Centre for Climate Change Economics and Policy

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Climate change policies and the UK business sector: overview, impacts and suggestions for reform

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Appendix 2
Methodology for the assessment of policy simplification

November 2013

Centre for Climate Change Economics and Policy
Grantham Research Institute on Climate Change and the Environment

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This policy paper is intended to inform decision-makers in the public, private and third sectors. It has been reviewed by at least two internal referees before publication. The views expressed in this paper represent those of the author(s) and do not necessarily represent those of the host institutions or funders.

Appendix 2 - Methodology for the assessment of policy simplification

The paper recommends that three existing energy policies, the Climate Change Agreement (CCA), Climate Change Levy (CCL) and Carbon Reduction Commitment (CRC) are replaced by a single carbon price: the CCL+ rate. Chapter 5 '*A proposal for simplification*' provides a first estimate of the fiscal revenues that could be generated by such a reform, assuming the carbon price embedded in the proposed policy package follows the path of the non-traded sector carbon price, as estimated by DECC (2013b). This appendix provides an explanation of the methodology used in Chapter 5 of the paper.

The following steps were taken in the analysis:

1. Identification of energy consumption by sector
2. Conversion of energy consumption into CO_2 emissions
3. Assumptions on policy applicability
4. Estimation of fiscal revenues associated to:
   4.1 Business-As-Usual (BAU) policies;
   4.2 Proposed policy reform in 2013;
   4.3 Proposed policy reform in 2020.

Step 1. Identification of energy consumption by sector

The data used in the paper on the consumption of electricity, gas, coal and liquid petroleum gases (LPG) is based on data from the Department on Energy and Climate Change 'Energy Consumption in the UK' (DECC, 2013a).

In particular, the data used on industrial sectors is based on Table 4.04, data on the service sectors on Table 5.12 and data on agriculture on Table 5.08. This data is for 2012 and is the latest available at the time of publication. We assume that similar consumption figures apply in 2013. Households and transport emissions have not been included, as these are outside the scope of this study. Data from DECC is broken down into the following sectors (Table A2.1):

Table A2.1 Sector categories

Category	SIC(2007) codes*	Sector
Industrial sector	08	Other mining and quarrying
	10	Manufacture of food products
	11	Manufacture of beverages
	12	Manufacture of tobacco products
	13	Manufacture of textiles
	14	Manufacture of wearing apparel

	15	Manufacture of leather and related products
	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	17	Manufacture of paper and paper products
	18	Printing and publishing of recorded media and other publishing activities
	19	Manufacture of coke and refined petroleum products
	20	Manufacture of chemicals and chemical products
	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
	22	Manufacture of rubber and plastic products
	23	Manufacture of other non-metallic mineral products
	24	Manufacture of basic metals
	25	Manufacture of fabricated metal products, except machinery and equipment
	26	Manufacture of computer, electronic and optical products
	27	Manufacture of electrical equipment
	28	Manufacture of machinery and equipment n.e.c.
	29	Manufacture of motor vehicles, trailers and semi-trailers
	30	Manufacture of other transport equipment
	31	Manufacture of furniture
	32	Other manufacturing
	35	Electricity, gas, steam and air conditioning supply
	36	Water collection, treatment and supply
	38	Waste collection, treatment and disposal activities; materials recovery
	42	Civil engineering/construction
		Unclassified
Service sector	64-66, 68, 69-75, 77-82	Commercial Offices
	53, 58-63	Communication and Transport
	85	Education
	84	Government
	86, 87, 88	Health
	55-56	Hotel and Catering
		Other
	45-47	Retail
	90-93	Sport and Leisure
	52	Warehouses
Agriculture	01 02 03	Crop and animal production, hunting and related service activities; Forestry and logging; Fishing and aquaculture

**SIC (2007) codes have been attributed by the authors on the basis of sectors description*
Source: Based on DECC (2013a)

A summary of energy consumption by category and source is provided in Table A2.2.

Table A2.2 Energy consumption by category and source, 2012 (ktoe)

	Electricity	Gas	Coal	LPG
Industrial sector	8,821	9,825	2,192	697
Service sector	8,349	8,263	16	-
Agriculture	333	132	1	-
Total all sectors	17,503	18,220	2,209	697

Source: DECC (2013a)

Step 2. Conversion of energy consumption into CO_2 emissions

Energy consumption data is converted into tonnes of CO_2 by applying the conversion factors outlined in Advani, Bassi et al. (2013). See Appendix B and sources therein for details.

As noted in Section 3.2 of the paper, when comparing different carbon prices embedded in policy instruments this paper adopts marginal conversion factors, on the grounds that we are primarily interested in the price signal associated with additional consumption at the margin.

When looking at actual emissions, however, it makes sense to use average emission factors, which allow estimating average emissions by sector, given sectoral energy consumption levels shown in table A2.2. The average conversion factors used for this analysis are shown in table A2.3 below.

Average and marginal carbon content are identical in the case of fossil fuels, but differ for electricity. For electricity, the average carbon content reflects the mix of all sources used for generating electricity (which includes fossil fuels, renewables and nuclear), while the marginal carbon content depends on whether coal or gas powered generation plants are used to generate an *additional* unit when demand increases, and the technical specification of the plant. We have assumed in this paper that combined cycle gas turbines (CCGTs) are the marginal power plants.

Table A2.3 Average conversion factors

	t CO_2/MWh	t CO_2/t fuel	t CO_2/ktoe
Natural gas	0.185		2,150
Coal (industrial)		2.139	3,317
LPG		2.929	2,491
Average Electricity (2013)	0.517		6,012
Average Electricity (2020)	0.050		582

Source: DEFRA & DECC (2012), except 2020 estimates from DECC (2013b)

For transparency, in table A2.4 we report also the marginal conversion factors which have been used for the calculations in Section 3.2 of the paper:

Table A2.4 Marginal conversion factors

	t CO_2/MWh	t CO_2/t fuel	t CO_2/ktoe
Natural gas	0.185		2,150
Coal (industrial)		2.139	3,317
LPG		2.929	2,491
Marginal Electricity (2013)	**0.392**		4,559
Marginal Electricity (2020)	**0.293**		3,408

Source: DEFRA & DECC (2012), except 2020 estimates from DECC & HMT (2013)

A summary of the resulting emissions, using the *average* conversion factors, is shown in Table A2.5.

Table A2.5 Emissions by category and source, 2012 (tonnes of CO_2)

	Electricity	Natural gas	Coal	LPG	Total
Industrial sector	53,032,656	21,119,802	7,269,885	1,737,247	83,159,591
Service sector	50,193,273	17,761,811	52,985	-	68,008,069
Agriculture	52,194,370	18,045,674	56,370	-	70,296,414
Total all sectors	105,227,026	39,165,476	7,326,254	1,737,247	153,456,004

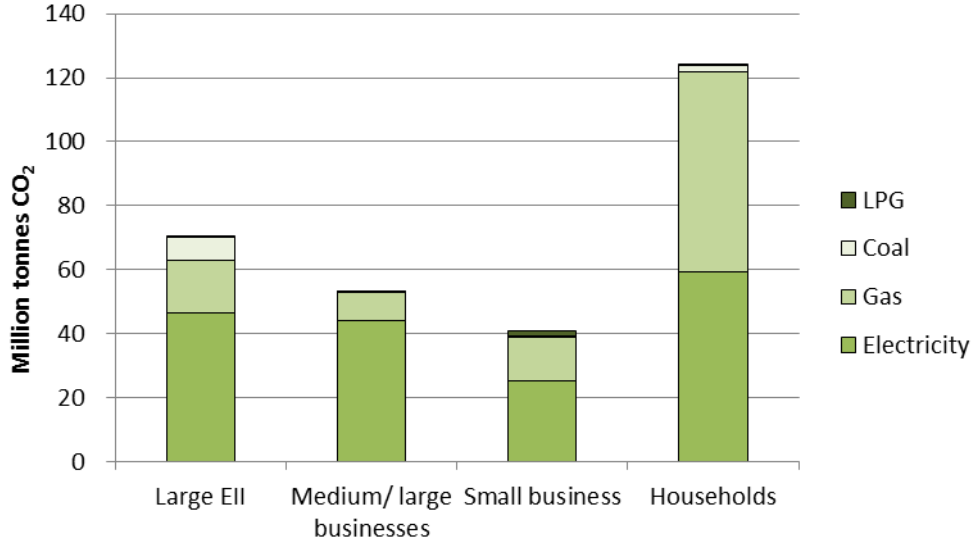
Source: Authors' calculations based on DECC (2013a)

Figure A2.1 displays the overall carbon emissions associated with the use of each fuel, by end-user. Business categories are defined according to applicable policy regimes, as follow:

- Large energy-intensive industries (EII): businesses that participate in the European Union Emission Trading System (EU ETS) directly, and businesses that are outside the EU ETS but are subject to a CCA. They generally do not qualify to the CRC.
- Medium/large businesses: they pay the CCL and are large enough to also be subject to the CRC.
- Small businesses: they pay the CCL, but not the CRC. The category includes very small businesses which are not subject to the CCL.

We include here also the households sector for comparison.

Figure A2.1 Average emissions by energy intensive businesses, other large/medium businesses, small businesses and households, 2012 (million tonnes of CO_2)



Source: Authors' calculations based on DECC (2013a)

Step 3. Assumptions on policy applicability

In order to estimate the fiscal revenues that are likely to result from the current policy regime (step 4 below), it is necessary to identify which policies apply to which sector. Sector analysis in the paper is based on DECC's (2013a) two-digit Standard Industrial Classification (SIC) categories. These sector categories are broad and do not provide a high level of detail about how policies apply at the sub-sector level. The analysis therefore relies on a number of assumptions:

European Union Emissions Trading System (EU ETS): The system covers emissions of carbon dioxide from power and heat generation plants, commercial aviation, and a wide range of energy-intensive industry sectors, such as oil refineries, steel works and the production of iron, aluminium, metals, cement, etc. The full list of categories of activities and thresholds to which the scheme applies can be found in Annex I to the EU ETS Directive (2009/29/EC)[1]. The activities listed in the EU ETS Directly broadly coincide with the following two-digit SIC sectors:

- Manufacture of paper and paper products (SIC code: 17)
- Manufacture of coke and refined petroleum products (SIC Code: 19)
- Manufacture of chemicals and chemical products (SIC Code: 20)
- Manufacture of other non-metallic mineral products (SIC Code: 23)
- Manufacture of basic metals (SIC Code: 24)
- Electricity, gas, steam and air conditioning supply (SIC Code: 35)

Not all the firms belonging to these sectors, however, automatically participate in the EU ETS, as there are sector-specific thresholds that determine eligibility. For instance, several activities (like fuel combustion, metal production etc.) are covered only if they have a net heat excess of 20 MW. The two-digit SIC sectors listed above therefore represent a slight overestimation of the amount of the emissions actually covered.

CRC Energy Efficiency Scheme (CRC): The CRC applies to large public and private sector organisations and all central Government departments. Organisations qualify as CRC participants based on their electricity usage[2]. Data from the UK Environment Agency[3] indicates that around 42 million tonnes of carbon dioxide were covered by the scheme in 2011/12, of which 33 million tonnes came from electricity and 9 million tonnes from natural gas. The emissions covered by the scheme are equivalent to approximately 50 per cent of the emissions from the non-traded sectors (according to our classification of ETS sectors described above). As an approximation, we consider that the same percentage (50 per cent) of emissions generated by each non-traded sector listed in our database is covered under the CRC. The EU ETS

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0063:0087:en:PDF

[2] Organisations or businesses are eligible if they (and their subsidiaries) had at least 1 electricity meter settled on the half-hourly market during 2008, consume more than 6,000 megawatt-hours (MWh) per year, and have less than 25 per cent of their emissions covered by the CCA or ETS.

[3] Personal communication

traded sectors (listed above) are considered completely exempt, while the public sector is entirely covered by the CRC, disregarding the amount of emissions generated.

Climate Change Agreement (CCA): The identification of the sectors covered by the CCA is more complicated, given the policy applies to categories which are smaller than those represented by the broad SIC 2-digit classification used in our database. To estimate a reasonable share of emissions covered under the CCA, we identify the specific subsectors which are eligible for CCA, as listed by the Environment Agency[4], using a more granular SIC classification (SIC 4-digit . Data on energy consumption at SIC 4-digit detail is available from DECC's (2013a) 'Energy Consumption in the UK' Table 4.13 for the industrial sector in year 2007 (based on the SIC 2003 codes). We estimate the share of energy used by the 4-digit sectors covered under the CCA over the total energy consumed by the 2-digit sector, and assume that a similar share of emissions are covered by CCAs in 2013. For example, sector 1422 'Mining of clays and kaolin', which can be eligible for CCA, was responsible for about 23 per cent of emissions from sector 14 'Other mining and quarrying' (which is sector 08 in the 2007 SIC classification). We therefore assumed that 20 per cent of the emissions generated by the sector 'Other mining and quarrying' were subject to CCA. The SIC 4-digit detail was not available for the service sector. For simplicity, we assumed that the CCA only applies to the retail sector.

Climate Change Levy (CCL): We treat this as a residual category that applies to all the traded and non-traded sector emissions that are not covered by the CCA. We also assume that, for some of the service sectors, the CCL only convers around 90 per cent of their emissions, to take into account that some of these will be generated by very small firms which may not qualify for the CCL.

Step 4. Estimating fiscal revenues

Step 4.1 The current policy regime (Business-As- Usual)

We first estimate the impact the current policy framework, namely of the CCL, CCA, CRC, EU ETS and Carbon Price Floor (CPF), has on tax revenues. The following carbon prices are applied (for information on the conversion of current tax rates into £/tCO_2 see Advani, Bassi et al. (2013), Appendix B). Note that, for the purpose of revenue calculations, carbon prices have been obtained applying average, rather than marginal, conversion factors, in order to be consistent with the conversion factors used for emission calculations. These are shown in Table A2.6.

[4] http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/PDF_List_of_Sector_Contacts_Updated_March_2013_a069ee.pdf

Table A2.6 Business-as-usual (BAU) average carbon tax rates across policy instruments and fuels, 2013-14 (£/tCO$_2$, 2013 values)

	CCL	CCA	CRC	EU ETS	CPF	RO/ CfD	FiT
Electricity	10.14	1.01	12.00	3.5	4.94	16.74	3.99
Gas	9.85	3.45	12.00				
LPG	4	1.4					
Coal	6.68	2.34					

Source: Based on Advani, Bassi et al. (2013)

For transparency, we include in Table A2.7 below the marginal tax rates described in the paper (Table 3.2 therein). It should be noted that the choice of marginal or average conversion factors here is a matter of preference and does not affect the final results, as long as they are used consistently (i.e. revenues will not change if both emissions and carbon prices are calculated using marginal conversion factors).

Table A2.7 Marginal carbon tax rates across policy instruments and fuels, 2013-14 (£/tCO$_2$, 2013 values)

	CCL	CCA	CRC	EU ETS	CPSR	RO/CfD	FIT
Electricity	13.37	1.34	16.56	3.5	4.92	22.08	5.27
Gas	9.85	3.45	11.92	-	-	-	-
LPG	4	1.4	-	-	-	-	-
Coal	6.68	2.34	-	-	-	-	-

Source: Based on Advani, Bassi, et al. (2013)

The resulting tax revenues are obtained by multiplying the carbon prices associated with the CCL, CCA and CRC by the sectoral emissions identified in Step 2, on the basis of policy applicability as described in Step 3.

Revenues from the EU ETS are calculated by multiplying the ETS carbon price by the total volume of European Union Allowances (EUAs) auctioned by DECC on the ICE auction platform in 2013 (95 million tCO$_2$e)[5].

As for the CPF, revenues are estimated by multiplying the Carbon Price Support Rate (CPSR) by the verified emission from combustion installations in 2012 (156.8 million tCO$_2$e)[6]. Total revenues amount to around £2.6 billion, as shown in table A2.8.

[5] https://www.theice.com/emissionsauctions.jhtml

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/181586/2012_eu_ets_results_april_2013.pdf

Table A2.8 Estimated fiscal revenues of BAU policy regime (million £, 2013 values)

	Electricity	Gas	Coal	LPG	Total
Revenues	2,149	435	10	6	2,600
of which					
CCL	524	207	3	6	740
CCA	43	51	7	0	101
CRC	478	177			655
ETS	333				333
CPF	771				771

Source: Authors' calculations

It is useful to compare these revenues with Her Majesty's Treasury's (HMT) own forecast of revenues from environmental taxation for 2013/14 (HMT, 2013). These appear to overestimate the revenues from the auctioning of EUAs, given the recent drop in their price. Our estimates are broadly in line with the HMT's forecasted revenues from the CRC, while our estimated revenues under the CCL/CPF are about 28 per cent higher, likely because of the simplifications made on sectoral coverage (see a comparison in Table A2.9). This may suggest that our estimate of the policy reform revenues may also be biased upwards.

Table A2.9 Comparing estimated revenues from current policy regime, (million £, 2013 values)

2013/2014	HMT (2013)	Our estimate
CCL/CCA & CPF	1,300	1,612
EU ETS	700	333
CRC	700	655
Total	**2,700**	**2,600**

Source: Authors' calculations and HMT (2013)

Step 4.2 The impact of the proposed policy reform, 2013

We assess the hypothetical impact of our proposed policy reform, had it been implemented in 2013. This policy reform assumes that the existing CCL, CCA and CRC rates are replaced by a new single CCL rate (here referred to as 'CCL+') which is consistent with the non-traded sector's carbon price in 2013, i.e. £59/tCO_2. The CCL+ rate applied to electricity is lower than for other fuels, as electricity already includes an implicit carbon price charged through the EU ETS, CPF, RO and FiTs (Table A2.10).

Table A2.10 Proposed policy reform, 2013/14 (£/tCO_2, 2013 values)

	Policy reform	Other policies (as in BAU)				Total carbon price
	CCL+	ETS	CPRS	RO	FiT	
Electricity	29.82	3.5	4.94	16.74	3.99	59
Gas	59					59
LPG	59					59
Coal	59					59

Source: Based on Advani, Bassi et al. (2013)

Fiscal revenues from the CCL+ are calculated by multiplying the above CCL+ carbon price by the total consumption of electricity, gas, LPG and coal from all sectors. The only exceptions are emission from gas, coal and LPG from EU ETS traded sectors (as identified in Step 3), which are multiplied by the CCL+ carbon rate reduced by the EUA price, as this is already paid by the EU ETS participants.

Revenues from the EU ETS and CPF are estimated as in the business as usual case described above. Total revenues amount to around £5.7 billion, as shown in table A2.11.

Table A2.11 Government revenues from the simulated energy policy reform, 2013 (million £, 2013 values)

	Electricity	Gas	Coal	LPG	Total
Revenues	4,169	2,238	201	102	6,710
of which					
CCL+	3,065	2,238	201	102	5,606
ETS	333				333
CPF	771				771

Source: Authors' calculations

Step 4.3 The impact of the proposed policy reform, 2020

In order to estimate energy consumption values for 2020 we rely on estimates by the Committee on Climate Change (CCC, 2013), which takes into account energy consumption reductions associated with the current policy landscape. This data suggests an average 5 per cent increase in electricity consumption, 21 per cent reduction in natural gas and 10 per cent reduction in coal consumption in the industrial sector between 2012 and 2020. We apply these percentage changes to our 2012 consumption data, assuming that service and agricultural sector emissions follow a similar path to industrial sector emissions. As the Committee on Climate Change data does not include specific values for LPG, we assume LPG consumption follows the average trend of electricity, gas and coal combined (a decrease of 9 per cent between 2012 and 2020). It is likely that this value underestimates the reduction in energy consumption that the proposed policy reform could deliver by 2020, given its higher carbon price in comparison to existing policies. Results should therefore be taken as an upper bound. Conversion factors are the same as for 2013, with the exception of electricity, as the power sector is expected to become increasingly decarbonised (see Table A2.12).

Table A2.12 Proposed (average) carbon tax rates, 2020 (£/tCO_2, 2013 values)

	Policy reform	Other policies				Total carbon rate
	CCL+	ETS	CPRS	RO*	FiT*	
Electricity	0	8.8	21.2	268	103	>>65
Gas	65					65
LPG	65					65
Coal	65					65

**Values are very high as we assume a very low average carbon intensity of electricity (0.05tCO_2/MWh)*
Source: Authors' calculations

It should be noted that, the analysis in this paper uses the average conversion factor of 0.050 tonnes CO_2/MWh. As a result the calculated carbon price rate for the policies that apply an implicit carbon price on electricity, the RO and FiT, is significantly higher than the rates which are calculated using a marginal conversion factor (0.293 tonnes CO_2/MWh) (as reported in Table 3.3 of the paper), but this does not affect the final results.

The resulting revenue estimates are shown in Table A2.13. For the EU ETS and CPF, it is assumed that emissions from the traded sectors will decline in line with the EU ETS cap decline[7]. This is likely to be an overestimate, as the CPF is expected to lead to faster emission reductions in the UK traded sector. The resulting revenues should therefore also be regarded as an upper bound. We assume that in 2020 all EUAs are auctioned.

Table A2.13 Government revenues from energy policy reform, 2020 (million £, 2013 values)

	Electricity	Gas	Coal	LPG	Total
Revenues	5,966	1,891	140	103	8,100
of which					
CCL+	-	1,891	140	103	2,134
ETS	2,270				
CPF	3,696				

Source: Authors' calculations

Step 4.4 Sensitivity analysis

The simplified analysis above assumes that business energy consumption in the future will follow the pattern estimated by the Committee on Climate Change. This, however, does not include the effect of a CCL+ tax of the size assumed in this paper. It is reasonable to expect that the reform here outlined, which will result in higher tax rates (especially for gas, LPG and coal), will lead businesses to improve their energy efficiency and reduce their emission. Indeed, this should be the key aim of

[7] The cap is meant to decline by around 37 billion allowances each year to reach 2.04 billion allowances in 2020 across the European Union, i.e. a total of around 260 million allowances between 2013 and 2020. This translates into a decrease of around11 per cent between 2013 and 2020.

the policy package. We therefore carry out a sensitivity analysis using different assumptions on how much businesses could change their energy consumption in response to energy price changes. Crucial in this analysis is the degree of price elasticity of demand from firms, which is an indication of *how much* energy consumption changes in response to a higher carbon price.

We then estimate the effect that the CCL+ would have on revenues, consumption and emissions, under these new assumptions. Following Advani, Johnson et al. (2013), we model a range of elasticities, from 0 (no behavioural response) to -1.0 (a demand decrease proportional to the price increase - e.g. if prices rise by 10 per cent demand for energy decreases by 10 per cent).

We obtain the average consumption of all non-domestic consumers from DECC (2013a) and calculate figures of 203.6 million MWh for electricity and 211.9 million MWh for gas. We take this as our baseline. Further, wholesale prices in 2012 are taken from DECC (2013c), and are £89.4/MWh and £25.8/MWh for electricity and gas, respectively.

As noted in Section 4.1, the carbon prices which apply to electricity and fossil fuels vary substantially across firms. As a first approximation, we base our analysis on 'average' carbon prices, calculated by dividing estimated yearly revenues post-reform for electricity (£3,065 million) and gas (£2,238 million) by consumption for each fuel. Using this backward-looking estimation, we calculate that the amount the proposed policy reform will add to energy costs, (in addition to variations in wholesale prices) will be between £15.05/MWh and £10.56/MWh for gas.

On the basis of these crude averages, we are able to estimate post-reform prices, with electricity prices increasing 17 per cent to £104.45/MWh and gas rising 41 per cent to £36.36/MWh. Based on this consumption and price data, we are able to estimate impacts on revenues, consumption and emissions assuming different measures of own-price elasticities of firms. We use average emission factors from DEFRA and DECC (2012) of 0.517 tonnes CO_2/MWh for electricity and 0.185 tonnes CO_2/MWh for gas; 2011 emissions data is taken from DECC (2012). Table A2.15 below provides the main results for the different own-price elasticities. Importantly, it is assumed there is no cross-price substitution between the two fuels.

Table A2.15: Impacts on revenue, consumption and emissions of different assumptions on price elasticity of demand

Elasticity	Revenue (£m)	Relative to elasticity=0 (£m)	Change in consumption (MWh, millions)		Change in CO_2 emissions (million tonnes)			Change as % of 2011 industrial emissions
			Electricity	Gas	Electricity	Gas	Total	
0	5,303	-	0.00	0.00	0.00	0.00	0.00	0.00
-0.1	5,160	-143	-3.43	-8.68	-1.78	-1.60	-3.38	-2.72
-0.2	5,016	-287	-6.86	-17.35	-3.54	-3.21	-6.75	-5.44
-0.3	4,873	-430	-10.28	-26.03	-5.32	-4.81	-10.13	-8.16
-0.4	4,730	-573	-13.71	-34.70	-7.09	-6.42	-13.51	-10.89
-0.5	4,587	-716	-17.14	-43.38	-8.86	-8.02	-16.88	-13.61

-0.6	4,443	-860	-20.57	-52.05	-10.63	-9.63	-20.26	-16.33
-0.7	4,300	-1003	-24.00	-60.73	-12.41	-11.23	-23.64	-19.05
-0.8	4,157	-1146	-27.42	-69.41	-14.18	-12.84	-27.02	-21.77
-0.9	4,014	-1289	-30.85	-78.08	-15.95	-14.45	-30.40	-24.49
-1.0	3,870	-1433	-34.28	-86.76	-17.72	-16.05	-33.77	-27.21

Source: Author's calculations based on Advani, Johnson et al. (2013), DECC (2012; 2013a; 2013c) and Defra & DECC (2012).

The results show that, as elasticity increases, the demand response to the price signal also increases. This reduces revenue, consumption and emissions. But what elasticity can be expected from firms in reality? Most studies assessing price elasticities focus on the residential sector, but two studies estimate firm elasticity. Adeyemi & Hunt (2007) review industrial energy demand in OECD countries and find that the average short-run price elasticity is -0.3. At an elasticity of -0.3, revenues from the reform are expected to decrease by £430 million, or 8.1 per cent, compared to a scenario with no behavioural response. Further, electricity demand falls by 5 per cent and gas demand by 12 per cent, leading to emissions reductions of around 10 million tonnes of carbon dioxide, amounting to 8.16 per cent of 2011 emissions from industry.

What can we expect in the long-run? Analysing British and German industrial sectors, Agnolucci (2009) finds the average long-run elasticity of demand to be -0.6. At this level, the impact of the proposed reform on revenues, consumption and emissions would be more substantial. Revenues are expected to decrease by £860 million, or 16 per cent of the baseline. Electricity and gas demand are estimated to reduce by 10 and 25 per cent respectively. This is likely to lead to emissions reductions of about 20 million tonnes of carbon dioxide, or 16.33 per cent of total industrial emissions in 2011.

The results suggest that demand responses to the reforms are unlikely to significantly reduce tax revenues in the short-run. This is because current technology does not enable significant energy efficiency gains. However, in the long-run, as industries are able to replace old equipment with newer, less energy-intensive capital stock, elasticities are estimated to increase more substantially. This could reduce tax revenues (and hence business costs), energy demand and emissions significantly.

Yet, as our results only represent averages across sectors, they should be interpreted with caution. As different sectors have different energy intensities and production functions, own-price elasticities vary greatly, ranging from relatively inelastic (for example, cement production) to highly elastic (for example, aluminium smelting) (Smale et al., 2006; Hepburn et al., 2013).

Future research may seek to estimate elasticities using micro-level firm data. Nevertheless, our modelling exercise allows us to estimate what might happen in to businesses' energy demand in response to price reforms. In the short-run, impacts are moderate. However, over the long-run, impacts become more substantial and reforms may have to be adapted in response to firm behaviour.

References

Adeyemi & Hunt, 2007. Modelling OECD industrial energy demand: asymmetric price responses and technical change. *Energy Economics*, v. 29, pp.693–709.

Advani, A., Bassi, S., Bowen, A., Fankhauser, S., Johnson, P., Leicester, A., & Stoye, G., 2013. *Energy use policies and carbon pricing in the UK*. London: Institute for Fiscal Studies & Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, LSE.

Advani, A., Johnson, P., Leicester, A., & Stoye, G., 2013. *Household energy use in Britain: a distributional analysis.* London: Institute of Fiscal Studies (IFS).

Agnolucci, 2009. The energy demand in the British and German industrial sectors: Heterogeneity and common factors. *Energy Economics,* v. 31, pp.175–187.

Commitee on Climate Change (CCC), 2013. *Reducing the UK's carbon footprint and managing competitiveness risks*. London: CCC. [pdf] Available at: http://www.theccc.org.uk/publication/carbon-footprint-and-competitiveness/ [30 September 2013]

Department of Energy and Climate Change (DECC) and Her Majesty's Treasury (HMT) ,2013. *Valuation of energy use and greenhouse gas emissions for appraisal - Tables 1-20: supporting the toolkit and the guidance, in*.[online] Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal [30 September 2013]

Department for Environment Food and Rural Affairs (DEFRA), & Department of energy and Climate Change (DECC), 2012. *Guidelines to DEFRA/DECC's GHG Conversion Factors for Company Reporting*. London: DEFRA & DECC. [pdf] Available at: http://www.defra.gov.uk/publications/files/pb13773-ghg-conversion-factors-2012.pdf [30 September 2013]

Department of Energy and Climate Change (DECC), 2012. *Official statistics: provisional UK greenhouse gas emissions*. [online] Available at: https://www.gov.uk/government/publications/provisional-uk-emissions-estimates [30 September 2013]

Department of Energy and Climate Change (DECC), 2013a. *Energy Consumption in the UK*. London: DECC. [pdf] Available at: https://www.gov.uk/government/publications/energy-consumption-in-the-uk [30 September 2013]

Department of Energy and Climate Change (DECC), 2013b. *Valuation of energy use and greenhouse gas (GHG) emissions - supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government. Tables 1-20: supporting the toolkit and the guidance.* London: DECC. [xls] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/248604/2013_Appraisal_Guidance_-_Toolkit_Tables_-_FINAL.xlsx [30 September 2013]

Department of Energy and Climate Change (DECC), 2013c. *Quarterly Energy Prices: September 2013*. [online] Available at:

https://www.gov.uk/government/publications/quarterly-energy-prices-september-2013 [30 September 2013]

Hepburn, C., Quah, J., Ritz, R., 2013. Emissions trading with profit-neutral permit allocations. *Journal of Public Economics*, v. 98, pp.85-99.

Her Majesty's Treasury (HMT), 2013. *Written Ministerial Statement - Environmental Taxation*. London: HMT. [pdf] Available at:http://www.parliament.uk/documents/commons-vote-office/March-2013/26-3-13/2.CHANCELLOR-Environmental-taxation.pdf [30 September 2013]

Smale, R., Hartley, M., Hepburn, C., Ward, J., Grubb, M., 2006. The impact of CO_2 emissions trading on firm profits and market prices. *Climate Policy*, v. 6, pp.31-48