FINANCIAL OPTIONS TO PROMOTE LOW-CARBON ELECTRICITY GENERATION[1]

This paper considers policy to promote investment in low-carbon electricity generation capacity. Here we develop a class of financial options that directly or indirectly guarantees the revenues of a new investor in electricity generation by means of a *put option* on the price of electricity or carbon. A call *option is the right but not the obligation to sell a unit of commodity at a certain price (the strike price)*. Such options may be attractive because they are likely to promote investment as they reduce the volatility of the electricity price and therefore the financial risk for a project.

A financial option to guarantee the minimum price of carbon (or electricity) is a contract whereby the government commits, in the event of the future price of carbon (or electricity) falling below a certain level, to pay a counterpart the difference between the realised price and that which was guaranteed. Such one-way contracts for difference have been proposed (Ismer & Neuhoff 2006) as instruments for improving the credibility of climate policy, and for promoting investment in low-carbon technologies. By affecting directly expectations and thus the relative risk of low- and high-carbon alternatives, there might be a significant effect on the carbon intensity of new investment.

We evaluate such instruments as means to promote the switch to a low-carbon economy through large-scale decarbonization of the electricity supply and electrification of other sectors. In particular we consider the transitional costs of system change and the relative political risks and constraints compared to a system of high current carbon prices alone. We also consider other risks inherent in such a system, including the lock-in to specific institutional structures and the potential for economic inefficiency.

After considering the relation between carbon and electricity prices, we compare guaranteed minimum prices to other systems such as contracts for carbon reduction (Helm & Hepburn 2007), the Renewables obligation, and feed-in tariffs, and consider whether financial options could or should be extended to support less mature but higher-cost technologies. We find that financial options have considerable advantages and can be considered complementary to conventional carbon pricing. However, there may be challenges in designing long-term contracts that are both legally watertight and flexible to potential future institutional changes.

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Why Support Low-carbon Electricity?

Coal Oil and Gas, make up (85%) of global primary energy supply and are available as respectively solid, liquid and gaseous *fuels*. Electricity is the most carbon intensive form of energy at present (in terms of greenhouse gases released per unit final energy), so decarbonizing the electricity sector is particularly effective at reducing carbon emissions.

If we are to convert our energy system away from fossil fuels and towards less damaging forms of energy, we need to shift from **fuels** to **electricity**. Our current energy system is dominated by **fossil *fuels*.** All forms of energy that don't produce significant amounts of greenhouse gases are electricity generation technologies and/or low grade heat. For example, renewable energy schemes such as: Hydroelectric power, Wind, Tidal, Wave and Photovoltaic Solar produce electricity produce electricity. Thermal power stations with low or zero carbon emissions include Concentrating Solar, Nuclear Fission, Coal with Carbon Capture and Storage produce Electricity (plus some low-grade heat).
In order to solve the climate problem, we will need to low-carbon electricity to convert not only the *existing* electricity sector (as Sweden and France have done), but also the energy sectors that currently use fossil fuels directly such as transportation (oil) and home heating (gas).

Some countries will decarbonize their economies more quickly than others. There is also the potential for a High Voltage DC Super-grid. In this case, low carbon energy produced in one part of Europe can help to displace carbon-emitting generation in another part of Europe. All low-carbon energy is helpful for reducing carbon emissions.

Investment is Needed: To convert our economy, we will need investment in low-carbon energy infrastructure - electricity generating capacity in the form of nuclear, renewable energies and perhaps coal with CO_2 sequestration. All these forms of electricity generation are **capital intensive**, that is, the majority of the cost of a unit of electricity is the upfront investment cost, very little is paid in the cost of fuel and ongoing maintenance. In the case of renewable energy, fuel is free; for nuclear energy, fuel is very small part of the cost of electricity.

Current Policy is Inadequate and Costly: Present policy is dominated by costly direct subsidies to renewable energy producers (Renewables Obligation), and heavy direct subsidies to legacy nuclear generators.

Very little carbon reduction is bought for this substantial cost. There is a grandfathered cap and trade system (the European Emissions Trading Scheme), which does not aid long term investment and does not reduce carbon emissions

Changing Public Discourse: Public discussion is dominated by the notion that decarbonization is difficult and costly. If this were true, it is unlikely that such policies would be adopted globally. But well designed policies need be neither difficult nor costly.

Coordination Problems with System Change and Uncertainty: Moving to a near-zero carbon economy will require system change. This will involve large-scale investment in electricity generating technology. Policy uncertainty will reduce investment.

Political Blockages: Higher investment gets round political blockages of a carbon tax or all-inclusive emissions trading scheme.

Learning by Doing: There is a case for specific policies to encourage deployment of technology and thus reduce its cost through the learning-by-doing effect. This is in particular the case for supporting renewable energy at the early stage of its development. This policy would complement niche support schemes such as feed-in tariffs; it is intended to create a level playing field to support large-scale technologies once fully commercialised (e.g. Wind).

Credibility and Investment

New investment depends on investors expectations of future carbon prices. Therefore, what matters for new investment is the credibility of the carbon price.

Credibility matters. If I hope to put together a party to scale a tall dangerous mountain, then whether I can find a team to do such a difficult to undertake such a difficult mission, will depend on my credibility: whether I have the tools and experience available to do so; fundamentally whether I appear likely to be successful. If I am not credible, then I am not going to make it, because people around me will fall away.

It is the same with investors. Investment decisions are typically modelled as a Net Present Value (NPV) Calculation. An investor will consider all the cash flows in a particular market; and determine what should be the cost and benefits of that policy. If the financial inflows are greater than the outflows, once discounting has been taken into account, then the investor will take the project.

The reasons that he will take the project are financial. Suppose the project is funded by debt finance. If the interest rate is less than the rate of return on the project, he can borrow some money from the bank; invest that money in the project, and then when the project returns revenue, the investor can pay off his loan and still be left with a profit.

Now let us introduce risk and uncertainty into the decision. If risk and uncertainty are important, then these need to be taken account of in the policy decision. There are a number of representations of how the decision should be taken when the outcome is uncertainty. In the case of uncertainty, the pay-offs for different options will depend on the future state of the world, which is uncertain. There are various possible decision rules.

Important examples of decision rules include: optimistic/maximax (what maximizes the best that can happen), conservative / maximin (what minimises the worst that can happen), minimize regret - maximin (the difference between what actually happens and what the best decision would be); and take the best average pay-off (assuming each is equally likely).

However, it seems likely, that actors' estimation of the probability attached to different outcomes plays an important role in their decision. Many things in life are possible however; many of the possibilities are not particularly likely.

It seems therefore that probability has a large impact on the decision. A straightforward decision role is to take the option with the greatest expected pay-off. An agent who works in this way is said to be risk neutral, taking the highest weighted average pay-off of the options.

Most agents are not risk neutral; a bird in hand is valued more than a 50/50 chance of catching two. Certainty is usually valued because it allows us to make more decisions and to finance our decisions with low-cost forms of capital such as bank lending. Uncertainty over future outcomes means that more money or resources need to be set aside to protect against a potentially adverse future

Under certain conditions (cross-ref other paper where I develop this in detail - maybe the electricity book), the outcome of different functions can be represented by a utility function. Risk aversion can be represented by a utility function that has curvature.

The Theory of Investment

Economic theory and investment. Standard neo-classical theory suggests that investment will take place if the net present value is greater than zero.
From Dixit and Pyndyck (1994):

"Neo-classical economic theory recommends investing in a project if the net present value is greater than zero. In the formulation by Tobin (1963), investment will take place if the capitalised value (which may sometimes be observed in the market or it can be imputed by the expected value of imputed profits) is greater than the cost of investment."
"The rate of expansion or contraction is found by equating the marginal cost of adjustment (?? e.g. the rate of expansion in capital stock) with the costs of adjustment, which depends on (q-1). Adjustment costs - investment above the current amount will require more investment to take place. Capital stock is flexible over 10 years or so."

NPV Criterion in Private and Social Decision Making: The net present value adds up the costs and benefits of an action. The NPV criterion is this:

An action should be taken if it has a positive net present value.
Two examples are the following:

- *Social Planner* (Economic Cost-Benefit Analysis): A policy should be adopted if it has positive NPV to society
- *Firm* (Financial Analysis): An investment should be made if it has positive NPV to the firm.

Costs and benefits in the future are *discounted* using appropriate long-term discount rates. The net present value depends strongly on the *discount rates* used.

Discount Rates: The discount rate determines how much one should value *future* costs and benefits relative to *current* costs and benefits. If I receive £1 today, what is an equivalent amount that would be just as good to receive in 1 year's time? If I believe that £1.10 in 1 year is equivalent to £1 now, then I am implicitly using a discount rate of 10%.

What discount rate should be used for infrastructure projects such as investment in electricity generation capacity?

Public Discount Factors (Economic Cost-Benefit Analysis): Economic and ethical arguments over discounting have been investigated extensively in the Stern review of climate change, and subsequent literature. Stern suggested a *pure rate of time preference* of 0.1%; the discount rate implied by this assumption depends further on assumptions over future growth in consumption. It approximately implies a 10 year discount rate of 3% falling to 2.5% over 40 years.

The treasury green book suggests 3.5% as a discounting rate for public infrastructure projects.

Private Sector Discount Rates (Financial Analysis): However, the private sector is likely to use a much higher interest rate than the socially optimal one. In general, the private sector will discount to take account of the *risk* in an investment. The riskier an investment, the higher the interest rate charged.

The discount rate used in the Energy White Paper cost benefit analysis is 10%, close to a likely *financing rate.* The cost benefit analysis is therefore at least in part a *financial* analysis rather than an *economic* cost benefit analysis.

> *This means that less investment will take place than is socially optimal.* It will therefore be useful to consider ways of reducing the financing rate.

Levelized Cost Of Electricity: A calculation of the relative NPVs of different options depends on the price of electricity. To compare the relevant costs of different technologies without referring to this we can use the levelized Cost of Electricity Approach**.**

Financial Risk and Investment in Low Carbon Electricity

What are the sources of risk for an investor?

The following financial risks are generated by the structure of liberalised electricity markets:

1. Policy Risk - that policy towards carbon or electricity may change
2. Mismatch between revenue (electricity prices) and costs (fixed).
3. Price risk - electricity prices in the future will be lower than expected, especially if investment is high.

Since these risks are largely the government's responsibility, it is appropriate that the government should act to mitigate them.

The government should also provide assurances over the following:

1. Regulatory risk - that regulations concerning the plant's operation will change

The following sources of financial risk are independent of this policy:

1. Construction risk - that the plant will cost more than expected
2. Back end costs - for nuclear, decommissioning and waste disposal
3. Operational risk - e.g. due to plant malfunction
4. Risks due to financial structure and financial management

These risks are largely the responsibility of the firm itself and therefore it is not the responsibility of government to intervene.

Mitigated Risk: Electricity Price Volatility

A *highly volatile* electricity price will tend to suit low capital intensity (low fixed cost, high variable cost) electricity generators

Mitigated Risk: Gas-Carbon-Electricity Correlation

In a spot electricity market, the price of electricity is determined by the 'swing' producer of electricity, usually gas. The price of this electricity is determined by the **price of gas**. Gas producers have a good deal - their revenues and costs move together. Capital intensive zero carbon energy (wind and nuclear) do not.

The market fails because it creates volatility and then passes it on to consumers.

Moral Hazard?

A danger of insuring investors against loss is that companies are encouraged to behave recklessly. This is not a major danger here. In this instance, a revenue stream is being guaranteed, not the business. The businesses could certainly sustain higher levels of leverage against a certain cash flow, but in this case would clearly have to pay higher interest rates from investors.

Assessing the relative economics of various energy technologies purely in terms of their levelised cost, fails to take account of the revenue risks. A gas turbine may seem to be uncertain in terms of it's levelised cost, but the net present value is relatively stable since the cost of fuels provides a natural hedge.

- Levelised Cost – gas looks risky, nuclear less so
- Net Present Value – nuclear risky, gas less so

Source (Blyth 2006)

Investment under Uncertainty

Investment is key to reducing emissions; and credibility in investment is closely related to credibility in Climate Policy
(Neuhoff 2007) provides a summary of some approaches to investment uncertainty.

Here we focus on the real option approach, as outlined by Dixit and Pindyck (1994) To accurately represent the investment decision we need to consider the option value of waiting to find out more information rather than to invest.

Blyth (2006) points out that representing only the relative levelized cost of electricity technologies misses out an important part of the picture: the revenue risk from various electricity prices. He points out that the electricity price is driven by short run marginal cost, which is determined by the 'merit order' of plants available.

Source (Blyth 2006)

Purpose of Instrument

What Is Needed? Full Scale Deployment Support

The purpose of this instrument is to encourage investment in electricity generation capacity which:

1. is economic on a levelized cost basis (costs less than the long-run price of electricity);
2. is capital intensive;
3. is low-carbon.

It is an instrument to encourage 'mass-deployment' of low-carbon technologies of a low enough cost.

It is not, in the first instance, an instrument to encourage less economic technologies to reach market.

Why encourage large-scale deployment of low-cost energy sources in addition to 'learning support'?

Price support for already low-cost energy sources is extremely effective at reducing carbon emissions for the following reasons.

- Given that electricity generation capacity is needed anyway, the net cost (the additional cost of making electricity investment zero carbon) is small or even zero.
- If these technologies are already nearly-competitive with coal, a small learning effect can have a large impact on the global competitiveness of the technology
- It is unrealistic to expect governments to subside energy on a very large scale, and yet very large investment is required.

Existing Proposals To Encourage Electricity Generation

The following support mechanisms have been proposed:

- Renewables Obligation (UK policy)
- Feed-in-tariff (Policy in many continental EU countries including Germany)
- Auctioning of Carbon Reduction Commitments (new policy proposed by Helm)
- Carbon Price Guarantees (new policy proposed by Newbery and Ismer/Neuhoff)
- Electricity Price Guarantees/Auctioned Carbon Free Electricity Contracts

The Renewables Obligation: The Renewables Obligation is a legal requirement for UK licensed electricity suppliers to supply a proportion the electricity they supply from renewable sources. The obligation is set at 9.1% for 2008/09 (DBerr 2008). Suppliers who have generated their energy from renewable sources are granted a Renewables Obligation Certificate (1ROC=1MWh supplied of Renewable Energy). Each supplier most present ROCs equivalent to the 9.1%,or pay the 'buyout price' to a fund, which is distributed equally to those who have presented ROCs. The buyout price is currently £35/MWh (Ofgem 2008).

Feed-in tariffs: A feed-in tariff is a guaranteed rate paid for the producers of renewable electricity. It has been used extensively in Germany (Neuhoff & Butler 2004). This tariff was finally set at 8.7c/kWh for the first 5 years and at 5.55c kWh for the remaining 15 years. The guaranteed rate declines in nominal terms by 2.00% for each year the investment occurs after the year 2000. Higher payments are made for non-optimal sites.
It was found (ibid.) that the Feed in tariff has been significantly more effective at encouraging investment than the Renewables Obligation.

Auctioning of Carbon Reduction Commitments: Helm and Hepburn (2007) propose the auctioning of Carbon Contracts. Governments would purchase a set of emission reducing options in a technology-blind auction at the lowest possible price. The advantage of this proposal is price discovery. The disadvantage is that it is posed in the counter factual; possible emissions reductions.

Carbon Price Guarantees: A carbon price guarantee is a contract or other assurance to guarantee that the long-term price of carbon (i.e. the cost of permits plus, possibly carbon taxes or other fiscal measures) does not fall below a certain level. In the event of the carbon price falling below this level, the writer of such an option would pay the difference between the real price and the floor price, or agree to buy back permits. Such a measure could support low-carbon electricity generation by lowering the downside risk to deployment of low carbon technologies. However, the deterrence effect of higher carbon prices on high-carbon investment would be unaffected. Neuhoff and Ismer (2005) note that such commitments can begin to solve the internal commitment problem (for central government to commit to long-term carbon prices for investors), and the external commitment to other countries.

Electricity Price Contracts: Ekins and Hughes (2007) have proposed the auctioning of low carbon electricity contracts. These have an advantage over Carbon Price contracts in that they are contracts for a positive item, and thus a guaranteed market.

Proposal: Guaranteed Minimum Electricity Prices

We proposed **guaranteed minimum electricity price** (indexed and time-averaged over each 5 year period, for the design life of each project) for long-term investors in **carbon free** (<50gCO2/kWh) electricity generation capacity. An Electricity Price Guarantee, is a method to guarantee the price of electricity. It is similar to a feed-in tariff, but is an option which is more suited to investments at or near the wholesale price of electricity. The advantage over a carbon price guarantee is that it provides a guaranteed market, which may be useful when contemplating whole-system change.

How Would It Work?

There would be a long-term contract between the government and any investors that the time averaged electricity price over a certain period would not fall below a certain point. In effect this is an Asian option on the electricity price. At the end of each time period the government would provide **direct financial support** in the event of a price falling below a certain level.

Contractual Arrangements

There are various types of call options. For example, an American call option would allow the purchase of the commodity at the price of the commodity at the end point. Contracts can deliver physically or not.

The government would write a contract for difference on the *average price* of electricity in each future 5 year period. So there would be CFD on the average electricity price in the period 2015-2020, and one for the period 2020-2025.

Who would qualify?

Initially, all 'Zero Carbon' electricity generators- i.e. those with emissions below 50g/kWh. It could be extended to all 'Low Carbon' electricity generators - those with emissions below 200g/kWh.

What level to support prices?

- A low price floor would provide little direct support but would nevertheless reduce downside risks.
- A high price floor would provide considerable direct subsidy.

It is recommended that the price floor for the current period should be slightly below the current price of electricity. This should be indexed according to general inflation.

Analysis of Costs and Benefits of the Policy

An electricity price floor at or below the current price of electricity would have a relatively low cost.

Who Wins?

- Planet Earth (fewer greenhouse gas emissions)
- Renewable Energy Industry (more secure energy price)
- Nuclear Energy Industry (more secure energy price)
- UK Consumers (more security of supply and lower long-term energy prices)
- UK Industry (more security of supply and lower long-term energy prices)
- Investors & Banks (more secure cash flows)
- UK government/ UK as a whole (security over future investment, lower financing costs for long term investors)
- Pensioners (long term, secure assets to invest in for pensions)

Who Loses?

Nobody loses out directly. The policy is equivalent to a trust-building measure. Since the measure enhances trust, this is a positive-sum game where all can win without anyone losing heavily.

Banks are not able to charge such high interest rates, but this is reflective of the lower risk of the investment.

The government would in theory have to pay out in the future should the price fall below the floor level. However, since the government will have control over carbon policy such an eventuality is unlikely.

Further Considerations

A policy measure to reduce emissions

The government has set strong goals for climate change policy, but at present does not have strong policies to achieve these goals. For example the UK government does not have control over the carbon price at present; this is set by the EU.

Reducing the Cost of Energy for Industry

By guaranteeing a minimum price for investors, large amounts of investment in low-cost capacity would be encouraged. By providing a floor on the price of energy, in the long term enough investment will be encouraged so that the potential

Policy Uncertainty Produces Policy Delay

There is considerable uncertainty over the future price of carbon. Whether there will be a systematic carbon tax or a cap and trade system. It is well known from real options theory that in these circumstances, investment is **delayed**.

We need guaranteed minimum prices to **encourage investment** in the midst of policy **uncertainty**. Minimum carbon prices will aid **policy credibility**.

Little Investment will happen without more certainty

At present the future price of gas, carbon and electricity are highly uncertain. There is likely to be little investment in *either* high-carbon choices such as coal (because of the danger of high carbon prices in the future) or low carbon choices such as wind or nuclear (because of uncertain revenues against fixed costs). ***There is a danger of the lights going out.***

Dangers of this system.
Institutional Lock-in. If the price of carbon is guaranteed, then there is a danger of not being able to change system.

Policy Extensions & Variations

Extension 1: Inclusion of carbon capture and storage (CCS) in the scheme.

Extension 2: A limited number of electricity contracts available at a higher guaranteed price for those new carbon-free generators that are first to produce electricity to the grid (likely to be renewable, first-of-series nuclear and carbon capture and storage).

Variation 1: Auctioning permits to all market participants rather than giving them away to low carbon producers

Variation 2: Floor on carbon price in addition to that on electricity.

Related but separate policy 1: Research, development and deployment support for novel or undeveloped low-carbon electricity generation options.

Related but separate policy 2: Current Carbon Price (ETS permits/taxes).

Extension 1

Inclusion of electricity produced with Carbon Capture and Storage (CCS).

Extension 2

In order to further encourage investment quickly it would be possible to give away a limited number of higher price contracts for those who are first to produce electricity. This might include renewable energy on a large scale and the first-of-series nuclear and first full-scale carbon capture and storage plants. The price would be declining in cumulative installed capacity.

An environmentally friendly option would be to offer 6p/kWh for first 10GW capacity, 5p/kWh for next 20GW, 4p/kWh for next 70GW.

This policy, when combined with an immediate carbon tax of 4p/kg CO_2= £40/tonne CO_2 (Stern - which would raise the price of electricity by 2p/kWh) could be achieved without an initial cash subsidy.

Variation 1: Auctioning Permits?

The current proposal is to give contracts away to low-carbon investors, on the completion of plant. An alternative proposal would be to auction the permits on the open market. Although this would not specifically support low-carbon industries it would still be a beneficial move and would actually raise revenue for the government.

Variation 2: Carbon or Electricity?

A floor on the price of carbon has also been proposed as a measure to ensure greater certainty and to aid policy credibility.

A carbon floor or associated contracts for difference is a policy measure that would certainly be effective at locking-in commitments to a carbon price. Electricity price support would support electricity investment. Carbon price support would support low-carbon investment. It would specifically support carbon capture and storage (CCS) technology. There are advantages in both strategies.

Related Policies 1: Measures for learning support

The basic scheme is not intended to be a method of reducing the cost of more expensive forms of renewable energy such as wave energy.

However, it is important that such novel energy forms are encouraged and brought to market rapidly.

The Renewables Obligation is set up to encourage the development of these forms of energy so as to reduce their cost. It has been recently banded to differentiate between technologies according to their level of market penetration.

Some have argued this method of support to be excessively costly. Greater direct research and development (R&D) support and feed-in-tariffs by energy type may be more efficient way to encourage these energy types. This is a different topic not part of the scope of this paper.

Related Policy 2: Why Not Just Impose a Carbon Tax?

A long term price on carbon should be the primary policy for carbon reduction. However, what determines low carbon investment is not the current price of carbon but the expectations of the future price of electricity. The effect of a carbon price is only that expectations of a *future* carbon price affects expectations of *future* electricity prices.

Economic costs of decarbonization will be reduced if there already exists significant alternative energy when carbon prices are raised.

Similarly, a significant carbon price may be being blocked politically by well-organised carbon intensive sectors such as fossil fuel extraction, electricity generation, aviation and heavy industry. It is necessary to *create* a significant well-funded carbon-free energy industry *before* punitive levels of carbon taxes are imposed so that industry has alternative energy sources available.

Conclusions

Probable Effects

There would be strong investment in all electricity generating capacity with low or moderate cost. The basic policy would encourage nuclear, onshore wind. The advanced policy would also encourage other forms of renewable generation and coal with carbon capture and storage.

Economic Justification

- Corrects market underinvestment arguably associated with liberalised electricity markets
- Corrects market underinvestment due to policy uncertainty
- Corrects a market failure by filling a gap in the market for risk instruments
- Reduces the financing rate for long-term electricity investment to closer to the social discounting rate without moral hazard
- Provides an extra policy tool to reduce carbon emissions

Political Justification

- Reduces carbon emissions
- Encourages investment and thus keeps the lights on
- Creates a low carbon industry and dispenses with political obstacles to a low-carbon future

Higher Prices for Quick Construction

- Provides incentives for first mover
- Rewards social advantages of first-of-build (cost information revelation, cost and time reduction)
- Provides credible signal that policy might be less generous in the future, thus further encouraging rapid investment.

Overall Conclusions

In order to encourage sufficient investment to decarbonize our energy system, we need to promote a more long-term framework for investors. This can be done by means of price risk mitigation for long term investors, such as a guaranteed minimum price for electricity or carbon.

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