Electricity in transition: economic and policy dimensions

Submission to the House of Lords Economic Affairs Committee's Inquiry into *The Economics of UK Energy Policy*

By UCL Energy Institute and Institute of Sustainable Resources

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Summary

1. The electricity system is undergoing a once-in-a-century transition. Other submissions, including by UK Energy Research Centre, may explore technological and other aspects of this transition. Our submission focuses upon the broader economic and policy dimensions, primarily in electricity.

2. Electricity has never been a 'free market'. As an essential commodity supplied through monopoly networks, along with several other core characteristics articulated here, electricity has always had either direct state or 'hybrid' governance. Governments have always had to define economic and regulatory frameworks to secure sufficient investment and deliver the 'trilemma' goals of energy security, affordability, and sustainability.

3. The technological and system changes under way offer the prospect of delivering better on all three of these goals. Though new technologies offer new forms of competition, we expect the hybrid characteristic to remain, and it is inescapable during the transition. However the radical changes underway (capital vs fuel costs; generation no longer centralised and more time- and location-dependent; greater flexibility) imply that the old institutional design, common policy assumptions and even economic metrics risk being dysfunctional.

4. Electricity costs are significant for a small group of basic industrial processes. These (and many other industries) are largely exempt from any impact of energy-environment policy on their electricity prices, and UK electricity prices are not extreme by international standards even *before* taking account of the recycling of 80% of the carbon floor price revenues back to the industries concerned. Any remaining impact of the carbon floor price is also greatly diminished as coal declines in the UK electricity mix.

5. The innovation required in the energy system can only be delivered by a healthy mix of private sector and public sector activity. The challenge is that of coherently coordinating both public and private activities to deliver innovation and deployment of new technologies. Particularly given the capital-intensity of many of the required investments, the impact of competitive auctions under the Electricity Market Reform (EMR) in reducing the cost of capital is a valuable achievement.

6. By several metrics, the UK is making reasonable progress in the transition, at moderate costs. Despite a backdrop of inadequate investment and headlines about 'lights going out' they have not yet flickered. This is not a reason for complacency, but some of the scares do arise from failure to understand the growing flexibilities in the modernising electricity system; and efficient policy can nurture these further.

7. For electricity generation the EMR reforms may suffice for the duration of this Parliament, with two important exceptions, as will be discussed in paragraphs 14-27; but radical change would be required in the next and thinking for this needs to be developed now.

Background: ‘Failures’ in the energy market

8. The Inquiry’s ‘core question’ is posed as *‘are there failures in the energy market and what measures are needed in the future to correct them?’* A simple reading of the question would imply a reasonably simple goal of ‘correcting failures’ with the expectation that this could align competitive energy markets with the public good. The challenges to this are indeed formidable. Dieter Helm (2004, p.418) observed that for electricity:

> “supply must instantaneously match demand ..; the assets are sunk and long-lived; the networks are natural monopolies; there are very great environmental externalities; and, critically, electricity and gas are complementary to the rest of the economy, in that failure to supply has (extremely) large costs to all economic activity. If the issue of fuel poverty and the distribution implications.. are also included, it is extraordinary that anyone could have regarded these as anything other than political industries.”

9. In fact there are even more extensive reasons why energy policy is necessarily more complex than ‘correcting market failures’. Organised around the intellectual framework of the lead author’s book (Grubb et al, 2014), Table 1 indicates the factors which drive (a) low levels of consumer engagement (particularly for poor and vulnerable households), (b) structural failures in generation markets, and (c) exceptionally low levels of private R&D investment, which at well under 1% of turnover are a small fraction of R&D intensities observed in sectors like IT and pharmaceuticals.

10. Finally, governments have struggled to put in place proper pricing for externalities, notably carbon pricing, which adds further to the challenge of ensuring that electricity markets deliver public goals.

The technology and system transition

11. The combination of changes in electricity generation technologies – including dramatic reductions in the cost of solar and wind (see paragraphs 22-23) – information and ‘smart’ demand-side technology, and various system technologies including DC transmission, grid control and storage, implies the evolution of a system which is:

a. more capital but less fuel intensive
b. more ‘hollowed out’ – with power inputs no longer focused on centralised generation, but with more decentralised generation, as well as more long-distance energy inputs from eg. interconnectors and offshore wind
c. less reliant on the implicit chemical stores of fuel for baseload generators, and hence with more need for explicit storage (electricity or heat), explicit backup, or interconnection
d. more time varying due to greater role of variable renewable sources

12. These changes also imply that dynamic balancing of supply and demand (from milliseconds to months) must move away from reliance on a

few large generators, to a system where these services are provided by a wide range of providers, more specialised around the balancing services required at different scales and timescales of the system. The growing need for resilience to extreme events (as witnessed by the Lancaster floods) also enhances the case for more distributed balancing and recovery services.

13. These characteristics pose various challenges, but the changes also offer the possibility to reduce some of the ‘barriers’ identified in Table 1, in particular offering the prospect of stronger consumer and community engagement, and greater diversity which could enhance competition and private innovation.

Table 1 Energy (particularly electricity) characteristics that impede efficient markets

"1st Domain" - Characteristics which lead to large satisficing behaviours, low consumer engagement	**"2nd Domain"** - Characteristics which impede efficient supply-side markets	**"3rd Domain"** - Characteristics which drive exceptionally low R&D intensity of energy (especially electricity) industries
(a) No (physical) product differentiation. All electrons are substantively the same; so are all methane molecules. Apart from cost, the physical product is undifferentiated at any one moment in time.	**1. economies of scale with immobile assets**	i) **High degree of endogenous learning** / learning-by-doing and industry (as well as plant) scale economies as well as dependence on largely fixed distributional infrastructure
(b) No substitutes. For the vast majority of uses there are no reasonable substitutes to electrons or methane.	**2. capital-intensity**	ii) **substantial long-lived capital-intensive assets** ("infrastructure" to the finance industry): this implies *large capital commitment with long timescales of investment and returns*, all amplifying the risks
(c) Incidental not deliberative consumption Energy demand is rarely a conscious choice; energy consumption is implicit in other decisions, and its cost is usually invisible (and often trivial) at point of use in relation to other factors of attention	**3. non-storability with fluctuating demand**	iii) **Baseload / low carbon options with low marginal costs are hence *inframarginal*** *in electricity markets and bear the risk of fossil fuel price volatility.* A 'spot' market is intrinsically tilted against clean / baseload energy generation, which (rather perversely) take the main risks associated with fossil fuel price variations;
(d) Continuous. There is no discrete point at which consumers need to "go and buy a new one"; consequently there is no natural point of conscious engagement with the need to take a decision.	**4. locational specificity generating location rents**	**iv) Dependence on regulated networks** which injects an element of (actual or perceived) regulatory risk;
(e) Essential The essential nature of energy makes it impractical to force this (eg. "choose or be disconnected") unlike many financial or insurance products with natural expiry terms.	**5. producing necessities or essential for the community**	**v) High externalities** (environment, security) which are hard or impossible for private actors to monetise themselves, and the value of which may be subject to large political uncertainty and are typically under-priced (if at all) in energy markets;
	6. involving direct connections to customers	**vi) Almost-fixed market size.** Size of the energy market almost fixed - No prospect for innovations to create a whole new market
*The undifferentiated, non-substitutable, incidental and continuous nature means that First Domain (**'behavioural' / satisficing) characteristics are exceptionally strong** in energy consumer markets. **Hence, a low level of engagement has been the natural state**, most of the time.*	*"Electricity fits [this] catalogue perfectly, which suggest reasons for public concern beyond just the exercise of market power." (Newbery 2016)*	*The result is high merchant risks (investment, political and market), combined with modest potential rewards to innovation.*

What are the key economic challenges for the energy market which the Government must address over the next decade?

14. Key economic challenges for the energy market include:

A. how to ensure adequate and timely investment in new energy generation and infrastructure consistent with the UK's legal targets (on climate and security standards);
B. how to ensure that this infrastructure is integrated into a system which functions in a secure manner;
C. how to avoid the costs of this transition becoming excessive, and to spread and mitigate the impacts of these costs in a socially equitable manner.

These three economic challenges will now be discussed in turn.

A. Adequate and timely investment

15. The UK's competitive electricity market in the form of NETA and BETTA did not deliver adequate investment. A crucial underlying challenge was that recovering capital investment in such a market was intrinsically problematic, because the wholesale electricity price was mainly determined by marginal operating costs of fossil fuel plants (coal and gas). For the same reason, the risks and costs were further exacerbated for capital-intensive, low marginal cost plant like renewables and nuclear, which (ironically) bore the risks of fossil fuel and carbon price uncertainties. The conclusion of the CCC (2008) and Ofgem (Project Discovery, 2009) that the NETA and BETTA market structures could not deliver adequate investment was a primary reason for the Electricity Market Reform (EMR).

16. Securing adequate and timely investment requires that energy companies and investors have sufficient confidence in future policy consistency and revenue streams to make the required investments in time. The EMR contracts for difference (CfDs), and the capacity mechanism, aim to give potential developers of different types of power generation sufficient vision of future revenue streams to justify their investments.

17. **Feed in tariffs and CfDs** (which have similar investment properties) have been shown to be an effective means of promoting low carbon energy technologies. However, because they lock in a price for a given length of time, they entail a risk of excessively rewarding energy companies if contracts are too long and/or the same rate is maintained as technology costs fall. The EMR's CfDs for renewables strike a reasonable balance (see paragraph 24). However FiTs / CfDs are not necessarily sufficient for technologies not yet close to market, or that have scale or infrastructure challenges, like CCS. This will require various kinds of coordination that go beyond the activities of any single company or technology developer. As such there are key roles for the government in coordination and infrastructure planning.

18. The capacity mechanism aims to ensure adequate firm generating capacity. However it may not be flexible enough, in its current incarnation,

for example on including demand side response (see paragraph 21). It also does not address the requirement for *flexibility.*

19. Government coordination may also be justified in other important areas of big infrastructure. The electricity transmission networks will need to be expanded. The future of the gas network could include possibilities for upgrading to carry bio-methane, hydrogen, or to be co-opted as part of a future CO_2 transportation network for CCS.

B. Secure operation

20. The characteristics of renewables and nuclear mean that a future low carbon electricity system could experience challenges in ensuring that power is generated both in the right place and at the right time. Existing cost-recovery and balancing charges within the electricity system – such as BSUoS and TNUoS charges – need to give clear locational and temporal signals for generation investment and dispatch. Similar locational and temporal incentives should also be made available on the demand side, to encourage load shifting and demand side response.

21. The design of the capacity mechanism should be reviewed. The two auctions held to date have demonstrated its power to secure capacity for peak loads at very low cost (so far, much lower than predicted: see Grubb 2016a). The fact that old coal and new diesel plants have been major beneficiaries is of some concern given the nature of the transition required (particularly given concerns about excessive ‘embedded benefits’ for locally-connected generators). An equally pressing concern is that the CM was clearly structurally designed for generation and this design means that it has struggled to attract a range of innovative capacity suppliers, including demand side response aggregators. **Reform of the Capacity Mechanism to address these specific problems should be one EMR priority for this Parliament.**

C. Minimising and fairly distributing costs

22. For capital-intensive investment, there is significant economic value to the right combination of risk management and competitive pressures. Economic theory indicates that risks are most efficiently borne by those best able to bear or control them, so it makes sense for governments to bear policy-related risks concerning long-term investment. The earlier UK FiTs and ROCs illustrated the risks of insufficiently flexible support systems as they struggled to keep pace with cost reductions.

23. The clearest example here is solar. Governments in several countries were caught by surprise by its sudden drop in price. This was caused by increasing volume sales driven by the generous feed-in-tariffs offered in several countries, as well as by major investments in manufacturing of the technology in China. Onshore and offshore wind have also seen significant price reductions in countries where political risk is deemed by the market to be low, and which harness competitive pressures (such as auctions) along with long-term secure revenues.

24. CfDs in principle offer a combination of investment efficiency with competitive pressures from the auctions of CfDs. Professor David Newbery's (2016) analysis suggests that the EMR's competitive CfD auctions have reduced the Weighted Average Cost of Capital (WACC) in all technology classes by over 3% - a saving of potentially billions of pounds in the energy transition.

25. The international evidence is that technology cost reductions also continue apace, particularly for systems which seek to minimise policy and planning risks. Minimising costs requires a basic stability in policy, and in the UK this could best be enhanced by timely implementation of the government promise to hold 3 further rounds of renewable energy CfD auctions in this Parliament.

26. In contrast to the 15-year renewable contracts there is legitimate concern about the implications of the 35-year contract for Hinkley Point, at a unit cost far exceeding renewables. In particular we draw attention to the possibility that by 2030, renewables and nuclear may at times be sufficient to meet all electricity demand. It appears that in these circumstances, the most heavily subsidised would displace the cheaper sources – an 'inverted merit order' effect which would cause inefficiency in both operation and investment (Smith and Grubb, 2016). **The risk of perverse incentives arising when long-term CfDs are in direct competition is the second problem which should be urgently considered in this Parliament.**

27. Finally, the cost of CM and CfD contracts are added to electricity bills. This is arguably economically efficient, but socially regressive. Alternative options could include underwriting the contracts from central government instead; fostering more direct consumer-based long term renewable energy contracts, for example with large consumers (like BT) that have pledged to go '100% renewable'; and shifting over time from CfD contracts to carbon-price-backed contracts underwritten by the government.

Has the market and the Government responded effectively to changes in external circumstances, such as significant shifts in technology and prices?

28. The move to competitive auctions in the EMR has gone a long way to addressing this challenge and the positive results can already be seen in the declining auction prices.

29. A growing challenge will be to devise temporal and locational price signals that help to smooth both supply and demand. This is likely to deliver more cost effective solutions than relying purely on conventional fast-response fossil plant to step in to meet the current high peak demand spike in a case of a shortfall in renewable output. In a system in which prices work well (both temporally and spatially) some forward planning and coordination of infrastructure may also deliver cost savings over piece-meal approaches to infrastructure expansion

30. Time of use pricing also enables those with greater flexibility of energy use to benefit from cost savings. Although for individuals, the constant monitoring of energy prices to judge the optimal moment to switch on appliances may be impractical, energy service companies or demand side aggregators which take on this role on behalf of clients, have the potential to offer significant savings.

31. The more the system can be optimised through the right price signals, and equal access to the market for demand side response as well as generation, the more that overall costs of energy can also be brought down, as the need to rely on the most expensive peaking plant is reduced. To support the later stages of the transition, the government needs to start considering reform of market design and contracts to enhance locational and temporal price signals.

How should Government promote research and development – could any shift in public funding improve the efficiency of the energy market? How long might it take for new technologies to displace the established capital stock?

32. Innovation cannot be equated purely with public R&D. The government needs to find appropriate ways to support the entire innovation chain (Figure 1). This includes technology push, market pull, and coordinating demonstration and commercialisation activities through the so-called innovation “valley of death”.

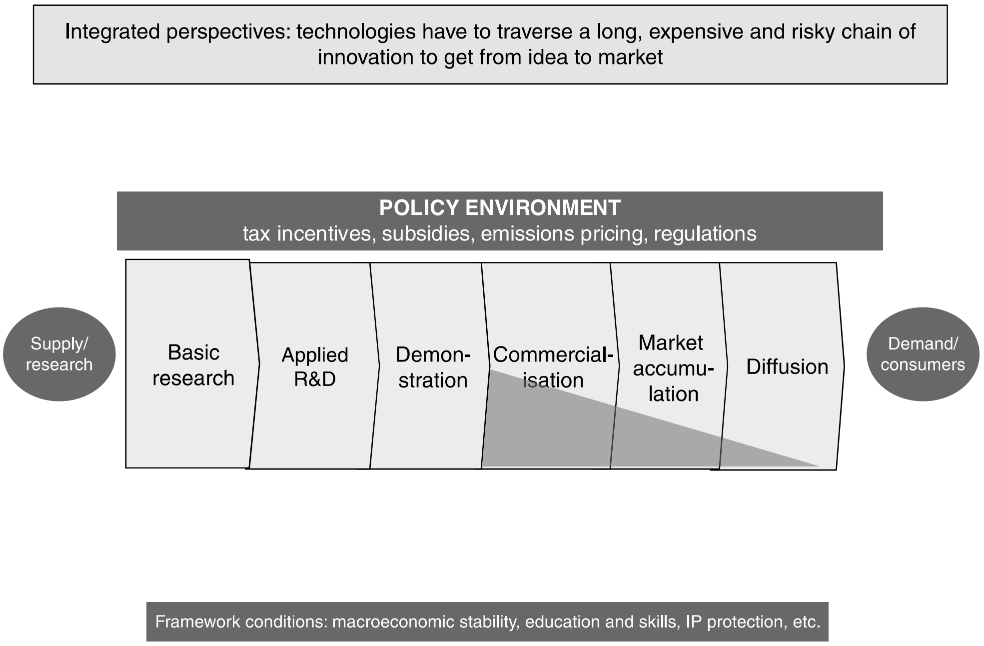

***Figure 1**: The innovation chain. Source: Grubb et al (2014), building on Grubb et al (2008)*

33. Technology push includes funding for basic R&D, and supporting commercial R&D through tax breaks.

34. Market pull means getting the right pricing signals (including locational and temporal, as discussed above), and ensuring that they, as well as the general policy framework, are consistent and show a clear future trajectory. Examples of how not to provide a clear and consistent market pull can be found in the history of the fuel duty and the carbon price floor, both of which have been subject to unexpected alterations and adjustments which owe more to short term political expediency than setting a clear long term signal.

35. But also important are the stages in the middle, around demonstration and commercialisation. The challenge here is that technology proven at lab-scale requires further scale-up and commercial demonstration. However, private investors are typically unwilling to support projects at this stage, preferring to wait until they are demonstrably market-ready. The involvement of government, and independent bodies set up by government, is crucial through this stage. In the UK, the Carbon Trust has played an important role as a broker between the R&D stage, and the need of investors for greater understanding, testing and scaling of the products involved. Public-private partnerships, incubators and market engagement (such as the Riso test laboratory in Denmark) also have important roles.

36. The ‘choice’ between R&D and deployment is thus largely a false dichotomy. The relevant challenge is to develop an effective integrated industrial strategy to accelerate both development and deployment of technology improvements as well as more radical, but plausible, innovations. Policy cannot be based on ‘innovation fairies’: nothing, for example, can change the laws of thermodynamics and we know the major physical resources upon which the UK energy system must rest.

37. CCS is a clear example of a technology that is currently struggling to overcome the ‘valley of death’. The basic technical concepts are established, and indeed are separately in commercial operation. However, bringing together a full large-scale CCS project in power or industry requires coordination of multiple actors, supply chains and the coordination of infrastructure which ultimately must be shared if it is not to be prohibitively expensive. As a result there is considerable full-chain risk that it is very expensive for individual companies to bear. There is therefore an important role for government, or an independent arms-length agency set up by the government, to act as the coordinator for this process.

What should the future balance between the roles of the public and the private sector be? Is further expertise needed within Government to understand the issues and to negotiate with external investors and suppliers?

Are returns for private investment in the sector adequate or excessive? How should the government attract sufficient investment?

38. As noted in previous paragraphs we argue that there are beneficial activities the government can perform in the energy system, providing system coordination, bringing together actors and supply chains, leading and taking some of the risk on major shared infrastructures as part of a ‘mission oriented’ innovation and industrial strategy. As noted above, energy is an industry with many special characteristics (eg. Table 1). Our impression is that government could significantly enhance its expertise on the nature of (and constraints on) innovation and investment in this sector.

39. However it is inevitable that suppliers will have a better knowledge of their technologies than government officials – it is not possible for the government to overcome this by increasing expertise. The situation is clearly most difficult in large projects where the negotiations are being carried out with one supplier (e.g. nuclear).

40. A Government-led industry and innovation strategy entails obvious and well-known risks – as does not having one. There is an inevitable trade-off: the greater the reliance on private sector, the greater the returns that the private sector will seek to compensate for risks. Attempting to minimise the role of government alongside curtailing private sector returns is a recipe for inadequate investment and stagnant innovation.

41. We are not aware that energy companies have returns that could be called excessive. The role of Ofgem in scrutinising the performance of energy companies will of course remain important.

42. As mentioned in previous paragraphs, the surest way of attracting sufficient investment is to honour commitments, including the structures established under the EMR and the Climate Change Act, so as to nurture a policy regime which is secure, trusted and whose future direction of travel is clearly signposted. These are the conditions which will encourage investors and developers to construct energy projects with decadal lifespans.

What is the relationship between high energy costs and the loss of industrial capacity in the UK? What measures should be taken to address this?

43. Industrial price comparisons are complex due to different sectors and contractual relationships, and exchange rates effects. Figures 2 and 3 show data for industrial energy prices for electricity and gas across IEA countries in 2015. UK electricity prices are towards the higher end, but below Germany, Japan and Italy. UK industrial *gas* prices, on the other hand, are lower than the IEA median. In both, taxes make a proportionally small contribution to the overall price. Structural differences are generally more important than taxation levels.

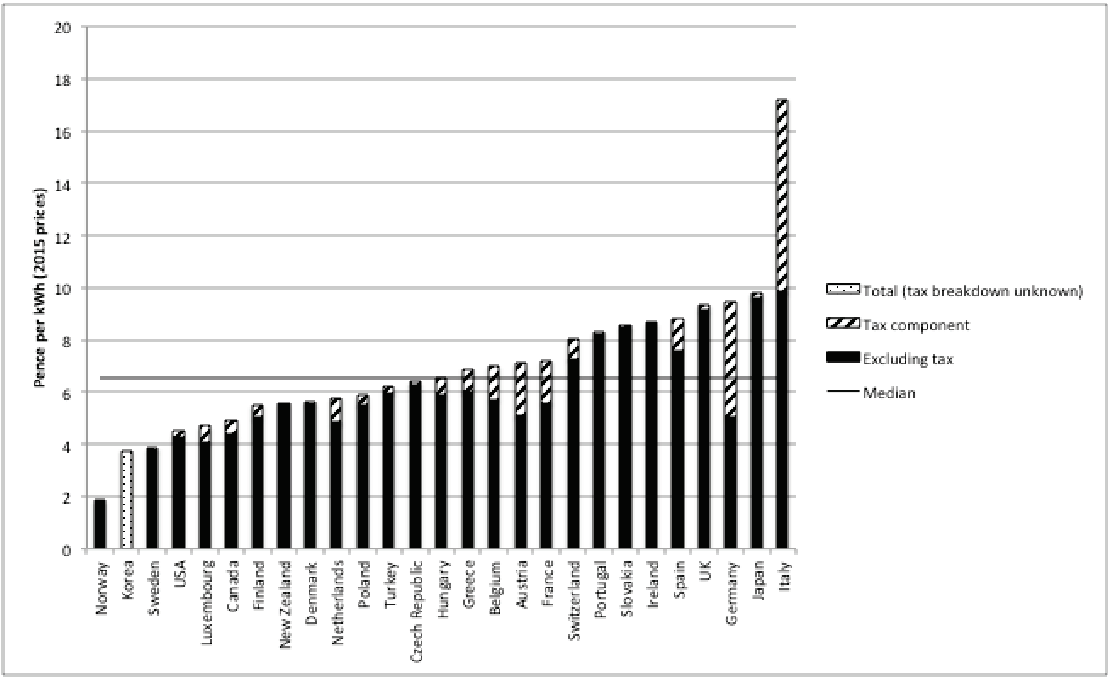

Figure 2: *Average IEA industrial electricity prices in 2015. Source: BEIS statistics. Note: Australia not included due to missing data.*

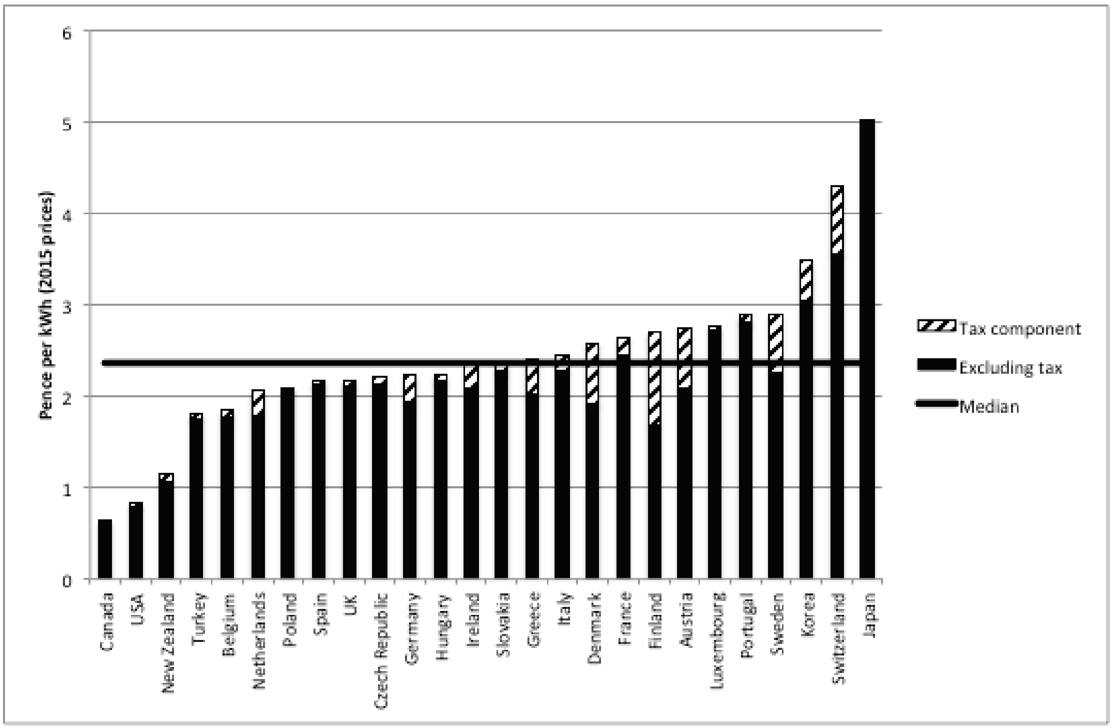

Figure 3: *Average IEA industrial gas prices in 2015. Source: BEIS statistics. Note: Australia and Norway not included due to missing data*

44. For the vast majority of the UK economy, energy prices are not a significant driver of competitiveness (they do not even register in the World Economic Forum index on national competitiveness). Energy costs however are significant for a few energy-intensive sectors. The 23 most energy-intensive activities, charted in Figure 4, in combination contribute more than

half of UK manufacturing CO_2 emissions, but amount to less than 1% of total UK GDP.[1]

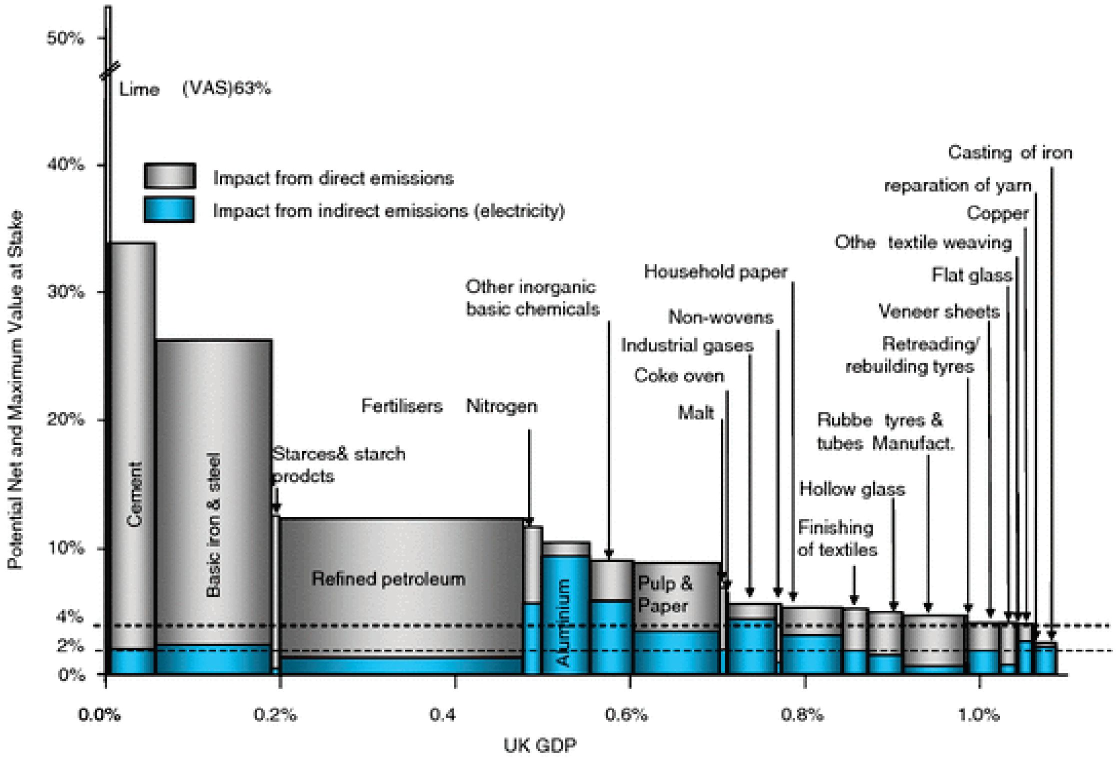

Figure 4: *Manufacturing industries most cost-sensitive to CO_2 pricing – potential 'value at stake', or added cost as percentage of sectoral GVA from a carbon price of €20/t CO_2 (vertical axis); and contribution of sector to UK GDP (horizontal axis). Source: Sato et al (2015); and Carbon Trust (2008)*

45. The concentration of CO_2 emissions within sectors that make a relatively small contribution to GDP reflects the fact emissions are highest in primary production activities, whereas gross value added is greater in downstream processing activities. Outside of these activities most sensitive to CO_2 pricing, the impacts of electricity or carbon pricing differences would be modest compared to for example changes in labour and other input costs, and exchange rate variations. Overall, one study on industrial energy prices and their effect on international trade has found that energy price differences between two country-sectors have a relatively small effect on trade balance, and that over time, differences in energy prices 'explain less than 0.01% of the variation in trade flows' (Sato and Dechezlepretre, 2015).

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[1] Figure 4 shows 'value at stake' from a carbon price of €20/t CO_2, which is comparable to the carbon price differential between the UK and EU ETS (note that France is introducing a similar floor price). The horizontal axis measures the contribution of the sector to GDP. The vertical axis measures the potential maximum cost increase as a percentage of the sector's GVA, under a carbon price of €20/t CO_2. The blue bars show the increase in cost through higher electricity prices, the grey bars show the increase in cost from direct fossil fuel consumption. The GVA data is for 2007 after which HMG stopped the relevant purchasers inquiry (they started again this year, to be published in 2017/18). Some values will have changed significantly e.g cement GVA down from £293m in 2008 to £113m in 2014, and iron& steel down from £2143m to £929m, with commensurate reduction in emissions, due primarily to contraction following the 2008 crisis.

46. Substantial industrial lobbying effort is being directed at energy-environmental costs and the UK carbon floor price. Much of this is disingenuous. There is no overall risk to competitiveness, and moreover, those sectors potentially exposed in practice are largely either exempt from or are compensated for those costs. The value at stake from carbon priced in direct emissions (grey bars) in Figure 4 is for most sectors more than covered by free emission allowances in the EU ETS. The value at stake in Figure 4 from carbon indirectly priced in electricity (blue bars) – where the UK carbon floor price is relevant – is for *gross* costs. However the UK has gained State Aid clearance to recycle 80% of the electricity price impacts of the UK carbon floor price back into the industries concerned (this will fall to 75% in the last two years of this decade). 85% of the costs of renewables financing can also be returned to these sectors.

47. The impact of the carbon price support on electricity costs will also be greatly diminished the more that coal plants retire from the system. Gas plants emit about half as much CO_2 per unit plant as coal; consequently, gas displacing coal as the marginal plant (as is increasingly occurring) roughly halves the impact of the carbon price floor on electricity prices. Efficient long-term contracts with renewable energy generators, if passed directly through, would obviate the impact of the carbon floor price entirely.

48. We also note the evidence, from comparing different countries over time, that the proportion of GDP spent on energy remains remarkably constant, at around 10%. In countries where the price of energy is higher, more energy efficient behaviour is stimulated; conversely, in countries where the energy price is artificially low, for example because it is subsidised, wasteful and energy-inefficient behaviour ensues. Trade is about exploiting natural areas of comparative advantage, and as noted, differences in energy prices between countries are more to do with structure than policy differences. It may in fact make sense for some electricity-intensive processes to take place in Iceland or Norway, where cheap and plentiful renewable energy sources provide electricity at very low cost. Energy policy in relation to UK industry should be aware of where the UK's competitive advantage truly lies.

49. Energy policy should focus on enabling UK industry and manufacturing to make a successful transition to activities that allow the sector to play a valuable contributing role with the economy as a whole, that are consistent with environmental goals, and, crucially, which are aligned with the UK's comparative advantage.