\Big)
\end{aligned}
$$

Check

$$0 \le h_{3c} \le h_{23} \le h_{12} \le 1$$

Application

Nuclear is reconsidered but is still mostly forbidden in the EU

Consider coal gas substitution (data inspired by Bouttes (2006))

	Coal	CCGT	GT	
capital cost	29	14	6	€/Mwh
fuel cost	2	4 or 6	4 or 6	€/GJ
efficiency	.46	.58	.3	%
emission factor	.8	.4	.77	ton/Mwh
Total ($CO_2 = 0$)	44.65	38.82 (4)	54(4)	
		51.24(6)	78(6)	
Total ($CO_2 = 15$)	56.65	44.82(4)	65.55(4)	€/Mwh
		57.24 (6)	89.55 (6)	

Peak demand: 22 GW; Base demand: 10 GW (Joskow's example)

Two reference situations VOLL vs. Price Cap (Gas price at Euro 7/GJ)

	VOLL (4000)	PCap (250)
Coal (GW)	15.524	15.524
CCGT (GW)	4.108	4.108
GT (GW)	2.349	1.933
rel	.9985	.9639
emission (10^6 t)	106.76	106.71
total cost (10^6 €) (interruption valued at 4000)	77.5042	80.6287
λ (€/t)	0	0

Coal@2, Gas@7, pcap@4000

	no cap	cap = 100	cap = 98	cap = 96	cap = 93	cap = 92
Coal (GW)	15.524	12.455	11.990	11.329	10.416	10.126
CCGT (GW)	4.108	7.578	8.077	8.772	9.733	10.036
GT (GW)	2.349	1.948	1.916	1.877	1.832	1.819
rel	0.9985	0.9985	0.9985	0.9985	0.9985	0.9985
total cost (10^6 €)	77.5042	79.6573	79.8905	80.2917	80.9970	81.2555
emission (10^6 t)	106.76	100	98	96	93	92
μ (€/t)	0	22.34	24.54	27.30	30.64	31.59

Coal@2, Gas@7, pcap@250

	no cap	cap = 100	cap = 98	cap = 96	cap = 93	cap = 92
Coal (GW)	15.524	12.71	12.00	11.33	10.43	10.13
CCGT (GW)	4.108	7.30	8.06	8.77	9.71	10.0
GT (GW)	1.933	1.50	1.44	1.40	1.34	1.34
rel	0.9639	0.9599	0.9592	0.9586	0.9579	0.9576
total cost (10^6 €)	80.6287	83.04	83.51	84.04	84.86	85.17
emission (10^6 t)	106.71	100	98	96	93	92
μ (€/t)	0	21.04	24.4924	27.3184	30.57	31.57

"Are there easy remedies to the missing money", see Joskow (2006)

1. Various sources of missing money (and uncertain remedies?)

2. most consumers are not exposed to high peak electricity prices (and hence cannot react)

3. "priority rationing contracts" cannot be implemented today

4. operating reserves have public good attributes

5. operating protocol may perturb scarcity pricing, e.g. voltage reduciton lack of sufficiently disaggregated relevant products

6. inelastic demand function in the short run

7. price cap look like a reason of missing money but are rarely hit

The missing money and the free allowances

Consider a solution of the equation of Section 5 with a desired CO_2 reduction target and a given "reliability" level h_{3c}.

Assume h_{3c} corresponds to a VOLL that you do not want to implement (but you want the investment level).

Then, we have

$$K_3 = h_{3c}[\text{VOLL} - (c_3 + e_3\,\lambda)$$

Suppose we implement a cap $\overline{p} \ll$ VOLL.

We can restore h_{3c} at equilibrium by giving free a_3 such that

$$K_3 - a_3\,\lambda = h_{3c}[\overline{p} - (c_3 + e_3\,\lambda)]$$

where h_{3c} and λ satisfy

$$K_3 = h_{3c}[\mathsf{VOLL} - (c_3 + e_3\,\lambda)]$$

or

$$K_3 - a_3\lambda = h_{3c}[\mathsf{VOLL} - (c_3 + e_3\,\lambda)] - h_{3c}[\mathsf{VOLL} - \overline{p}] = K_3 - h_{3c}[\mathsf{VOLL} - \overline{p}]$$

Suppose $h_{3c} = .0015$, VOLL $= 4000$, $\overline{p} = 250$, $K_3 = 6$, $\lambda = 15$

$$15a_3 = .0015(4000 - 250) \text{ or } a_3 = 0.0001 \times 3750 = 0.3750$$

Each MWh of gas turbine would receive .375 allowance. Alternatively each MW of gas turbine would receive .375 $\times$ 8760 allowances. This This essentially covers the investment costs (6-0.375*15=0.375 Euro/MWh)

Coal@2, Gas@7, pcap@250, free allowances endogenous

Objective: minimize the value of the free allocation
Constraint: satisfy the reliability constraint

	cap = 100	cap = 98	cap = 96	cap = 93	cap = 92
Coal (GW)	12.38	11.66	11.04	10.15	
CCGT (GW)	6.30	7.04	7.72	8.67	
GT (GW)	3.35	3.28	3.22	3.15	cannot find
rel	0.9985	0.9985	0.9985	0.9985	a solution where
total cost (10^6 €)	79.7010	80.038	80.4424	81.1507	coal $\geq$ 10 GW
emission (10^6 t)	100	98	96	93	
μ (€/t)	22.97	25.95	28.44	31.50	
α (t/MW capacity)	.2514	.223	.20	.18	

This is obviously not a good policy (see total costs), but it is better than no policy.

Risk

The merchant system is risky.

Consider a life of 30 years and assume a discount rate going from 5% (risk free rate) to 10 % (CCGT when gas makes the price most of the time) to 15 % (coal when gas makes the price most of the time)

$$K_1 \text{ goes from 29 to 29 } \times \frac{17}{7}$$
$$K_2 \text{ goes from 14 to 14 } \times \frac{11}{7}$$

We want

$$K_1^{5\%} = K_1^{15\%} - a_1\,\lambda$$
$$K_2^{5\%} = K_2^{10\%} - a_2\,\lambda$$

or for $\lambda = 15$

$$
\begin{aligned}
a_1 &= \frac{29}{15} \times \frac{8}{7} = 2.2 \\
a_2 &= \frac{14}{15} \times \frac{4}{7} = .533
\end{aligned}
$$

In order to achieve the desired reduction (the one leading to a λ of 15 €/ton), we would allocate allowances tocompensate the risk of the merchant system of 2.2 allowances/Mwh of coal unit and .533 Mwh of gas unit.
(Coal is the risky plant if gas is setting the electricity price (Roques 2006)!)

Refinement (an APT view)

Isolate the $\left.\begin{array}{l} CO_2 \\ \text{gas} \end{array}\right\}$ contributions to revenue

Revenue

During curtailment: the price is independent of CO_2 and gas price

When GT is at the margin the price is

$$\frac{3.6\ C_{\text{gas}}}{\text{eff}_{GT}} + \lambda\, e_{GT}$$

When CCGT is at the margin the price is

$$\frac{3.6 C_{\text{gas}}}{\text{eff}_{CCGT}} + \lambda\, e_{CCGT}$$

Cost: only GT and CCGT are influenced by the cost of gas

We revise our equilibrium conditions to account for specific risk premia

$$
\begin{aligned}
K_1 - \xi_\lambda a_1 \lambda &= (h_{12} - h_{23})[\xi_2 c_2 - \xi_1 c_1) + \xi_\lambda \lambda (e_2 - e_1) \\
&+ (h_{23} - h_{3c})[(\xi_3 c_3 - \xi_1 c_1) + \xi_\lambda (e_3 - e_1))] \\
&+ h_{3c}[\overline{p} - (\xi_1 c_1 + \xi_\lambda e_1 \lambda)]
\end{aligned}
$$

$$
\begin{aligned}
K_2 - \xi_\lambda a_2 \lambda &= (h_{23} - h_{3c})[\xi_3 c_3 - \xi_2 c_2) + \xi_\lambda \lambda (e_3 - e_2))] \\
&+ h_{3c}[\overline{p} - (\xi_2 c_2 + e_2 \xi_\lambda \lambda)]
\end{aligned}
$$

$$
K_3 - \xi_\lambda a_3 \lambda = h_{3c}[\overline{p} - (\xi_3 c_3 + \xi_\lambda e_3 \lambda)]
$$

How are the ξ determined

Consider $\sum_{t=1}^{T} \dfrac{1}{(1+r)^t}$ where r is the risk free rate.

Let $\sum_{t=1}^{T} \frac{1}{(1+r+\eta)^t}$ where η is a risk premium

Take $i = 4\%$ and e.g. $\eta_1 = 2\%, \eta_2 = 4\%, \eta_{\mathrm{CO}_2} = 8\%$

Over 30 years we define

$$\xi = \frac{\displaystyle\sum_{t=1}^{T} \left(\frac{1}{1+r+\eta_i}\right)^t}{\displaystyle\sum_{t=1}^{T} \left(\frac{1}{1+r}\right)^t}$$

or

$$
\begin{array}{lll}
\xi_{\text{coal}} = \xi_1 \sim .8 & \text{or} & 1 - \xi_1 = .2 \\
\xi_{\text{gas}} = \xi_2 = \xi_3 \sim .65 & \text{or} & 1 - \xi_2 = 1 - \xi_3 = .35 \\
\xi - CO_2 = \xi_\lambda \sim .46 & \text{or} & 1 - \xi_\lambda = .54
\end{array}
$$

High Discounting

	cap = 98	cap = 96	cap = 93
Coal (GW)	11.88	11.24	10.32
CCGT (GW)	7.65	8.35	9.31
GT (GW)	2.45	2.3	2.3
rel	.9985	.9985	.9985
total cost (10^6 €)	79.87	80.27	80.98
emission (10^6 t)	98	96	93
μ (€/t)	19.04	19.7	19.72
α_{Coal} (t/MW capacity)	.6467	.6115	.5645
α_{CCGT} (t/MW capacity)	.400	.400	.400
α_{GT} (t/MW capacity)	.30	.2951	.2897

Low Discounting

	cap = 98	cap = 96	cap = 93
Coal (GW)	11.8	11.23	10.33
CCGT (GW)	7.62	8.32	9.29
GT (GW)	2.48	2.43	2.4
rel	.9985	.9985	.9985
total cost (10^6 €)	79.87	80.27	80.98
emission (10^6 t)	98	96	93
μ (€/t)	16.37	16.72	17.13
α_{Coal} (t/MW capacity)	.5854	.5410	.4819
α_{CCGT} (t/MW capacity)	.400	.400	.400
α_{GT} (t/MW capacity)	.35	.3425	.3344

Restructured electricity market systems suffer from several market failures

- These may hamper investments
- The role of free allowances should be considered in the context of these market failures
- Free allowances may thus correct distortion due to market failure instead of creating market failures in a perfect market
- But the allocation mode may differ depending on the market failure that one considers
- This is an awkward way of doing things but it may be better than waiting for the blackout