Natural Gas: Renewables supporter or opponent?

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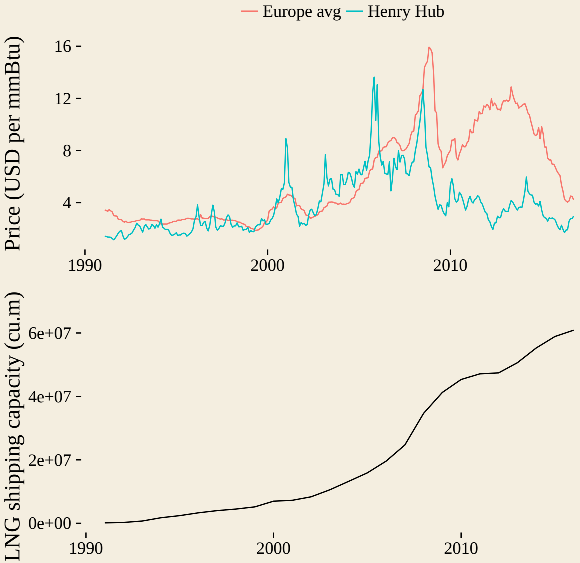
The story

Natural gas markets in constant flux

Natural gas market is changing

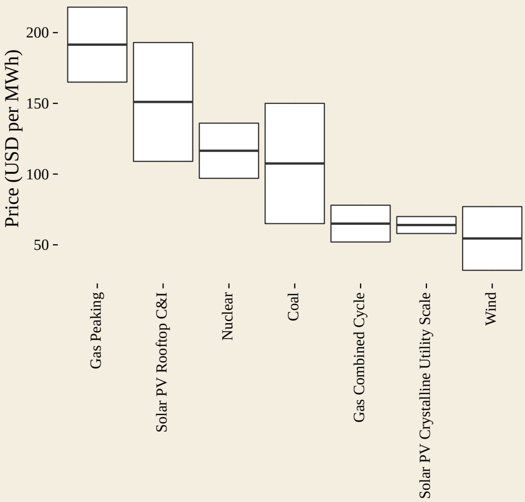


The story

Natural gas markets in constant flux; could play a major role in generation

Similar costs for renewable (esp. wind) and conventional generation technologies

Renewables becoming competitive on price



Source: Lazard, 2015 estimate for 2020 unsubsidized prices

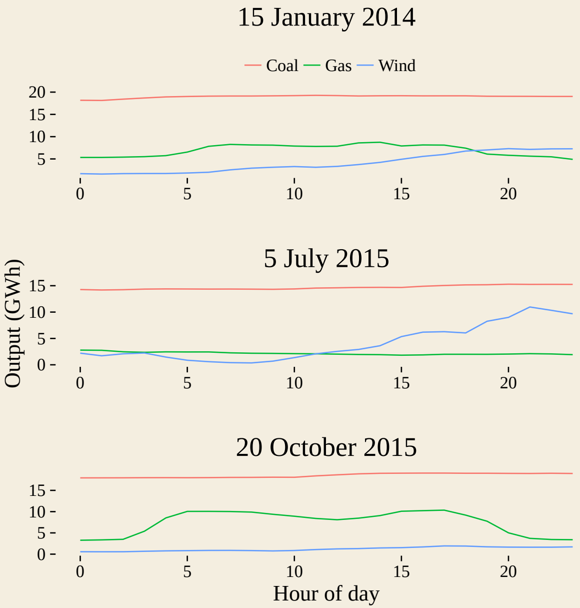
The story

Natural gas markets in constant flux; could play a major role in generation

Renewable energy costs (esp. wind) similar to conventional technologies'

Unfortunately renewables are also fickle

Variable output from wind



Research Objective

The story so far is about the *whole* electricity system

Unrealistic to claim a description of the *whole* system

Simplest description of how the wind–gas–coal interaction affects supply

What conclusions can we draw using this model?

Literature

Literature review of this area: Crew et al. (1995)

Integration of different generation technologies:

Crampes & Moreaux (2008)

Natural gas evolution:

Krupnick et al. (2014); Holz et al. (2013); Knittel et al. (2016)

Gas vs. coal emissions:

Cathles et al. (2012)

Literature explicitly considering intermittency in the gas-wind relationship?

Approach here inspired by Ambec & Crampes (2012)

Basic Model: Ingredients

Static model

3 technologies: gas, coal, wind

Characterised by installation cost, operating cost & emissions

Fundamental difference: fossil output can be forecast, wind cannot

2 states of the world distinguish when renewables can be employed

Decision: how much capacity to build, then how much capacity to dispatch

Maximisation Problem

$$\max_{K_\tau, q_\tau^\kappa} \left\{ \sum_\kappa Pr(\kappa) \left[S\left(\sum_\tau q_\tau^\kappa \right) - \sum_\tau c_\tau q_\tau^\kappa \right] - \sum_\tau r_\tau K_\tau \right\}$$

$$\kappa \in (b,\ s)$$

Such that:

$$q_\tau^\kappa \geq 0,\ K_\tau \geq q_\tau^\kappa$$

Assume:

$$S' > 0,\ S'' < 0$$

κ – state, wind blowing b or still s

τ – technology

g – natural gas

l – lignite/coal

w – intermittent wind

c_τ – production cost

r_τ – installation cost

Possible cases

Fossil fuel(s) only

Wind too expensive to be installed

Mixed wind and fossil fuels

Wind and fossil fuel(s) installed
Wind and fossil fuel when windy

Specialised wind and fossil fuel(s)

Wind and fossil fuel(s) installed
Wind only when windy, fossil only when not windy

Possible cases

Fossil fuels only

$c_g + r_g > c_l + r_l$

$\frac{r_w}{v} > c_l + r_l$

Mixed wind and fossil fuels

$c_l + r_l < c_g + r_g$

$r_w < c_l + r_l$

Specialised wind and fossil fuels

$r_w + (1 - v)c_l + r_l < r_g + c_g$

$\frac{r_w}{v} < c_l$

$\frac{r_w}{v} < c_l + r_l$

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Adding Emissions

Key motivation to add renewables to the grid

Low/zero emissions during production

Policies to internalise emissions cost

Explicit limit on emissions

Emission Limiting System

$$\max_{K_\tau, q_\tau^\kappa} \left\{ \sum_\kappa Pr(\kappa) \left[S\left(\sum_\tau q_\tau^\kappa \right) - \sum_\tau (c_\tau q_\tau^\kappa + e_\tau q_\tau^\kappa) \right] - \sum_\tau r_\tau K_\tau \right\}$$

Such that:

$$q_\kappa^\tau \geq 0$$
$$K_\tau \geq q_\tau^\kappa$$

$$\bar{e} \geq \sum_s Pr(\kappa) \left(\sum_\tau q_\tau^\kappa e_\tau \right)$$

Assume:

$$S' > 0, \; S'' < 0$$

κ – state, wind blowing b or still s

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Possible Cases with emissions

Fossil fuels only

$$c_g + r_g + e_g + \lambda e_g > c_l + r_l + e_l + \lambda e_l$$

$$r_w > c_l + r_l + e_l + \lambda e_l$$

Mixed wind and fossil fuels

$$c_l + r_l + e_l + \lambda e_l < c_g + r_g + e_g + \lambda e_g$$

$$r_w < c_l + r_l + e_l + \lambda e_l$$

Specialised wind and fossil fuels

$$\frac{r_w}{v} < c_l + \lambda e_l$$

$$r_w + r_l + (1 - v)c_l + \lambda(1 - v)e_l < r_g + c_g + \lambda e_g$$

κ – state, wind blowing *b* or still *s*

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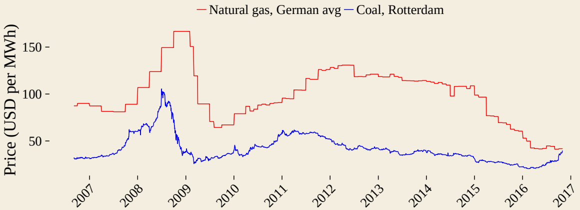
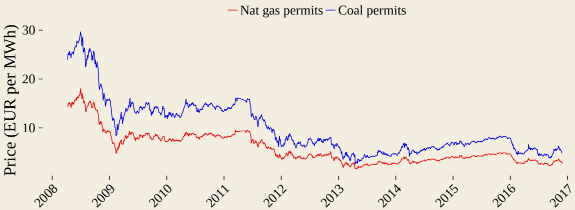
r_τ – installation cost

λ – emission limit Lagrange multiplier

Gas and Coal Prices per MWh



EU ETS Permits Cost for Gas and Coal



Source: IMF Macroeconomic Data & ICE Commodity Prices Wiki *via Quandl*

Coal:

10.08 mmBtu/MWh

19.42 mmBtu/short ton

0.96 tCO2/MWh

Natural gas:

10.41 mmBtu/MWh

0.57 tCO2/MWh

Source: EIA

Policy Insights

Is gas a bridge to renewable future or not?

…it depends

Intermittency of wind makes backup [fossil] a requirement

Small changes in cost of the backup technology do not affect wind power

In this regime any backup technologies compete with each other

But for larger changes in cost, this is no longer the case


That's all Folks!

Questions? Suggestions?

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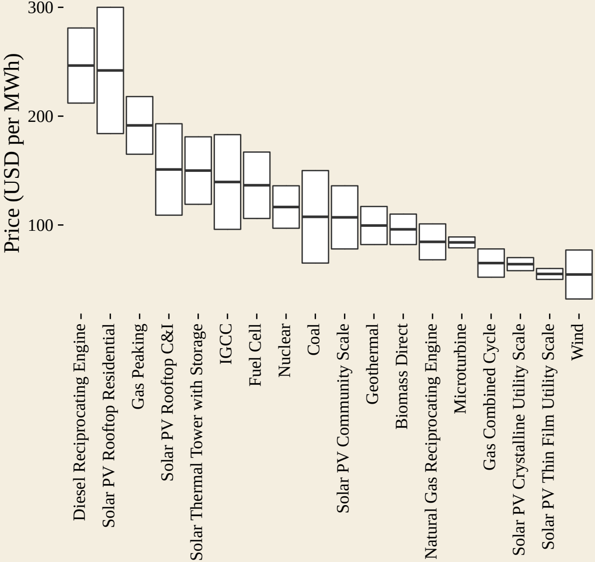
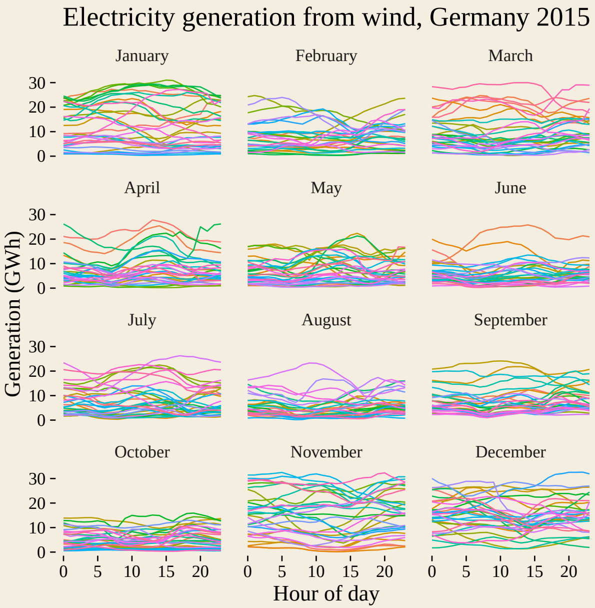
LCOE Expectation for 2020 (Source: Lazard)

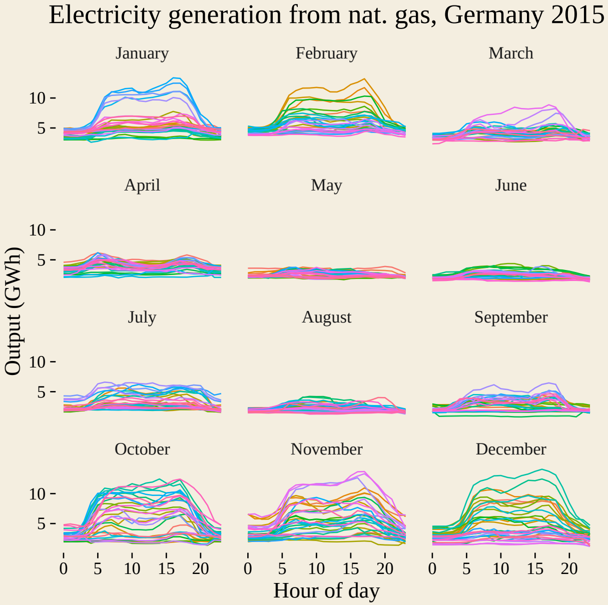


BACK

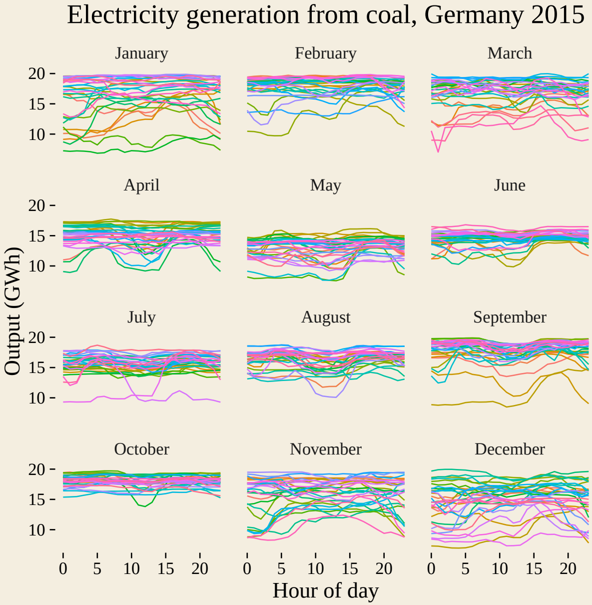
Output of wind generation…



…compared to gas



…compared to coal



BACK

Possible cases: gas dominant

Fossil fuels only

$c_g + r_g < c_l + r_l$

$\frac{r_w}{v} > c_g + r_g$

Mixed wind and fossil fuels

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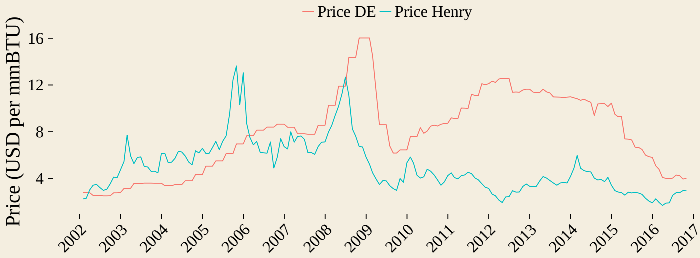
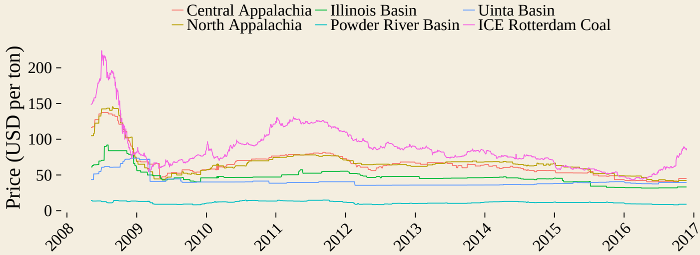
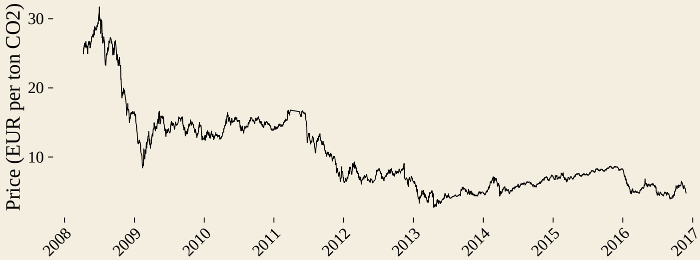




Sources: EIA, IMF Macroeconomic Data and ICE Commodity Prices Wiki *via Quandl*

EU ETS prices



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