CHATHAM HOUSE | INDEPENDENT THINKING ON INTERNATIONAL AFFAIRS

Aligning Climate and Energy Policy:

Creating incentives to invest in low carbon technologies in the context of linked markets for fossil fuel, electricity and carbon

Report prepared by William Blyth and Kirsty Hamilton, April 2006

This is a background document for the Chatham House workshop on 21st April 2006 on behalf of the UK Stern Review and Energy Review. The underlying question that the workshop intends to address is how climate change mitigation policy should be formulated given that it needs to influence investments and operational behaviour in the electricity sector, and that the electricity sector has a complex pre-existing set of behaviours, rules, trends, constraints and policy objectives that vary considerably from one part of the world to another.

Considering the complexities of electricity systems, there is no single answer on how best to superimpose climate change policy. This paper will look at the problem from two broadly opposing viewpoints: a market-based view, and a non-market view. The market view holds that electricity and fuel systems are close enough to a market ideal to make market-based climate policies the instrument of choice. The non-market view holds that the world's electricity and fuel systems are generally so far from a market ideal that according to the theory of second-best[1] an optimal outcome requires a different starting point.

In OECD countries, access to electricity has almost come to be seen as a 'right' – expectations of high levels of reliability of electricity supply means that the electricity system is highly politicised. This puts electricity uncomfortably on the boundary between a private good suited to control by market forces and a public good suited to control by public policy. Arguments can be made either way on many of these issues depending on one's pre-conceptions. There are many other possible 'world views' and shades of grey between these two contrasting views - bearing in mind that this is a discussion paper rather than a definitive analysis, the aim is to identify the key factors and put them into some context to help structure discussion.

The first section reviews investment drivers in electricity systems, section 2 then discusses the ways in which climate change policy can be introduced, and Section 3 draws conclusions about the implications for international climate change policy design.

1 Investment drivers in electricity systems

Electricity is fundamentally different from other forms of energy carriers for three reasons: a) it cannot be stored in significant quantities, so that delivery has to be carried out in real time, b) there is no way to control the real-time flow of power to a

[1] Lipsey, G. and Lancaster, K. "The general theory of second best" *Review of Economic Studies* 24 no. 1 (1956-1957): 313-22

specific customer, as they can vary the amount of power the draw from the system from moment to moment, and c) although users are an integral part of the electricity system, their demand tends to be unresponsive to short-term price spikes in the spot market. The combination of these factors can lead to a situation where a simple market-clearing model breaks down. Since real-time prices are not visible to both user and generator, demand could simply exceed supply resulting in black-outs.

Any well functioning electricity system therefore has to manage this so as to provide the required level of reliability of supply. This can either be done by ensuring adequate investment in generation capacity to meet peak demand (the usual focus of electricity policy), or alternatively through efforts to make electricity users more responsive to real-time electricity price – e.g. through intelligent networks and appliances. The separation between supply and demand decision making in centralised electricity systems may make it harder for these demand-side measures to reap the full commercial benefits of 'avoided cost' of new supply capacity.

Electricity generation is interdependent with other fuel supply systems, each of which has its own dynamics and policy priorities that vary considerably in different regions of the world (Figure 1).

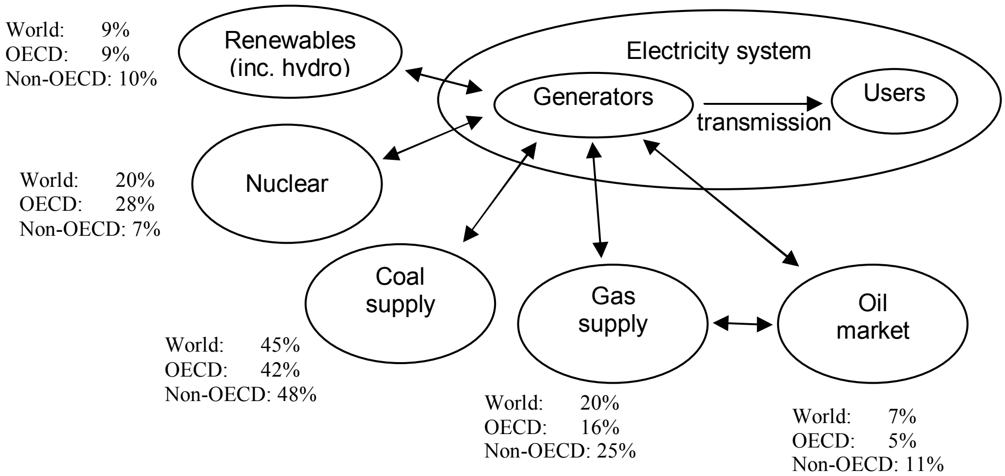

Figure 1. Electricity systems interact with all the other fuel supply systems. Electricity users are an integral part of the electricity system. Percentages represent the share of primary input energy into electricity generation.

Power generation is also an important share of each of these primary energy sources, accounting 40% of total primary energy supply[2] (TPES) for OECD countries and 27% of TPES for non-OECD. Within the fossil fuels, the share of TPES used for electricity generation is highest for coal (81% in OECD, 53% in non-OECD), followed by gas (29% in OECD, 36% in non-OECD), and a small share for oil (5% in OECD, 8% in non-OECD).

Although oil has the smallest share of fuel in power generation (and electricity does not constitute a major part of the end-use for oil products), in many regions oil is a strong driver of gas prices, so it has important indirect effects on electricity systems. This link persists despite the relatively low degree of substitutability between oil and gas amongst end users. The linkage in prices is connected with upstream production and ownership patterns. In the UK and USA, where gas on gas competition is more

[2] Including CHP

established than in other regions, gas prices had become de-coupled from oil prices for several years, although even in those countries there is evidence more recently of a re-coupling[3]. Coal prices also move in response to increases in other fuel prices, but are generally lower and less volatile.

Changes in demand for electricity and relative price shifts between the fuels can therefore lead to complex feedback between the prices of each energy source because of the linkage through power generation.

There are many factors that drive the choice of power generation technology to be invested in, but they broadly fit into two categories:

1. Economic performance of plant, including expected technical performance, fuel prices, electricity prices, capital costs, operation and maintenance costs, environmental costs, decommissioning costs etc over the lifetime of the plant.
2. Strategic issues including geopolitical energy security, broader risks to the economy not accounted for in individual plant economics, consequences for other sectors of the economy (e.g. employment in upstream energy sector, impacts on downstream electricity users).

These two broad categories of investment driver are explored in the next two sections.

1.1 Economic performance

One simple way of comparing technologies is to use levelised costs – that is discounting all costs (fuel, operation and maintenance, capital, CO_2) to present value, and dividing by the expected output in MWh also discounted to present value to give a total generation cost in $/MWh (Figure 2).

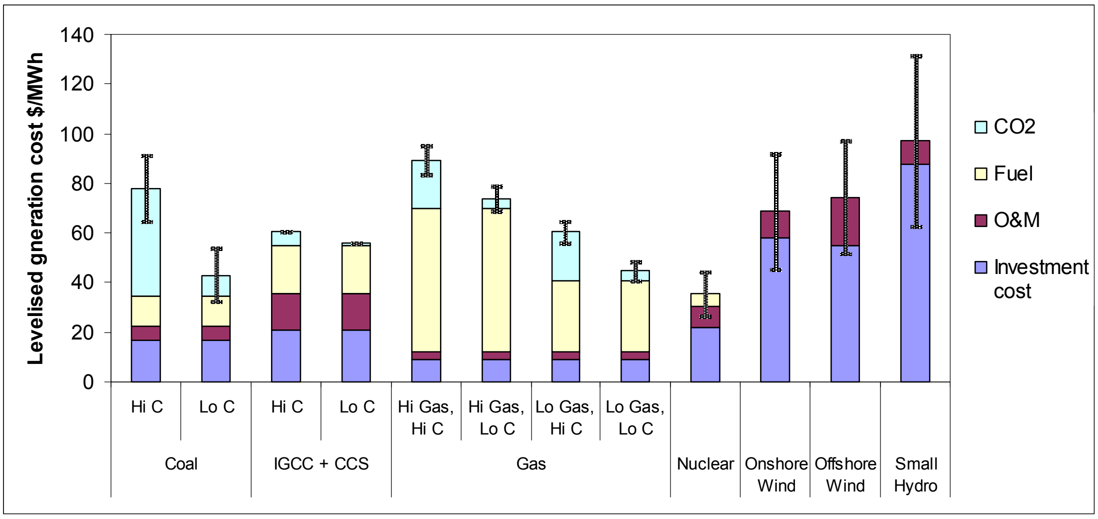

Figure 2. Levelised generation costs for different technologies[4] with different scenarios for gas and CO_2 price. High carbon price ($50/t$CO_2$), low carbon price ($10/tCO_2), high gas price ($6.6/GJ) and low gas price ($3.8/GJ)[5]

[3] Personal communication Jonathan Stern

[4] Adapted from "Projected costs of generating electricity – 2005 update" IEA 2005. The error bars represent ± 1 standard deviation for the range of values given from the IEA survey results except for small hydro where an outlying value was omitted. There is no range given for IGCC as only a single set of data was given in the IEA survey.

In practical terms however, levelised generation costs are of limited value in choosing a technology. Whilst different scenarios can be incorporated into the cash-flow analysis to look at sensitivity to different parameters, levelised cost comparisons do not adequately account for the different risks and benefits of different types of generation technology. Companies making investment decisions would undertake a more sophisticated risk analysis taking account of electricity price scenarios, details of grid connection, demand profiles, expected performance of plant in the portfolio of existing generation, expectations of competitors behaviour, regulatory risks, and policy incentives. These investment risks vary depending on the technology, but the framework for assessing these risks will be determined by the design of the electricity system. To quote from Walt Patterson: "…*comparing the cost of electricity from a remote coal-fired power station with the cost of electricity from a photovoltaic roof on the building where it is to be used, without mentioning location, time of day and year, accounting basis or other system costs and risks, including the risk of disruption, is a grossly distorted comparison.*"[6]

In a competitive market, the incentive to invest in response to electricity prices is quite complex. In theory, market players will wait until prices rise above long-run marginal costs for the most cost-effective plant, and then they will invest. The problem is that all players receive the same investment signals, and so there is a danger of overinvestment which would again push prices down below the long-run investment threshold, leading to boom and bust investment cycles[7]. This means that companies do not face a symmetric threat from variable / uncertain electricity demand – if demand drops suddenly, profits drop in response to lower prices, whereas if demand increases suddenly, this will stimulate new entry or expansion by competitors, dampening the price increase. This asymmetry reduces the expected payoff from investment, so that the threshold price that justifies investment should actually be higher than the long-run average cost[8].

In an oligopolistic market, investment decisions have to take into account expected actions by competitors as described by game theory. One problem with electricity markets in particular is that governments are also one of the players in the game. If a government's 'nerve' doesn't hold and they step in with subsidies for fear of underinvestment, this will alter the rules of the game. Even the possibility that this may happen will tend to alter investment behaviour amongst the power companies. Given the politicised nature of most electricity systems, it is difficult to remove this 'gaming' tendency.

In a pure command and control system, investment and technology choice will be determined by central planners who determine likely investment needs based on projected demand. In many regions, a hybrid somewhere between market-based and command and control systems is in place where companies are established to operate plant and determine necessary investment levels, but these companies may be largely state-owned and subject to low levels of competition (this situation applies to both OECD and non-OECD countries). In such cases, companies may respond to to price-based drivers, but often the prices are to varying degrees centrally controlled. The level of distortion that any particular system faces in terms of its investment choices will then depend on how cost-reflective these prices are. Comparing India and China for example, in both countries electricity generators

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[5] Low gas price scenario is based on long-run expectation of gas price reverting to a price set by LNG – this is in line with the price scenario for Europe for the end of this decade in WEO 2004 (p147)

[6] Patterson, W. 2004. "Networking Change, Keeping the Lights On" *Working Paper No.3Royal Institute of International Affairs.* Available from URL: http://www.riia.org/pdf/research/sdp/WPJun04.pdf

[7] White, A. "Concentrated power" *Public Utilities Fortnightly* Feb 2005

[8] Dixit, A. Pindyck, R. "Investment under uncertainty" *Princeton University Press (1994)*

operate within certain price ranges for input fuels and supply electricity to different users at fixed tariffs. But in China these tariffs are roughly cost-reflective so that sufficient returns can be made on investment to sustain investment levels, whereas in India, prices to large proportions of users are subsidised such that the generators cannot recover their costs, leading to problems of underinvestment and bankruptcy in the electricity sector. The situation is expected to improve in India as a result of the Electricity Act 2003.

1.2 Strategic issues

Strategic issues include indirect economic factors such as energy security and wider economic impacts beyond the electricity generation sector itself.

Energy security is concerned with minimising risks of supply disruptions – the problem with defining energy security is that there are so many different types of risk ranging from technical and operational reliability of delivery systems through to geopolitical concerns connected with the scarcity and uneven geographical distribution of primary fossil fuels. A report by the IEA[9] attempted to develop a quantitative indicator of geopolitical energy security based on access to diverse sources of energy (as opposed to diversity between fuel types *per se*). That work indicated that dependence on a few major suppliers increased risks, particularly if political risk factors for those suppliers were high. This would be exacerbated if a country's demand level represented a large fraction of the supply base thereby reducing the options for switching between different suppliers. For example, in the UK, the concern for the electricity sector has largely been in relation to gas supplies, since coal is relatively 'safe' with a diversity of supply sources from low political risk countries. With falling levels of N. Sea gas production, concentration of gas supply is increasing in the UK, but using IEA scenarios of LNG market growth, this situation would be expected to reverse in the longer term due the diversity of suppliers in a future LNG market.

A market-based view would argue that companies will take into account the geopolitical risks of gas supply disruption in their estimates of the likely economic performance over the lifetime of a gas power plant. The presence of such geopolitical risk should create a disincentive to invest in gas, and create an incentive for gas companies to provide solutions – for example investing in additional pipeline or LNG projects to increase diversity of supply sources – in order to maintain the value of their product. In this world view, intervention by governments in the name of energy security is effectively a form of subsidy, distorting investment choices, and undermining the willingness of companies to invest in these solutions themselves.

A non-market view would argue that the responsibility of power generators is limited to 'normal' operating conditions, and that the risk of geopolitical events such as a breakdown in relations between gas exporting countries and gas importing countries is the realm of foreign policy, not the responsibility of power companies. In this world view, governments therefore need to intervene to create the conditions for a secure supply of primary energy into their country. Failure to do so will put the country at a disadvantage compared to other neighbouring countries who take a more active role.

In addition to the risk of a catastrophic disruption in supply, there are also strategic concerns with the effect of gas price volatility and uncertainty that have risen to the fore over the past few years. Because gas prices often set the marginal price of

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[9] Blyth, W. Lefevre, N. "Energy security and climate change policy interactions" *IEA information paper* (2004)

electricity, then gas price volatility and uncertainty causes similar volatility and uncertainty in electricity prices and therefore has broader economic consequences for consumers.

A market view would again assert that private investment decisions would factor in the cost to the wider system of high volatility. If electricity price volatility causes economic damage to the end user, this would create an incentive for the user to contract for electricity from sources that are less variable even if the average price was higher. This in turn should create incentives for the power generation companies to invest in non-gas power generation. Exposure of end users to volatile prices would in fact be an important driver to make the market more efficient by creating incentives to increase the range of generation types and contractual options on offer.

A non-market view would assert that markets do not function sufficiently well to be able to capture all the downstream economic consequences of price volatility. Several authors have attempted to quantify the broader economic costs of gas price volatility and the distortion that this creates if these costs are not borne by the power generators[10]. These arguments can be used to show that if fuel price risk is incorporated into a portfolio approach, then an optimal (in terms of risk/return ratio) mix of generation technologies would include greater levels of renewable energy than if only static prices are considered[11]. These techniques have also been used to look at optimal generation mixes at the national level in the Netherlands[12].

Governments often intervene for strategic reasons to support domestic energy resources available to a country for energy security and other broader economic reasons such as employment. An obvious example is with renewable energy to which all countries have access, but which in most situations requires additional financial support. Domestic coal resources also often get economic support and nuclear energy also requires government support in one form or another to make it a viable investment choice. In the next section, there is further discussion of the investment choices in the context of climate change policy.

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[10] Bolinger, M. Wiser, R. Golove, W. "Accounting for fuel price risk" *Lawrence Berkeley National Laboratory(2003)* http://eetd.lbl.gov/EA/EMP

[11] Awerbuch, S. (2000) "Getting it right: the real cost impacts of a renewables portfolio standard" *Public Utilities* Fortnightly, Feb 15, 2000

[12] Jansen, J. et al. "Application of portfolio analysis to the Dutch generating mix" *ECN February 2006*

2 Introducing climate policy to electricity systems

Climate change policies are very diverse – in this paper, we are concentrating on policies that stimulate investment in the electricity system. The drivers by which climate policy can do this can as before be divided into two categories

1. Economic measures – typically through a price mechanism (tax or trading scheme), but also any subsidy or other incentive mechanism that changes the economics of different technologies, aiming to establish a least-cost introduction of low-carbon technology
2. Strategic measures – recognising that a transformation of the energy system is required and aiming to accelerate development and deployment of a range of technologies that may not currently be cost-effective

The following two sections briefly outline the key issues arising from price-based mechanisms and some considerations behind taking more strategic measures.

2.1 Economic measures – aiming for least cost solutions

The uptake of abatement measures can be represented by an abatement supply curve as shown in Figure 3[13]. A price-based mechanism works by increasing the cost-effectiveness of abatement technologies and stimulating uptake – effectively moving the supply curve downwards so that a greater level of abatement can be carried out cost-effectively. As measures are taken up, the remaining cost-effective potential reduces, new developments resulting from technological learning and R&D will gradually replenish the supply of cost-effective technologies.

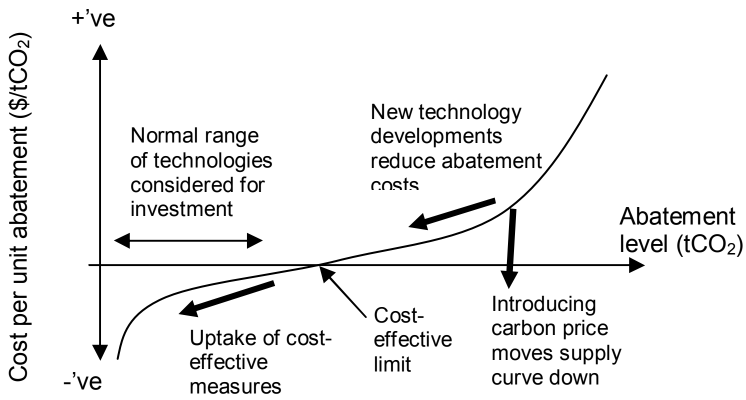

Figure 3. Abatement supply curve showing the dynamic equilibrium between uptake of cost-effective measures and new technology development and the role of carbon price measures in increasing the cost-effective potential

A least-cost approach involves investing in the lowest cost measures first, and then gradually working up the supply curve. In power generation, the supply curve is somewhat 'lumpy' with broad tranches of measures at different cost levels. Typically end-user energy efficiency would be towards the left of the curve, improved generation efficiency and fuel switching from coal to gas would be in the middle, and investment in nuclear, renewables and carbon capture and storage further up to the right.

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[13] Derived from "Long-Term Reduction in Greenhouse Gas Emissions in the UK – Annex D" Interdepartmental Analysts Group, DTI (2002)

The particular shape of the supply curve will vary depending on the sector and local conditions. It is these variations in abatement costs that lead to the efficiency gains ascribed to carbon policies that act through a carbon price rather than by a deterministic imposition of certain technology solutions. It can be shown that for a group of emitters with diverse abatement costs, it is cheaper to set an overall emission target for the group than applying the same fixed abatement level to each individual emitter. This is because a group target would allow them to distribute their individual abatement efforts so that those with low abatement costs abate more than those with high abatement costs.

This is the principle behind the economic benefits of cap and trade schemes. The same efficiency argument goes for taxes. Estimates of the economic benefits of trading in the Kyoto Protocol range from $26-106bn depending on whether trading of surplus units from the former Soviet Union are included in the analysis. These benefits arise almost entirely due to the redistribution of the burden of effort in meeting the overall emission reduction target. For emissions trading at the company level, emissions trading may also provide additional hedging value against uncertain future levels of emissions in addition to the redistribution of abatement burdens[14].

Although taxes and trading systems both act through a carbon price, they differ to the extent that taxes determine a fixed carbon price but leave emission levels uncertain, whereas cap and trade schemes determine a fixed level of emissions but leave carbon price levels uncertain. If the total amount of abatement and the costs of abatement were known for certain, then the two instruments would be equivalent. In the face of uncertainty in both these parameters, it can be shown that if marginal benefits increase only slowly as a function of annual abatement levels (which tends to be true in the case of a 'stock' environmental problem such as climate change), then a tax instrument would be economically preferable to a cap and trade instrument[15].

The problem with tax instruments is that they require an explicit political commitment to a certain cost. Particularly where this has to be agreed across national boundaries, this can lead to what seems to be an insurmountable political hurdle. Cap and trade schemes on the other hand allow some room for manoeuvre since valuable allowances can be allocated for free to incumbent emitters, offsetting the political difficulty of introducing the scheme. Whilst free allocation may be warranted as a way of reducing the problem of stranded assets, it can also be a problem because free allocation often occurs to a much greater extent than needed simply to restore the asset value of the incumbent emitters. Allowing the emitters to capture the scarcity rents in this way reduces the expected efficiency gains of the emissions trading scheme[16]. The extent to which power generators pass through the price of carbon on to the price of electricity is the subject of debate, and has generated political tension due effects on end-users, but most economic commentators assume that the carbon price is more-or-less fully passed through. Policy options to counteract this have been considered, but essentially higher electricity prices are an integral part of the effects of a trading scheme where generators are given emission targets.

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[14] Webster, M et al. "The value of emissions trading" *MIT Joint Program on the Science and Policy of Global Change* Report no. 132 (2006) http://web.mit.edu/globalchange/www/reports.html#pubs

[15] Weitzman, M. "Prices vs. quantities" *Review of Economic Studies* 41, 4 (1974) 477-491

[16] Fullerton, D. Metcalf, G. "Environmental controls, scarcity rents and pre-existing distortions" *Journal of Public Economics* 80 (2001) 249-267

In principle it may be possible to combine the political benefits of cap and trade schemes with carbon taxes by introducing hybrid instruments[17]. The use of price caps, price floors and carbon contracts have been mooted, depending on whether the perspective is to increase certainty for investors or reduce prospect of price-shocks to consumers. Pizer shows that a an emission trading scheme with a cap on prices could be designed with overall economic benefits close to that of an emission tax as long as the price cap is expected to be reached most of the time (i.e. the price cap is relatively low compared to the ambition level of the emission reduction set in the emission trading scheme). It has also been argued that since the presence of a price cap reduces risks of higher than expected costs, hybrid instruments allow a more ambitious target to be set[18].

Much of this analysis of the benefits of price caps has been carried out by looking at the overall costs to an economy, focussing on uncertainties over abatement costs. However, viewed from the perspective of individual company in an emission trading scheme, it is the carbon price that matters, not the overall economic cost. There are many different factors influencing carbon price uncertainty, including regulatory uncertainty. One of the key risks for investors considering investment in low-carbon technology is that the policy supporting the carbon price level necessary to make the technology economically viable might be withdrawn in the future exposing the company to a loss. Viewed from this perspective, capping prices simply reduces risks for high-carbon investments, but does nothing to reduce risks for low-carbon investment. What would be needed is a price floor in addition to the price cap.

Policy uncertainty is also expected to increase the price at which companies would make investments because they have the option to wait for more clarity on policy direction, so the investment value would have to overcome this option value. These uncertainties could increase the CO_2 price at which companies would consider investing in low-carbon technologies such as carbon capture and storage by 40% or more. The effect of policy uncertainty depends among other things on the length of time before an expected change in policy. Periodic adjustments to policy such as might occur with regular allocation periods in an emissions trading scheme might exacerbate investment cycles in the power sector[19].

In the EU emissions trading scheme, power generation is a dominant sector, so CO_2 prices are quite strongly linked with fundamentals in the power sector. At current conditions of energy prices and demand for allowances, the marginal abatement option is considered to be fuel switching from coal to gas. The price of CO_2 therefore roughly equilibrates at a level that stimulates this switch (although some commentators have suggested that EU-ETS prices are too low to effect much switching in reality). As gas prices increase, the price of carbon required to stimulate a switch from coal also increases, so based on this fundamental relationship, the price of CO_2 and the price of gas would be expected to be linked as shown in Figure 4. This link creates even greater uncertainty in CO_2 price, since there is not only a regulatory uncertainty component, but also a component linked to uncertainty about fuel prices.

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[17] Pizer, W. "Combining price and quantity controls to mitigate global climate change" *Journal of Public Economics* 85 (2002) 409-434

[18] Philibert, C. "Certainty vs. Ambition" *IEA for the Annex I Expert Group* (draft paper 2006)

[19] Blyth, W. Yang, M. "Impact of climate change policy uncertainty on power generation investments" *IEA interim report*

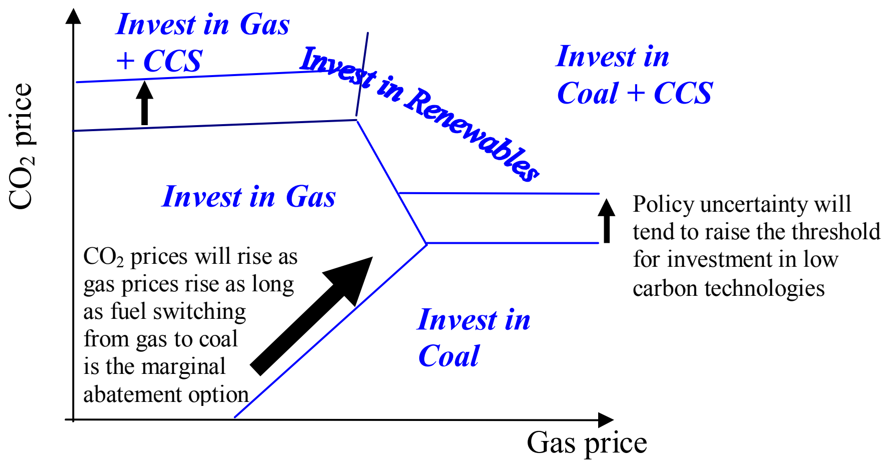

Figure 4. Dynamics of CO_2 and gas price. Straight lines indicate expected boundaries between regions where different technologies would be expected to be cost-effective. The carbon price required to stimulate investment in low carbon technology will be higher as a result of policy uncertainty.

In many electricity systems, gas-fired generation forms the shoulder capacity in the merit order, and often drives the electricity price. Assuming that this situation holds for a range of gas and carbon prices, variations in electricity prices would also be quite closely correlated to gas and carbon price variations. In this case, when gas prices are low, electricity prices would also be expected to be low, so that the carbon prices would have to be correspondingly higher to offset the lower electricity prices to stimulate investment in renewables. Figure 4 is adapted from the IEA report (Blyth, W. Yang, M.) – in that report, renewables are not included. The position of renewables on the chart is indicative only.

If expectations of long-term prices exceed these levels (say above \$40-50/tCO_2), then CO_2 prices would be expected to become de-coupled from gas prices – this would reflect a situation where there was a policy amibition for deeper CO_2 cuts than could be achieved simply through fuel switching, and investment in the new technologies would be driving the price.

2.2 Strategic measures – achieving step change

An important feature of electricity systems that has characterised their historical development in OECD countries is economy of scale – large generation plant are more thermally efficient, and generally have a lower investment cost per unit of electrical output. Historically, investment in large centralised power plant (mostly under public ownership) has been accompanied by development of a centralised transmission and distribution system (also under public ownership) that reinforces the economics of large plant. There have been concerns raised by some commentators that the sunk costs of the transmission and distribution system continues to distort the choices that private investors make about investment. The fact that investments are so large and 'lumpy' also creates potential problems for private investors, as well as having undesirable effects on the electricity market itself[20], and increases the risk that the system becomes 'locked-in' to a certain pattern of generation and dependence on fossil fuel[21].

[20] Finon, D. Johnsen, T.A. Midtten, A. "Challenges when electricity markets face the investment phase" *Energy Policy* 32 (2004) 1355-1362
[21] Unruh, G. "Understanding carbon lock-in" *Energy Policy* 28 (2000) 817-830

One of the challenges for any electricity system is therefore to allow access to innovation in the electricity system in both supply and use. As well as technological 'lock-in' there is also a danger of system design lock-in. Electricity markets are focussed on the generators and suppliers as being the central players, treating electricity as a commodity. The more kWh sold, the greater the profit, whereas what customers want is not so much the kWh themselves as the energy services they provide[22]. A system based on energy services rather than energy as a commodity might provide better incentives for more rational use of energy, and would probably lead to different technology choices, but would require a different market structure.

In terms of the timeframe for change, the next 15 years will be crucial because of the significant investment phase expected in many parts of the OECD, and because of the high growth phase in non-OECD economies. Given the time taken for new technologies to be developed and to enter the market, the timing of policy will therefore be essential[23].

The costs of mitigating climate change are very dependent on assumptions about technology costs. As new technologies become more established, costs tend to come down due to technological learning and economies of scale in production. This can create a problem of first-mover disadvantage, since early adopters of technology will tend to pay more than technology laggards. However, in the absence of technology uptake, costs will not come down. Overcoming this either requires active intervention in the form of specific subsidies in the early stages of technology research and deployment, or strong signals on climate policy generally creating expectations that carbon prices will increase despite technological learning effects.

In the absence of sufficiently strong price signals, policy has tended to focus on specific support to certain technologies. A market view would assert that such support is unnecessary, since private actors would carry out the necessary technology development in response to expectations of future needs. However, there are reasons to suppose that investment in R&D will be lower than optimal in a market-based system because the learning gains from any individual company's investments will also accrue to its competitors (technology spillover)[24]. This may also apply at the country level, requiring international policy action to promote sufficient levels of government research and development of new technologies.

At present, carbon price has very little influence on investment in renewable energy. A shift from renewables support mechanisms to an energy policy system harmonised around carbon price signals, while not impossible would require very clear transition and a perception of very strong political stability around the carbon policy in order not to disrupt current investments.

These arguments suggest that climate change policy should not just be about promoting a smooth progression up the abatement supply in Figure 3, but should also actively engage with developing the technologies further up the curve in order to speed up cost reductions. In terms of policy design to achieve this, there are grounds to believe that combining policy 'sticks' and 'carrots' may be more effective than just sticks or carrots on their own. Early analysis of the Climate Change Agreements in

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[22] Patterson, W. "The electric challenge: getting the story right" *CCGES Transatlantic Energy Conference, York University, Toronto, 9-10 September, 2005* *http://www.chathamhouse.org.uk/pdf/research/sdp/WPspeech0905.doc*

[23] Kohler, J. et. al., 2005. *New Lessons for Technology Policy and Climate Change, Investment for Innovation: a briefing document for policymakers*, Tyndall Briefing Note No. 13, Tyndall Centre for Climate Change Research, UK. Available from, URL: www.tyndall.ac.uk

[24] Golombek, R. Hoel, M. "Second-Best Climate Agreements and Technology Policy" *Advances in Economic Analysis and Policy* Vol 6, issue 1 (2006)

the UK was an example of this where the energy efficiency targets agreed for industry in exchange for a tax rebate were apparently greater than the amount of energy savings that would have been achieved by introducing the tax at the full rate. Conversely, modelling has also shown that tax credits promoting investment in energy efficiency are likely to be ineffective compared to mandatory efficiency standards[25]. Similar arguments could be used to promote the idea of selectively recycling the revenue from carbon taxes or the auctioning of emissions trading allowances to target investment in low-carbon technologies.

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[25] Hassett, K. Metcalf, G. "Energy conservation investment: do consumers discount the future correctly?" *Energy Policy* (June 1993)

3 Conclusions - comparison of market vs non-market approaches

A market-based view of the world would assert that both economic and strategic objectives for energy and climate change policy would be best delivered through market mechanisms, with innovation and investment in new technologies responding to appropriate price signals in the market – Figure 3a. A non-market based world view would assert that separate policies would be required to deliver appropriate levels of investment and innovation of new technologies – Figure 3b.

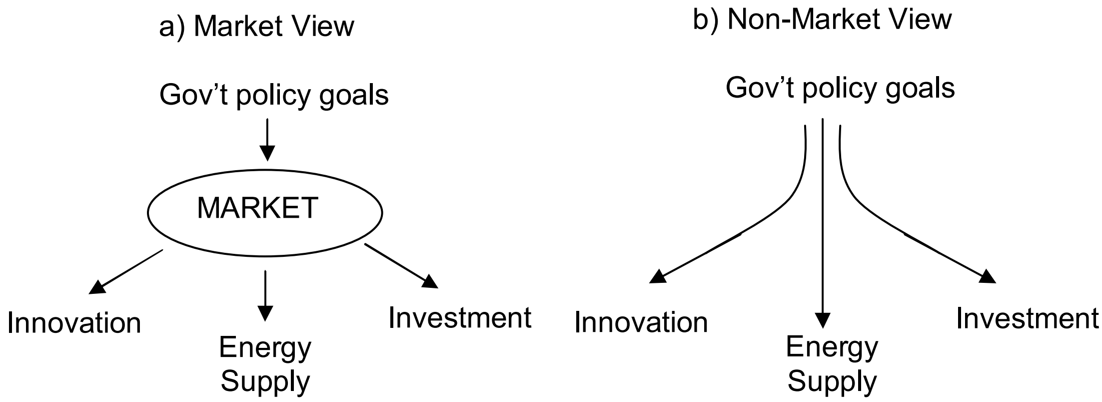

Figure 3. Delivering government policy goals in a) market-based world view – government policy making should be via the market, b) non-market world view distinct policy mechanisms will be required

A market-based world view asserts that environmental constraints should be imposed through a market (i.e. price) mechanism. Specific concerns that arise from taking a price-based approach include:

- Companies may be slow to respond to price-only signals, at least partly because of the effects of regulatory and general market uncertainties. Responses would likely be evolutionary rather than transformative, and may not achieve deep structural change that would lead to a more efficient outcome.
- Establishing carbon taxes is politically difficult, particularly if it requires cross-border agreement. Emissions trading schemes may initially be easier politically, but without cross-border economic commitment to the agreed emission cuts, maintaining political will in face of significant flows of money between countries may be just as difficult as agreeing carbon taxes.
- The ability to give free allocation to incumbent emitters is one of the reasons why emissions trading is politically easier than taxes, but the private rents this creates reduces the efficiency gains of trading.
- The ability to recycle taxes / auction revenues is an opportunity to improve the environmental effectiveness of the policy. However, enforcement and governance of any revenue-raising policy, particularly at the international level will be difficult but crucial.

In a non-market-based electricity system, investment choices are more-or-less centrally determined to balance the whole range of energy policy priorities. Imposing price-based policies for companies will be ineffective unless the price is included in the determination of which technologies to build / operate. A much more direct route to imposing climate policy is through a regulatory-based approach. This could have the advantage of avoiding the uncertainty associated with price-based mechanisms, and in principle there might be relatively little delay between establishing the political will for action and actual implementation on the ground. Specific concerns that arise from taking non-market based approaches include:

- Regulatory approaches may result in a more rapid deployment of technology, but this does not mean that the risks have gone away – they are simply transferred. A social planner should take into account uncertainties just as much as private companies, and although the responses may be different, the costs of uncertainty will still be borne somewhere in the system. The danger of taking rapid action in the face of uncertainty is that chosen solutions turn out to be inappropriate given actual outcomes.
- Direct policy support for particular technologies may be effective in stimulating uptake, but in the absence of a long-term shift in underlying fundamentals, those technologies may be unsustainable. For example, capital subsidies for carbon capture and storage may stimulate the initial capital investment, but in the absence of an ongoing operational subsidy (such as would be created by a sufficiently high carbon price), the abatement plant would simply be switched off reverting to normal emission levels.
- It is generally considered that non-market based systems are less well suited to promoting innovation and may not provide as many opportunities for system learning and adopting / developing new technologies[26].

Deciding which of these 'world views' is most appropriate is ultimately a political call which needs to take account of how close real power systems are to operating along market driven principles, and whether / how quickly the system might evolve in that direction. It will also need to take account of what is required from climate policy regarding the balance between least cost carbon reductions and longer term system change, as the latter is unlikely to be least cost in the near term.

In a nut-shell…

Imagine the energy system as a large tanker out in the ocean. In a market-driven world, the tanker would have no driver; its direction would simply respond to changes in currents and wind direction. Introducing a carbon price would constitute a change in wind direction – this would be expected to change the direction of the tanker, but could take an awfully long time. In a non-market driven world, the tanker has a driver that is more-or-less responsive to instructions. The tanker could be steered more quickly, but without ongoing instructions, or with a wavering attention span, the tanker would revert again to drifting on the currents in the original direction.

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[26] Jaffe, A. Newell, R. Stavins, R. "Environmental policy and technological change" *Environmental and Resource Economics* 22 (2002) 41-69