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The impact of the GB Carbon Price Support on CO_2 emissions from electricity

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Winter Seminar, Cambridge

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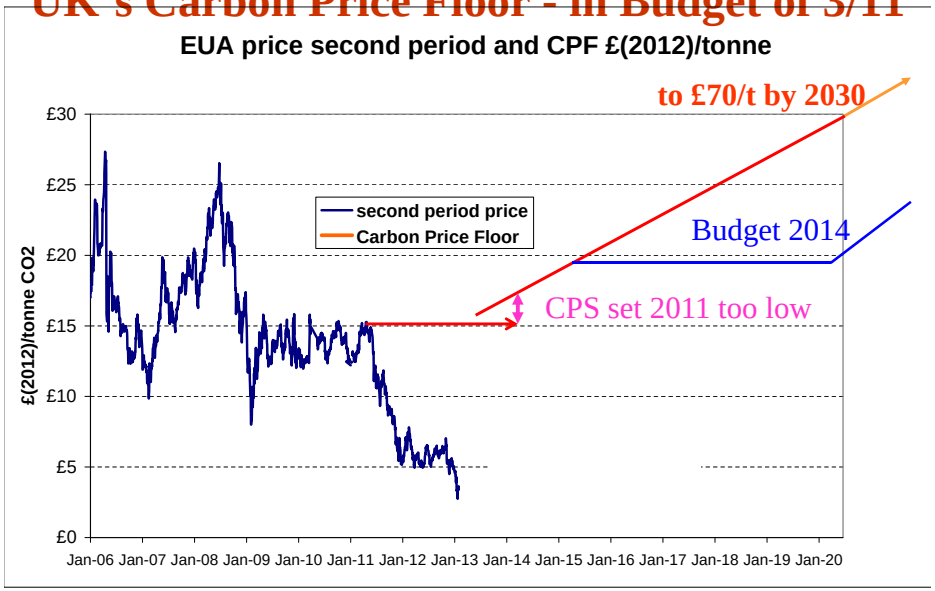
Outline

- Design of GB carbon price floor CPF
  - at Budget (September 2010) set EUA = €15 £(13.6)/t
  - CPS to bring CO_2 price to path to £(2011)30 by 2020
- Paper "The political economy of a carbon price floor for power generation",
  - Newbery, Reiner, Ritz (2018) *En. J.* forthcoming
  - Commissioned by Iberdrola, stimulated extra research

=> Questions: what is/might be impact of CPS

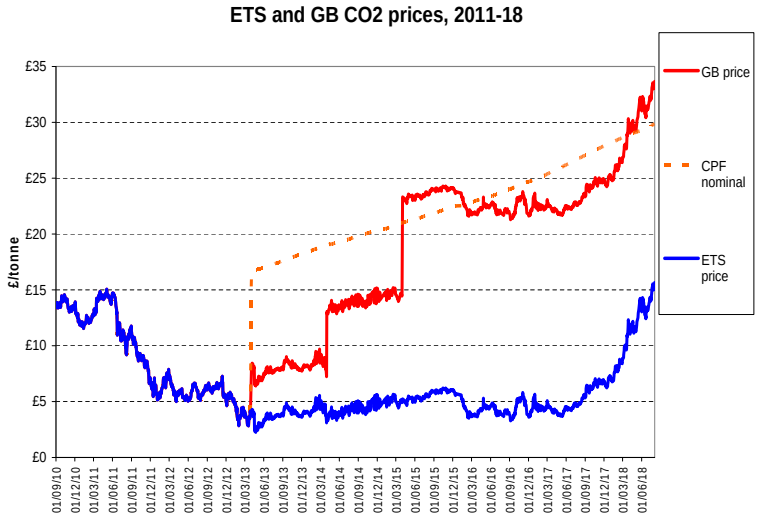
- On marginal displacement factor of wind and demand?
- On prices, interconnector flows, investment, …?

UK's Carbon Price Floor - in Budget of 3/11



Source: EEX and DECC Consultation

Combined impact of CPS and ETS



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Impact of Carbon Price Support

- CPS raises cost of coal relative to gas
  - Depending on coal and gas prices can shift coal from base to mid-merit or peaking
- Marginal plant sets price, determines trade
  - Depending on fuel determines marginal CO_2/MWh
  - Complicated by constraints (min load, ramp rates, etc.)
  - Different over 5-mins and an hour
- Wind displaces marginal plant
  - CO_2 saving depends on marginal fuel – **Marginal Displacement Factor, MDF**
- Expect MDF higher when coal is at margin
- **CPS moves coal to mid-merit Q1 2015**

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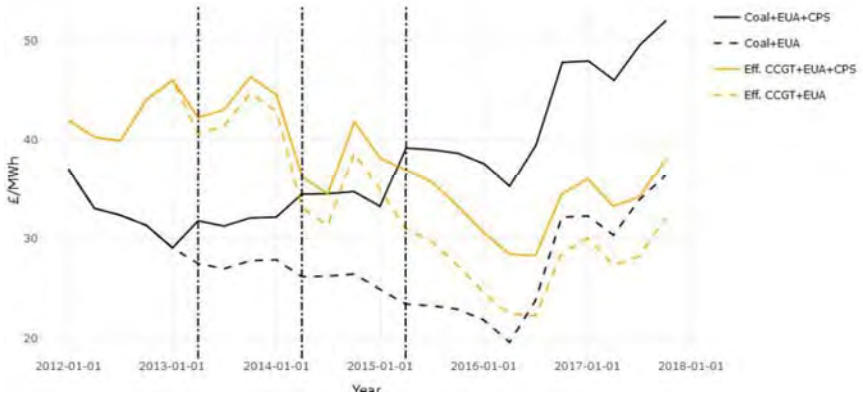
CPS changes fuel costs

Coal cheaper without CPS, not with CPS



Prices and costs of fuels 2012-2017, from BEIS *QEP*

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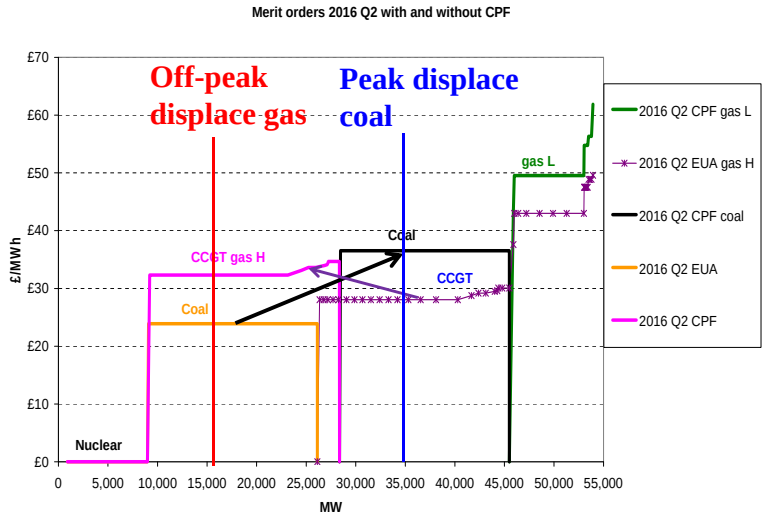
Merit order Q2 2016



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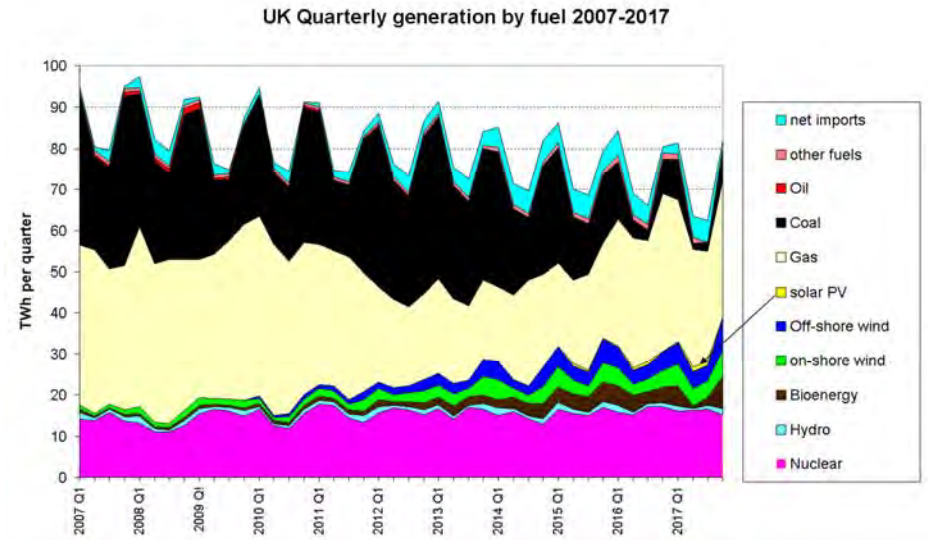
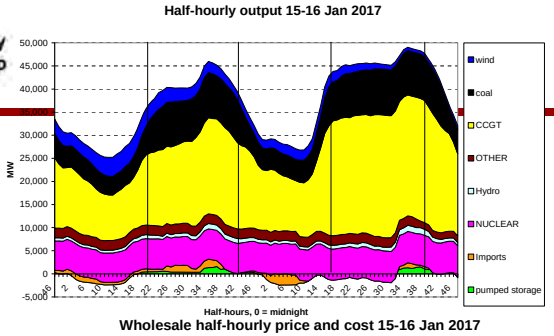
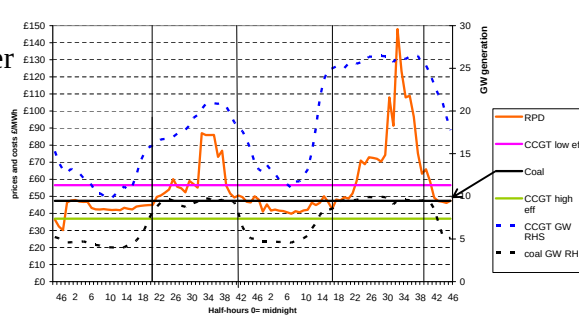
CPS has displaced coal



The vertical lines show where coal changes from negative dark green spread to positive or v.v.

Note: coal runs at min load when unprofitable to deliver in profitable hrs, can ramp up but not down, so could respond in BM to fall in wind

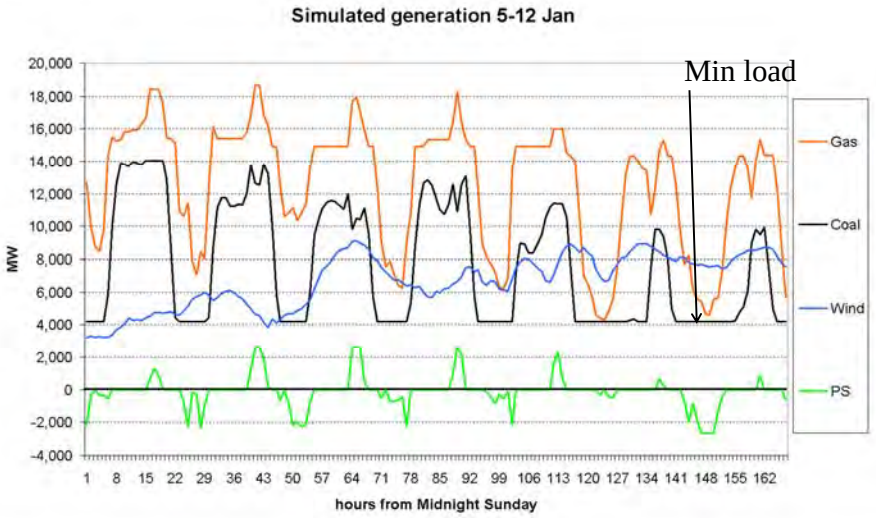




Measuring long run impact of CPS on MDF of wind

- **Long run**: simulate optimal dispatch with a reference wind year vs. one with 25% more wind capacity *at hourly resolution*
  - Control for **residual demand** - affects plant at margin
  - But min and max load impact coal (plenty of flexible gas)
- **Short run**: identify relationship econometrically *from 5-min or half-hourly changes*
  - Distinguish when coal or gas base load
  - Control for time

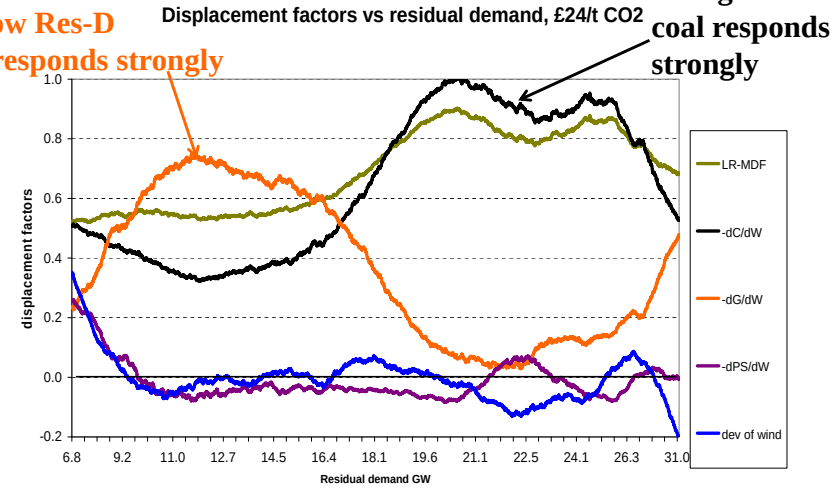
Base case £24/t CO_2 Simulation January



Simulating 2015 with constant fuel prices: Residual(Net) demand

At low Res-D gas responds strongly

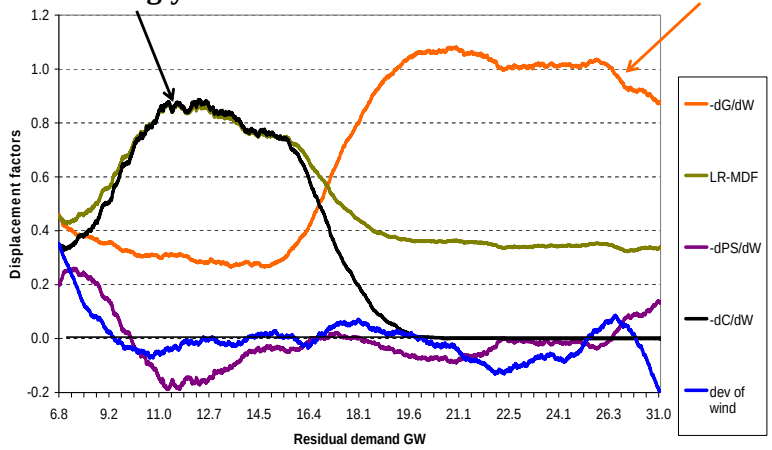
At high res-D coal responds strongly



MDF no CPS, £6/t CO_2

Off-peak: coal responds strongly

Peak: gas responds strongly



Measuring *short run* impact of CPS on MDF of wind

- **Short run**: identify relationship econometrically
  - Distinguish when coal or gas base load
  - Control for time
- **Results**
  - Coal would only be the marginal fuel during off-peak hours (23:00-07:00) when coal is cheaper.
  - CPS moves coal from base to mid-merit, but coal does not become the peak-hour marginal fuel – gas is the marginal fuel for the entire day.
  - MDF higher when coal is the base load (pre CPS); MDF lower when gas is the base load (post CPS)

Econometrics specification

- Econometrics starts from change in half-hourly emissions, ΔE_t, responding to changes in Demand, D, Wind, W, and other factors, c:

$$\Delta E_t = a\Delta D_t + b\Delta W_t + c_t.$$

- But given emissions factors e_x, $x \in \{C, G, O\}$ (coal, gas, other)

$$\Delta E_t = e_C \Delta C_t + e_G \Delta G_t + e_O \Delta O_t.$$

- Estimate

$$\Delta C_t = \alpha_0 + \alpha_1 \Delta W_t + \alpha_2 \Delta D_t + \boldsymbol{\theta' X_t} + \varepsilon_t.$$

$$\Delta G_t = \beta_0 + \beta_1 \Delta W_t + \beta_2 \Delta D_t + \boldsymbol{\delta' X_t} + \mu_t.$$

- giving

$$e_C\alpha_2 + e_G\beta_2 \approx a = \text{MEF},$$

$$e_C\alpha_1 + e_G\beta_1 \approx b = \text{SR-MDF}.$$

Non-linear results

- Linear results shows that the marginal effect of ΔW depends on the hour of the day (i.e. demand) as well as the generation cost difference between coal and gas, $\tilde{P}_t \equiv P_t^C - P_t^{G^e}$;
- Then we run the following non-linear regressions:

$$\Delta C_t = \alpha_0 + f(\tilde{P}_t)\cdot\Delta W_t + k(\tilde{P}_t)\cdot\Delta D_t + \boldsymbol{\theta' X_t} + \varepsilon_t, \quad \text{(iii)}$$

$$\Delta G_t = \beta_0 + g(\tilde{P}_t)\cdot\Delta W_t + l(\tilde{P}_t)\cdot\Delta D_t + \boldsymbol{\delta' X_t} + \mu_t, \quad \text{(iv)}$$

- where $f(\tilde{P}_t)$, $k(\tilde{P}_t)$, $g(\tilde{P}_t)$, and $l(\tilde{P}_t)$ are non-linear functions of $\tilde{P}_t$, of order 4, e.g.,

$$f(\tilde{P}_t) = \alpha_{1,0} + \alpha_{1,1}\tilde{P}_t + \alpha_{1,2}\tilde{P}_t^2 + \alpha_{1,3}\tilde{P}_t^3 + \alpha_{1,4}\tilde{P}_t^4.$$

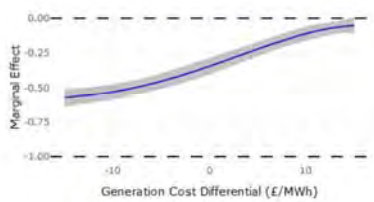
- Hence

$$e_C k(\tilde{P}_t) + e_G l(\tilde{P}_t) \approx \text{MEF},$$

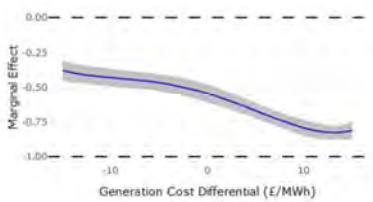
$$e_C f(\tilde{P}_t) + e_G g(\tilde{P}_t) \approx \text{SR-MDF}.$$

Marginal fuel impacts of wind as function of ***cost difference (P^{coal}-P^{ccgt})***

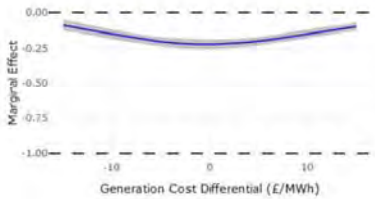
dCoal/dWind off-peak



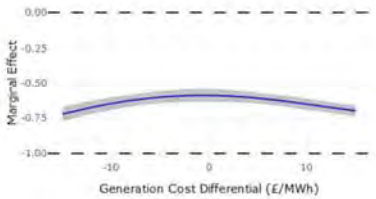
dGas/dW off-peak



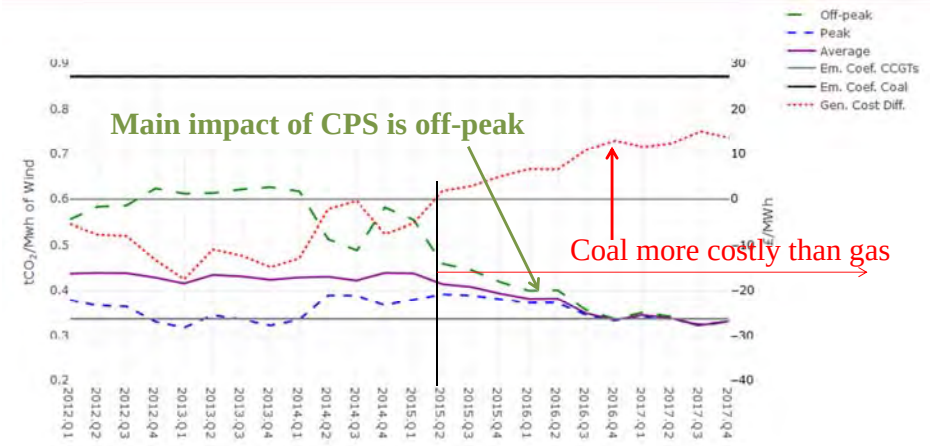
dC/dW peak



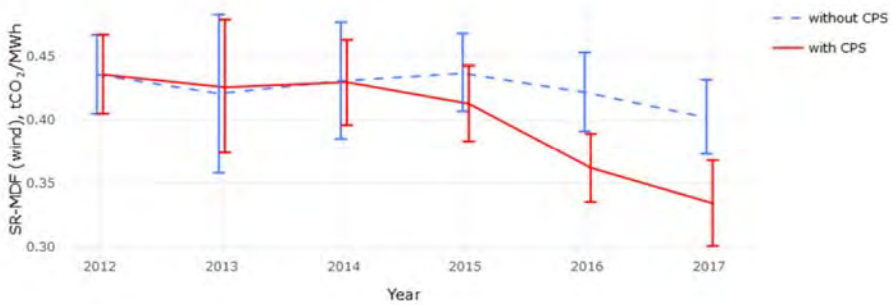
dGas/dW peak



Short-run MDF of wind vs generation cost difference



Price impact of CPS



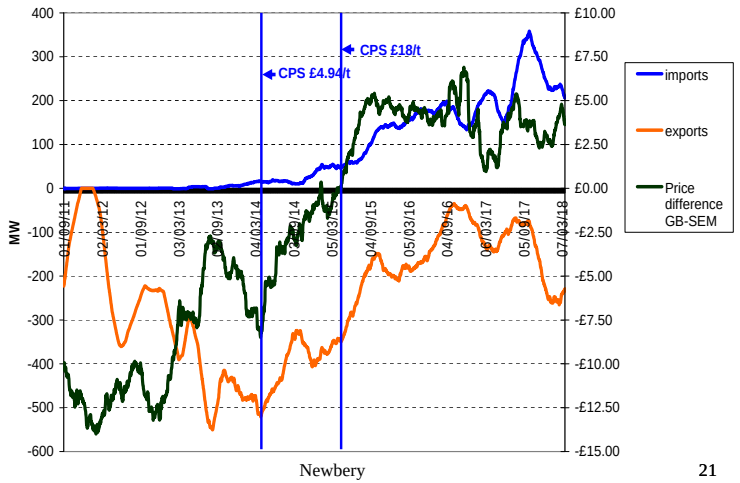
- Without the CPS, the SR-MDF would stay relatively high,
- the average SR-MDF in 2015 would be 0.44 tCO_2/MWh instead of 0.41 tCO_2/MWh, **or 7% higher**;
- in 2017 it would be 0.40 tCO_2/MWh instead of 0.33 tCO_2/MWh, or **21% higher**.

Impact of CPS on interconnectors

- **SEM** faces higher fuel prices than GB (imports gas)
- SEM has mix of coal, CCGT, wind, some hydro, small amount of peaking distillate
- SEM typically imported from GB, after CPS now exports
- Interconnectors to FR, NL normally imported from cheaper Continental market
- CPS amplifies price difference, not change direction on IFA, BritNed
- **Implication: main distortion on SEM-GB**
- Solution: SEM adopt CPS? (NI was exempted)
  - But that would raise already high retail electricity prices

Main impact has been on trade with SEM. Fuel prices pre-CPS similar

Flows and price difference GB-SEM, lagged quarterly moving averages

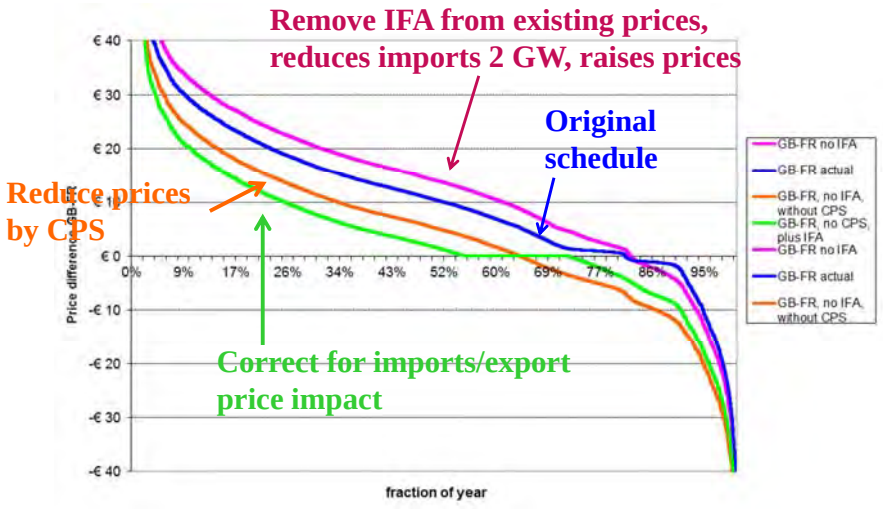


Counterfactual price impacts removing CPS

- Marginal efficiency factor measures impact of demand changes
  - – dCO_2/dD x CPS = **price impact**
  - => imports lower price, exports raise price
- Change in trade: P_{GB} : €1.25/GW, P_{FR} = €0.75/GW, total $\Delta = P_{GB} - P_{FR}$ changes €2/GW
- Rank $\Delta = P_{GB} - P_{FR}$ = price difference duration

Then adjust as below!

Impact on French inter-connector of removing CPS



Conclusions

- **C**arbon **P**rice **F**loor has driven considerable decarbonisation in GB electricity
  - – As has wind, made **less costly to support**
  - – CPS ***lowers*** wind MDF in the balancing market but ***raises*** if for predictable volumes of wind
  - – Prices rise, trade changes, **Continent gains IC profits**
    - **IFA 2016 gained €38 million**, BritNed perhaps half that
- CPF **+ MSR** reduces EU emissions
- EU CPF gives better investment signals than ETS

⇒A desirable change for the rest of EU

⇒Accelerates decarbonising GB

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Acronyms

BM	Balancing Market
CCGT	Combined cycle gas turbine
CPF	Carbon Price Floor
CPS	Carbon Price Support
EUA	EU Allowance (1 t CO2)
ETS	Emission Trading Scheme
IC	Interconnector
IFA	Interconnector France Angleterre
MDF	Marginal Displacement Factor tonnes CO_2/MWh of wind
Res-D	Residual demand
SEM	Single Electricity Market of island of Ireland
SR-MDF, LR-MDF	short-run and long-run MDF
ΔC, ΔG, ΔW	changes in Coal, Gas (CCGT), Wind

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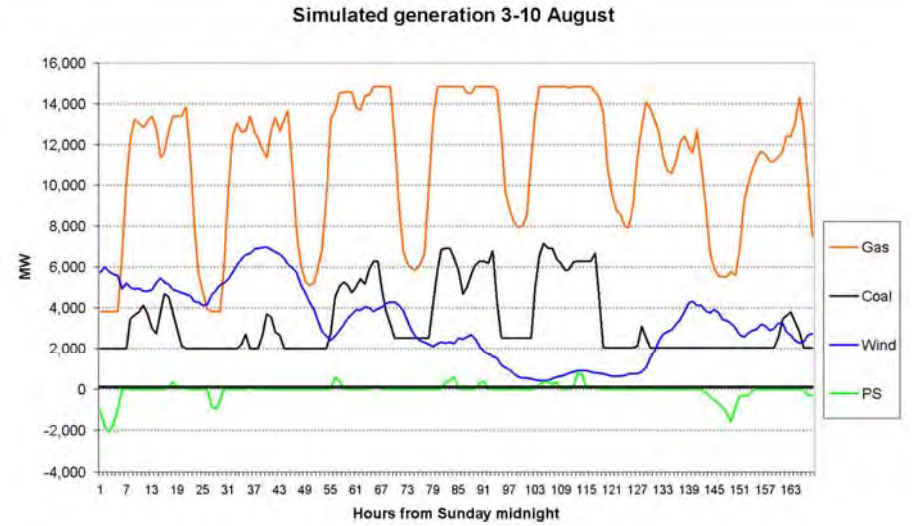
Simulated base case £24/t CO_2 August 2015



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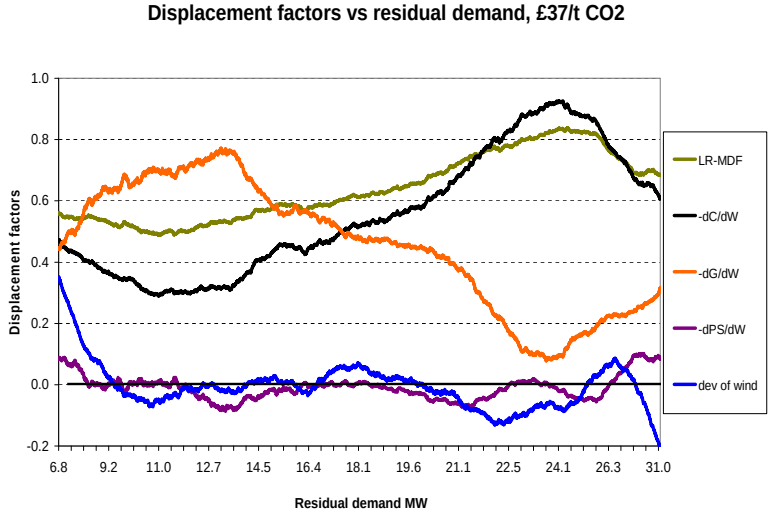
Simulated High CO_2 price £37/t



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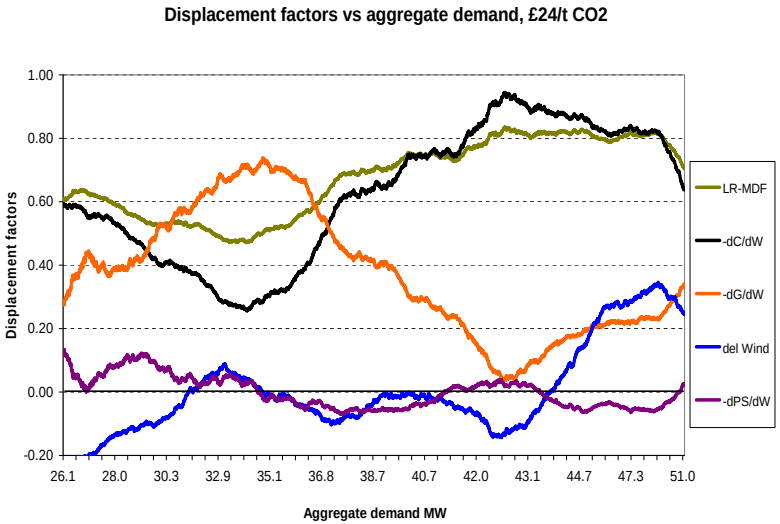
MDF vs aggregate demand 2015



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Linear results

(a) Off-peak Period (23:00-07:00)

	ΔC_t		ΔG_t	
	COAL-BASE	GAS-BASE	COAL-BASE	GAS-BASE
ΔW_t	-0.52^{***}	-0.15^{***}	-0.41^{***}	-0.75^{***}
	(0.02)	(0.01)	(0.02)	(0.01)
ΔD_t	0.42^{***}	0.20^{***}	0.55^{***}	0.74^{***}
	(0.00)	(0.00)	(0.00)	(0.00)

(b) Peak Period (07:00-23:00)

	ΔC_t		ΔG_t	
	COAL-BASE	GAS-BASE	COAL-BASE	GAS-BASE
ΔW_t	-0.15^{***}	-0.15^{***}	-0.66^{***}	-0.65^{***}
	(0.01)	(0.01)	(0.01)	(0.01)
ΔD_t	0.14^{***}	0.21^{***}	0.64^{***}	0.61^{***}
	(0.00)	(0.00)	(0.00)	(0.00)

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

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Fuel mix in the SEM