

HARVARD ELECTRICITY POLICY GROUP SEVENTY-SIXTH PLENARY SESSION

**Renewable Energy and Carbon Policy:
What Exactly is the Relationship?**

October 2, 2014
Charles Frank

QUESTION: Can renewable incentives substitute for carbon regulation?

Renewable Incentives

- Feed-in tariffs
- Renewal Portfolio Standards and renewable energy certificates
- Tax benefits, including production tax credits and investment tax credits

Carbon Regulation

- Carbon price through carbon tax
- Carbon price through cap and trade
- Carbon emission standards

SOME PROBLEMS WITH RENEWABLE INCENTIVES

- Can cause unnecessary increases in capacity
- Capacity increases may not be justified by energy savings and CO2 emission reductions
- May reduce emissions very little if renewable energy displaces CC natural gas or nuclear rather than coal
- Renewables provide little system benefits and may generate substantial system costs
- Are not technology neutral

ELECTRICITY CAPACITY ADDITIONS (GW)

TOTAL GENERATING CAPACITY

Year	2007	2011	Change	% Change
Germany	134.3	159.5	25.2	18.8%
Spain	88.8	101.8	13.1	14.7%
UK	83.5	93.2	9.6	11.5%
US	994.9	1,052.9	58.0	5.8%

WIND AND SOLAR CAPACITY

Year	2007	2011	Change	% Change
Germany	26.1	54.2	28.1	107.9%
Spain	15.6	26.0	10.4	67.2%
UK	2.5	7.5	5.0	202.0%
US	17.0	47.5	30.5	179.4%

Most additions to capacity are wind and solar capacity

CAPACITY AND CONSUMPTION

GENERATING CAPACITY (GW)

Year	2007	2011	Change	% Change
Germany	134.3	159.5	25.2	18.8%
Spain	88.8	101.8	13.1	14.7%
UK	83.5	93.2	9.6	11.5%
US	994.9	1,052.9	58.0	5.8%

ELECTRIC CONSUMPTION (TWh)

Year	2007	2011	Change	% Change
Germany	550.6	537.9	-12.7	-2.3%
Spain	255.2	243.9	-11.3	-4.4%
UK	345.0	320.9	-24.1	-7.0%
US	3890.2	3882.6	-7.6	-0.2%

Capacity increases not necessary to meet demand.

NET BENEFITS PER MW OF CAPACITY

	DISPLACING COAL OFF PEAK AND GAS SC ON PEAK (\$thousand)							
	ENERGY SAVINGS		EMISSION SAVINGS		TOTAL SAVINGS		NET BENEFITS	
	Wind	Solar	Wind	Solar	Wind	Solar	Wind	Solar
Germany	\$90.9	\$62.4	\$76.9	\$39.0	\$167.8	\$101.4	(\$102.4)	(\$250.0)
Spain	\$115.9	\$122.8	\$98.2	\$76.8	\$214.0	\$199.6	(\$56.2)	(\$151.9)
UK	\$132.1	\$53.2	\$112.0	\$33.4	\$244.0	\$86.6	(\$26.1)	(\$264.8)
US	\$112.3	\$74.9	\$127.4	\$75.2	\$239.6	\$150.0	(\$30.6)	(\$201.4)
	DISPLACING GAS CC OFF PEAK AND GAS SC ON PEAK (\$thousand)							
	ENERGY SAVINGS		EMISSION SAVINGS		TOTAL SAVINGS		NET BENEFITS	
	Wind	Solar	Wind	Solar	Wind	Solar	Wind	Solar
Germany	\$140.0	\$84.1	\$33.0	\$19.7	\$173.1	\$103.8	(\$97.1)	(\$247.7)
Spain	\$178.0	\$165.0	\$42.2	\$38.7	\$220.2	\$203.8	(\$50.0)	(\$147.7)
UK	\$202.3	\$71.4	\$48.1	\$16.8	\$250.4	\$88.2	(\$19.8)	(\$263.2)
US	\$87.7	\$62.3	\$54.7	\$37.9	\$142.4	\$100.2	(\$127.8)	(\$251.3)

SYSTEM BENEFITS AND COSTS

- Wind and solar capacity contributes very little to system reliability, particularly with high penetration.
- Wind and solar production can cause premature retirement of nuclear and gas CC plants.
- Wind and solar may require substantial investments in transmission.
- Wind and solar intermittency can impose additional balancing costs.
- Intermittency imposes significant cycling costs by (a) increasing maintenance cost, (b) reducing energy efficiency and (c) increasing CO₂ emissions of fossil fuel power plants.

TECHNOLOGY BIAS

- Renewable incentives are often technology biased, e.g. solar over other renewables
- Renewable incentives normally exclude no-carbon alternatives, e.g. hydro and nuclear
- Renewable incentives exclude increased fuel efficiency, e.g. gas CC and supercritical coal
- Renewable incentives not designed to minimize CO₂ emissions

CARBON PRICE REGULATION

- Technology neutral; aimed at CO2 emission reductions whatever the energy source
- Can achieve emission reductions by merit-order dispatch with no capacity increases
- Can achieve the lowest cost CO2 emission reductions in both short- and long-term
- Can be combined with internalization of system benefits and costs

CAPACITY FACTOR ASSUMPTIONS

	Full Year		Off-Peak		On-Peak	
	Wind	Solar	Wind	Solar	Wind	Solar
Germany (1) (5)	18.8%	10.3%	18.1%	8.0%	25.9%	33.5%
Spain (2) (5)	24.0%	20.3%	23.1%	15.7%	33.1%	66.0%
UK (3) (5)	27.4%	8.8%	26.4%	6.8%	37.7%	28.7%
US (4) (5)	31.2%	19.9%	30.0%	15.4%	42.9%	64.6%

(1) Full Year Mean 2007-2011 from EIA international data

(2) Full year Mean 2010-2011 from EIA international data

(3) Full Year Mean 2011-2013 from DUKES 2014, Chapter 6, Table 6.5

(4) Full Year Mean from EIA, Monthly Electricity Report

(5) Ratios of Off and On Peak based on Japanese data

FUEL PRICE ASSUMPTIONS

	2013 Price/ton	2013 Price/mmbtu	
	Coal	Coal (5)	Gas
Germany (1)	\$81.69	\$3.84	\$10.72
Spain (2)	\$81.69	\$3.84	\$10.68
UK (3)	\$81.69	\$3.84	\$10.63
US (4)	\$71.39	\$3.36	\$3.71

Source: BP Statistical Review 2014

(1) German Import Price for gas

(2) Average Germany and UK for gas

(3) Heren NPB Index for gas

(4) US Henry Hub for gas

(5) mmbtu/metric ton coal

21.27

OTHER ASSUMPTIONS

	Coal	Gas CC	Gas SC	Nuclear
Heat Rates (btu/KWh)	10,498	7,050	10,850	N/A
Variable O&M/MWh	\$4.47	\$3.27	\$10.37	\$2.14
Emissions (lbs/mmbtu)	206.0	117.0	117.0	0.0
Emissions (lbs/MWh)	2,162.6	824.9	1,269.5	0.0