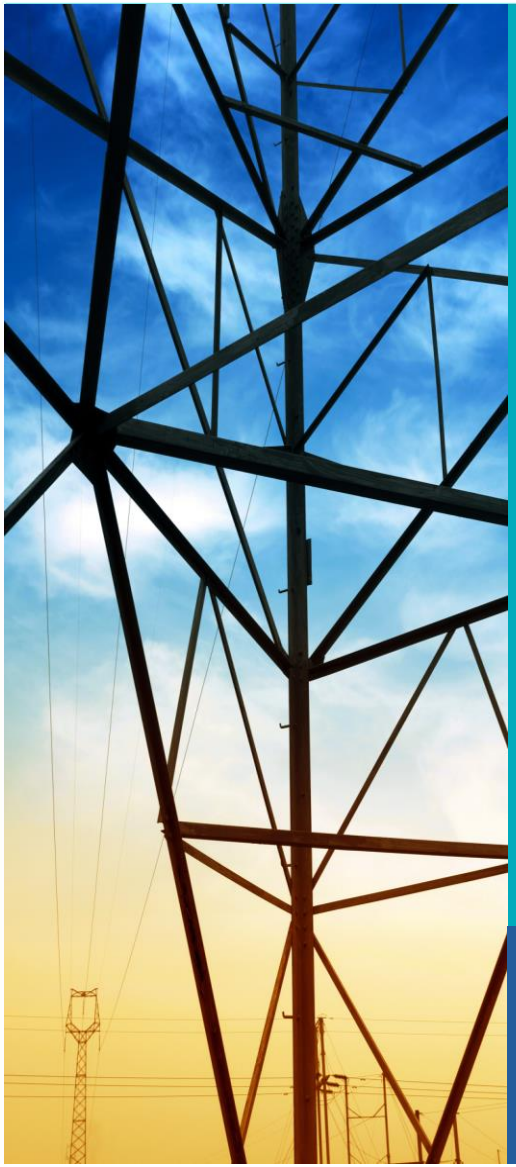

Ensuring Capacity Adequacy and CO_2 Emission Reductions with Low Carbon Technologies under Free Allocation of Allowances

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MARKET DESIGNS FOR LOW-CARBON ELECTRICITY GENERATION

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Market Designs for Low Carbon Technologies

Three essential strategies:

1. **Flexibilisation**

   Intraday markets, demand response, curtailment, storage, interconnections etc.

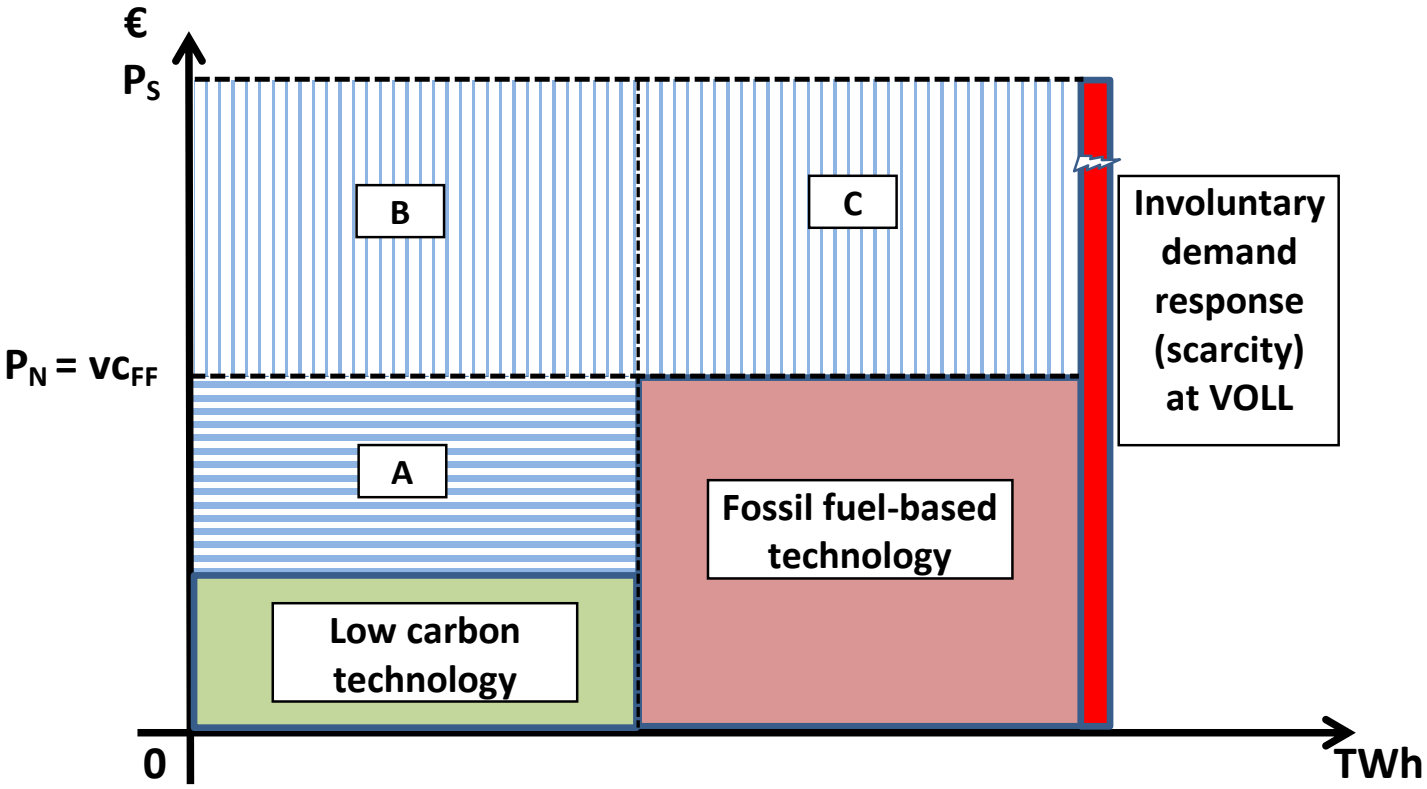
2. **Long-run revenue guarantees for low carbon technologies with high fixed costs**

   PPAs, FITs, CFDs, long-term contracts, capacity support for low carbon technologies etc.

3. **Reform of carbon markets**

   Strengthening targets, raising prices, increasing visibility, returning to free allocation.

1. The Stylized Long Term Situation in an Electricity Market without Carbon Pricing

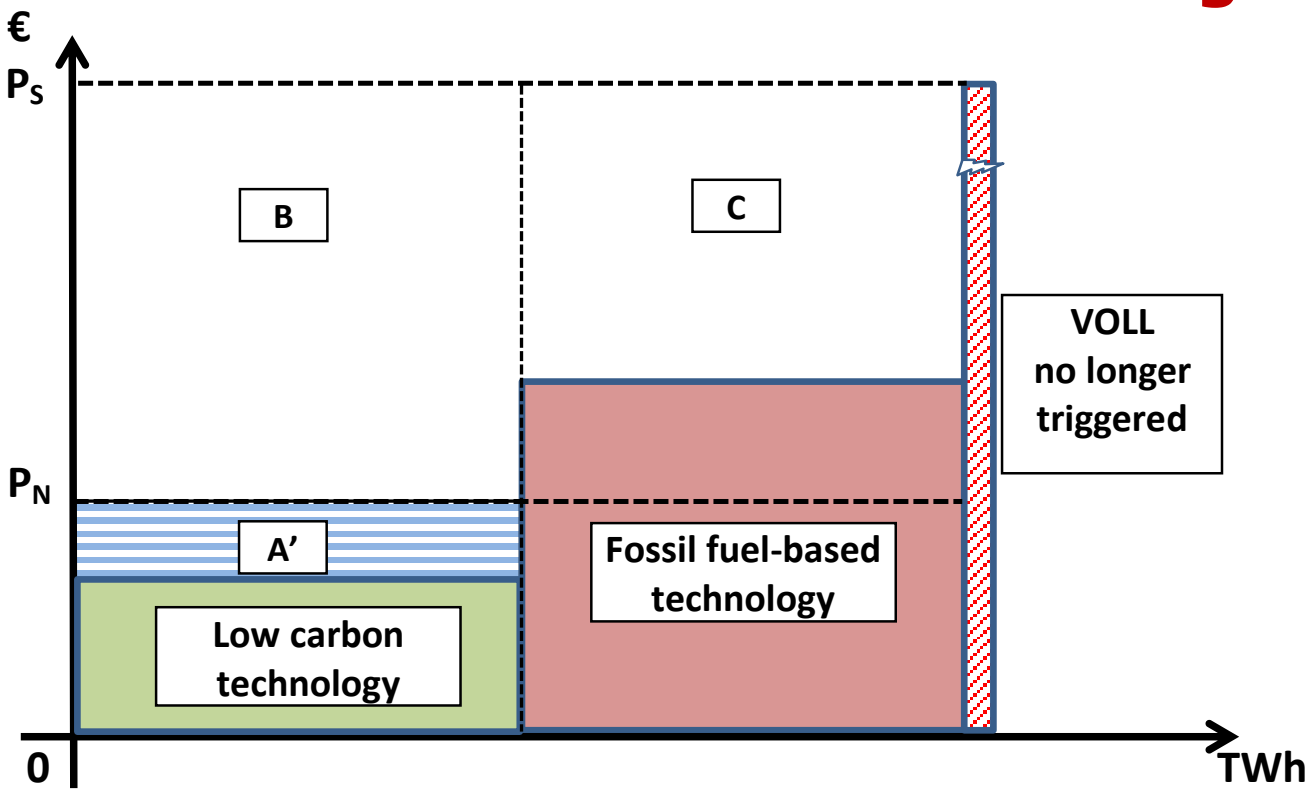


Profit of low carbon technology: $\Pi_{LC} = A + B - vc_{LC}*q_{LC} - INV_{LC} = 0$

Profit of fossil fuel technology: $\Pi_{FF} = (P_N - vc_{FF})*q_{FF} + C - INV_{FF} = 0.$

With $A = P_N*q_{LC}*(8760 - h_{VOLL})$, $B = q_{LC}*VOLL*h_{VOLL}$, and $C = q_{FF}*VOLL*h_{VOLL}$.

2. The Current Situation (with modest carbon pricing and out-of-market financing of selected low carbon technologies)



Profit of low carbon technology (no support): $\Pi_{LC} = A' - vc_{LC}*q_{LC} - INV_{LC} < 0$

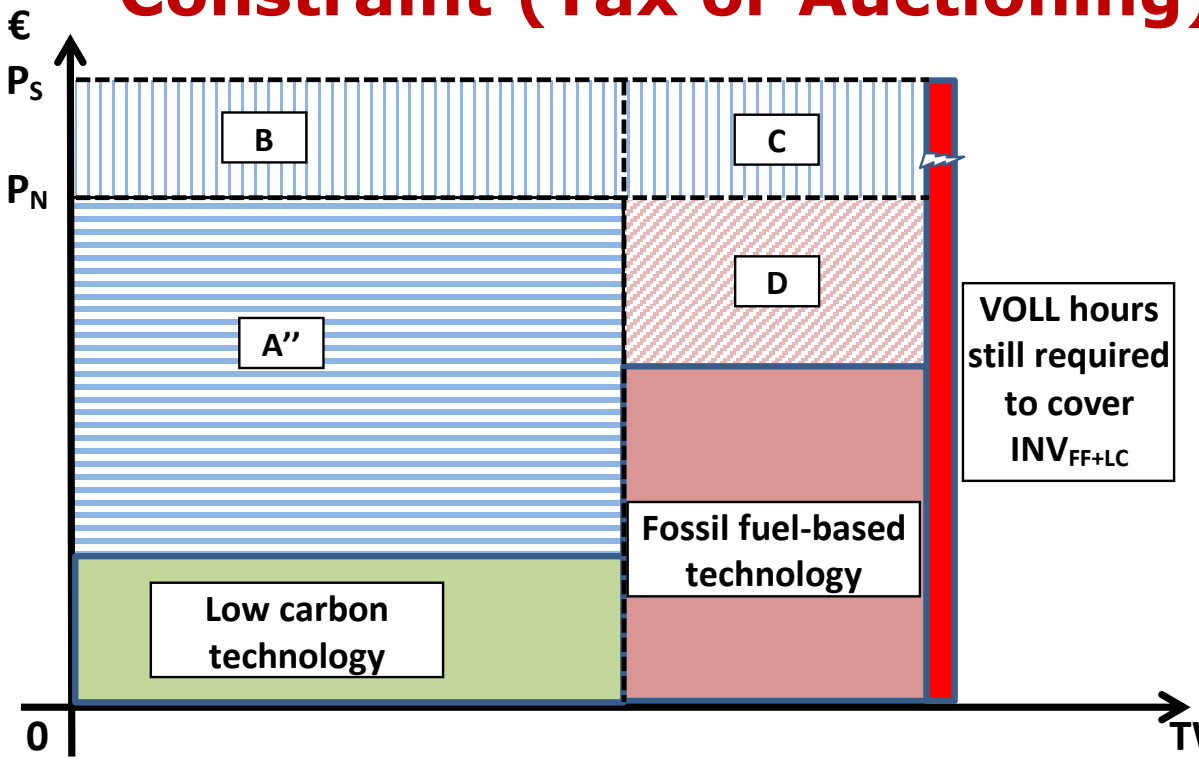
Profit of fossil fuel technology: $\Pi_{FF} = (P_N - vc_{FF})*q_{FF} - INV_{FF} << 0$

With $P_N = \alpha*vc_{LC} + (1 - \alpha)*(vc_{FF} + p_{CO2}*CO2_{FF})$

If low carbon technology receives out-of-market support (e.g., CSPE or EEG) profit becomes:

$\Pi_{LCS} = A' - vc_{LC}*q_{LC} - INV_{LC} + (INV_{LC} - (A' - vc_{LC}*q_{LC})) = 0.$

3. The Long Run Situation with a Carbon Constraint (Tax or Auctioning)



Situation similar to Case 1 as carbon tax is analytically identical to an increase in the variable costs of the fossil-fuel based technology.

Electricity consumers transfer part of CS as monetised resource rent to taxpayers (govmt.).

Share of LC technology increases. Scarcity pricing still required for covering fixed costs.

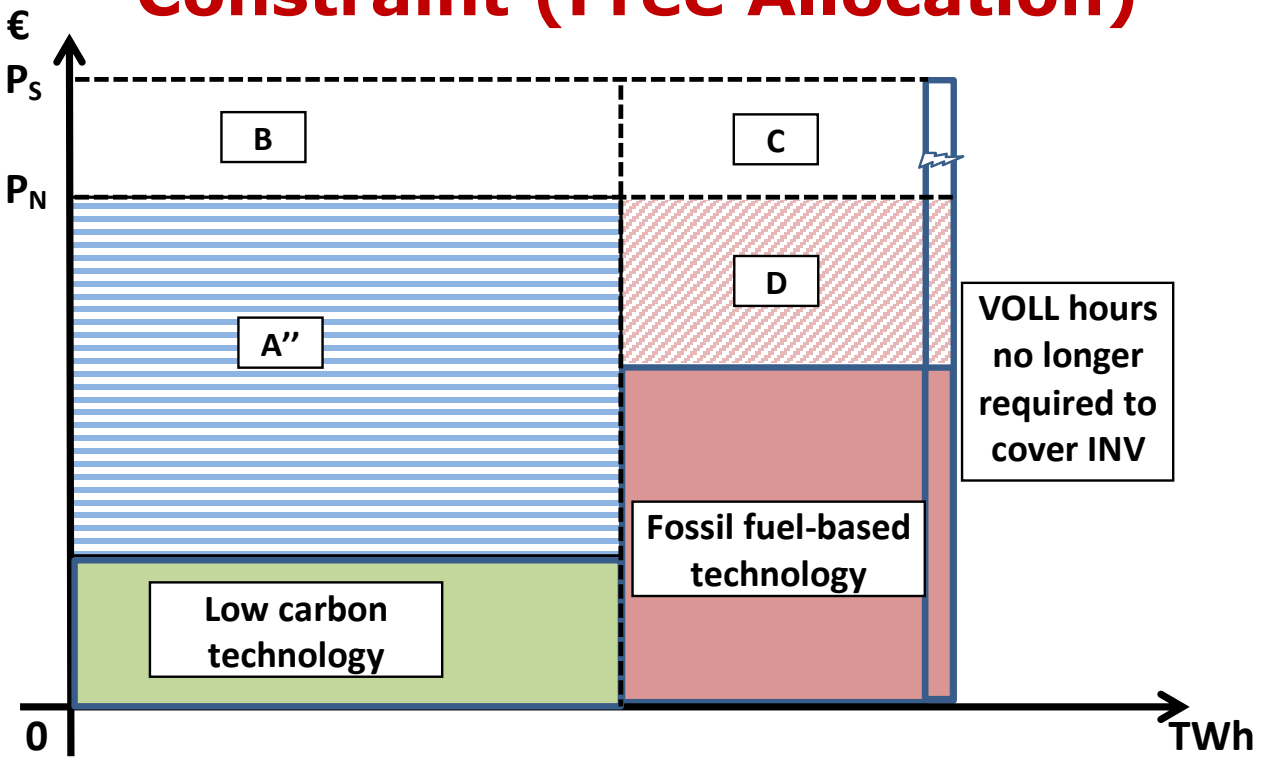
At European level, politically difficult to realise.

Profit of low carbon technology: $\Pi_{LC} = A'' + B - vc_{LC}*q_{LC} - INV_{LC} = 0$

Profit of fossil fuel technology: $\Pi_{FF} = (P_N - (vc_{FF} + p_{CO2}*CO2_{FF}))*q_{FF} + C - INV_{FF} = 0$.

With $P_N = vc_{FF} + p_{CO2}*CO2_{FF}$ and $D = p_{CO2}*CO2_{FF}*q_{FF}*(8760 - h_{VOLL})$.

4. The Long Run Situation with a Carbon Constraint (Free Allocation)



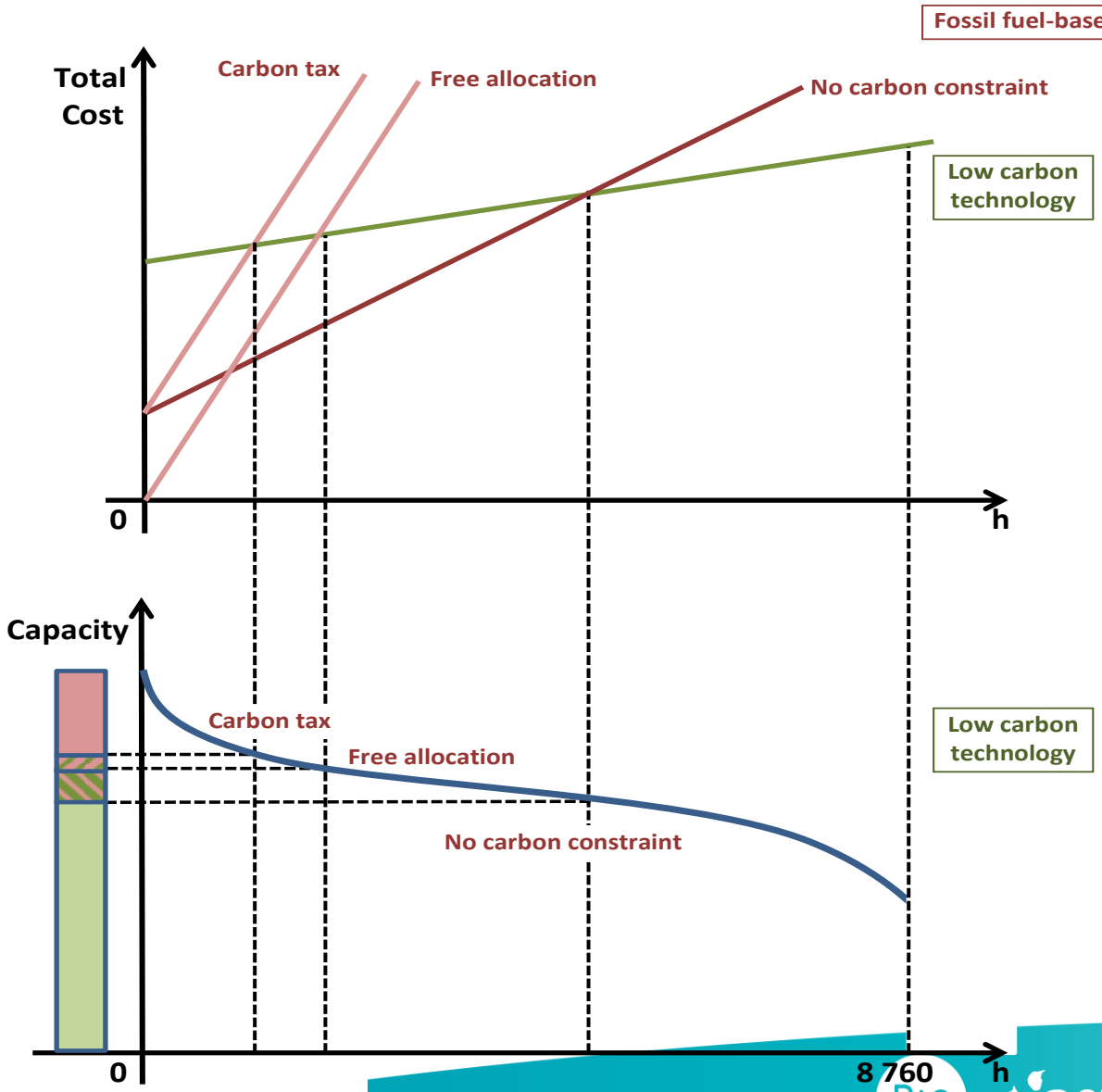
- Opportunity cost principle will ensure that marginal values are *not* affected.
- Marginal FF technology now earns rent (equivalent to *capital-cost subsidy*). Same effect as capacity payment covering "missing money". Scarcity pricing no longer required.
- Share of LC technology slightly lower than in Case 3, but higher than in Case 1.
- Environmentally, Cases 3 and 4 are identical (same CO2 target). EU political acceptability.

Profit of low carbon technology: $\Pi_{LC} = A'' - vc_{LC} * q_{LC} - INV_{LC} = 0$

Profit of fossil fuel technology: $\Pi_{FF} = (P_N - vc_{FF}) * q_{FF} - INV_{FF} = 0$.

With $P_N = vc_{FF} + p_{CO2} * CO2_{FF}$ (same as Case 3) and $D = p_{CO2} * CO2_{FF} * q_{FF} * 8760$.

5. Screening Curves Look as Follows



6. Welfare Considerations

A sufficiently high carbon constraint with free allocation of allowances in a competitive electricity market with free entry will yield a long-term equilibrium with

- Full remuneration of all factors including investment costs for both low carbon and fossil-fuel based producers.
- A CO2 emission reduction target that is identical to that under auctioning or an equivalent tax.
- No need for involuntary demand response during scarcity hours at VOLL.

How is this possible? The monetised resource rent embodied in the allowances works like a capacity payment for the fossil-fuel based producers.

NB: Not a theoretical first best solution. With perfect information and absence of lumpy investments or security of supply externalities, scarcity pricing remains least-cost solution.

However, the net efficiency losses are second-order. The opportunity costs of taxpayers in terms of lost revenue are compensated by increased CS and PS in electricity market.

In a broader framework that includes the security of supply externalities resulting from scarcity pricing, free allocation might well be the welfare optimising solution.

7. Conclusions

Research analyses impacts of carbon pricing on long-term equilibrium in electricity market.

- CO2 tax or auctioning combined with scarcity pricing remains first best but poses issues:
  - Inversion of historical CO2 use rights (res. rent transferred from electricity sector to taxpayers).
  - "Missing money" issue, capacity investment and security of supply remain unresolved.
  - Limited impact on electricity consumers as price increases are off-set by decreases in CSPE/EEG.
  - EU consensus for stricter targets and higher CO2 prices difficult for countries with fossil fuels.
- Return to free allocation of CO2 allowances as practiced during 2005-12, when EU ETS was widely seen as functioning, would have a number of significant advantages:
  - Respect of historically established CO2 rights (resource rent remains in electricity sector);
  - Identical to tax or auctioning in terms of environmental integrity. EU consensus for stricter targets and higher prices with countries relying on fossil fuels becomes possible.
  - Resolution of "missing money", capacity investment and security of supply by leaving monetized resource rent to producers.
  - Share of LC electricity lower than with CO2 tax but higher than in absence of carbon pricing.
  - Limited impact on electricity consumers as price increases are off-set by decreases in CSPE/EEG;
  - Inclusion of security of supply externalities points towards overall welfare maximization.

Returning to free allowances with strengthened targets is by far the most straightforward and quickest way to put the European electricity sector back on an economically sustainable low carbon footing!