Energy Solutions for 60% Carbon Reduction **Gordon Taylor** **2004-07-30**

Part II – Delivering Energy Solutions for Reduced Carbon

1 Introduction

The UK Government has entered into various international agreements, such as a 12.5 % reduction in greenhouse gas emissions by 2008-12, under the Kyoto Protocol, and 10 % of electricity from renewables by 2010, to the EU. Also there have been repeated suggestions that UK could become a leader in energy saving and renewable energy. However, these targets and objectives are unlikely to be met by just exhortation and small inducements. It is no use exhorting small end users when the best options are large in scale, or best done on a large scale, and they have no access to low cost capital. Also, households move about every seven years on average, and many live in rented properties, and so are reluctant to make investments that will not benefit themselves. Furthermore, for many end users, energy costs are relatively small, and they have other priorities, while the rest are likely to have very small incomes. Even the recent Renewable Obligations do not cover heat or transport fuel, and therefore do not of themselves ensure carbon reduction.

In the UK, the domestic gas market is worth £ 5 billion a year, the domestic electricity market is worth £ 5 to 6 billion a year, and the transport fuels market is certainly worth many billions a year. However, very few energy savings opportunities are being taken up, and almost no energy R & D is being done. It is clear that a new form of organization is needed in order that the available energy technology options are taken up and the reduced carbon emissions delivered.

2 A Proposal

The business of any company - even an energy company - is to make a profit, and not necessarily to sell more energy. Even after spending vast sums - e.g. in the North Sea - the oil and gas are running out. The energy companies already realise this better than anyone. Moreover, they are well aware that – because of oil and gas exhaustion and climate change – they must start the transition to sustainability. They should therefore be discouraged from any more exploration and development West of Shetland. These are deep and hostile waters, so would be very expensive to develop. It is open to the UK Government to withhold licences for such development. Instead, the companies' investments should be employed to reduce the UK national carbon emissions. They should be equally well able to make money selling energy services, including energy savings and renewable energy supply, symmetrically with fossil energy supply.

The UK Government could ensure the delivery of their international obligations and national targets. Instead of exhorting and inducing the end users, the Government should obligate the fossil fuel suppliers to reduce their collective (net) carbon emissions. Indeed, this has already been proposed in the UK. [Ref. MTP, http://www.mtprog.com on Domestic Heating. Etc.]). This would simply be 'the price of doing business' in the UK. Instead of setting targets for energy savings and renewables, the Government should set targets for carbon emissions, and leave the means open.

Government should first satisfy itself that energy technology options have been identified which are robust over a wide range of scenarios, and have found broad support abroad. These should be subject to peer review and the collection of evidence, including internationally, and by energy service companies. Then they could invite these last to take up franchises for sections of the UK market - along with Carbon Reduction Obligations.

Holding an energy service franchise would be a good business, and - given that they could no longer sell unlimited amounts of fossil fuels or derivatives thereof - allow the companies to make the transition to sustainability. Hence the suppliers of coal, oil, and gas (and derivatives thereof, such as heat, electricity, and transport fuels) would have to convert their businesses to supplying energy services, such as heat, electricity, and transport fuels, with ever-lower (net) carbon output. If the existing energy suppliers in the UK were reluctant, Continental or North American energy service companies would probably seek franchises. Many of these already have experience of financing, building and operating major energy

options, such as CHP and DH. For example, ESCo International of Denmark has already formed a joint venture with Woking Borough Council to provide heat and electricity from CHP. [Ref. DEFRA, E & E Mgt, 7-8/01, p 12].

Then Government can leave the professionals to deliver such solutions as required to meet the progressively reduced carbon targets. Competition and consumer protection would be assured by the multiple franchises in each market, the performance and price of which could be compared.

The companies would almost certainly prefer this arrangement, since the greatest enemy of business is uncertainty. The carbon targets would be signalled years ahead in international agreements - such as the Kyoto Protocol. Instead of ever more expensive investments in oil and gas, they should prefer to invest in energy savings and renewable energy supply. While the UK accounts for only a tiny share of the world market, no energy company is going to walk away from markets worth (at retail) many billions a year.

Appropriate carbon emissions targets would be set for each franchise, for the company to meet by a certain date - and then less each year. In order to meet the targets, only a certain total of carbon (in fossil fuels) may sold by the holder of each franchise each year – or more may be offset by verified sequestration. This would mean that the obligations of the Government's and the companies would be precisely aligned. This is probably the only way to guarantee meeting the national and international targets. The great advantage for the Government is that - rather than millions of individual householders - they would be dealing with relatively few companies. Moreover, these would be professionals, and be far less subject to short-term 'political' considerations. Indeed, in the event of under-performance, Government would retain the ultimate sanction of withdrawing the franchise and re-letting it - as with the railway and broadcasting franchises.

Each heat and electricity franchise would cover a substantial area, with a mix of supply and generating assets, and of customer properties. Likewise, each transport fuel franchise would amount to a substantial initial market share. Indeed, if and when transport fuels are synthesised at CHP plants, the same companies could supply heat, electricity, and transport fuels. (See Part I).

Changes in sales volume could be handled by carbon trading. The carbon certificates issued to each franchise would be tradable, so that if a company wanted to change its market share, it could buy or sell accordingly in the carbon trading market. For example, in the limit, a company could do nothing to reduce the carbon emissions of its franchise, and rely on purchasing carbon certificates on the market. However in most cases, and because it is the price of doing business, the E S Cos. would probably prefer to make their own investments. After all, carbon trading is pointless unless someone is actually reducing carbon emissions.

For its part, Central Government should also require all its departments and agencies, and Regional and Local Governments to facilitate the deployment of major energy technology options, such as heat and electricity generation facilities, and district heating networks. These would impact many aspects of local planning, from the disruption of traffic, to the improvement of air quality. For example, replacing millions of gas boilers in private ownership with tens to hundreds of CHP plants in corporate ownership would make it far easier to measure and control all emissions - both CO2 and noxious.

3 Heat and Electricity

3.1 Heat and Electricity - Energy Service Company Responses

Putting the energy suppliers under Carbon Reduction Obligations is by far the best way of overcoming the problem of the NETA rules, which are operating against the adoption of CHP and renewable electricity. Electricity from CHP has fallen by 61 % since NETA started. [Ref. DEFRA, CHP Strategy, p 11]. In the new operating environment, the Energy Service Companies (ESCs) would see the need to save energy or acquire 'green' energy, and so help to reduce their franchise carbon emissions.

3.1 Heat and Electricity - Energy Saving

The ESCos could offer energy saving options, such as building insulation and low energy appliances. Although insulation and advanced windows are often purchased by individual owners, the prices are much better, and the coverage is complete, if done on a large scale. Also, low energy appliances could be made available, either by bulk purchase and resale or - more probably – by leasing. These means would help overcome the previously poor take up of energy saving measures, such as condensing boilers. [Ref. PIU working paper, DEFRA, 'eestrategy.pdf', Sep. 2001].

In order to meet their targets, most (probably all) ESCos will need to invest in District Heating networks, and the conversion of their power stations to CHP operation. District Heating with CHP plant is widely - and increasingly - deployed by our European neighbours. DH provides much better exergy matching between the energy carrier and the heating end-use. This greatly reduces losses, and hence will never become obsolete. (See Part I). Also, although DH may take many years to deploy extensively, it is long-lived. As with other long-lived fixed assets of proven utility, such as buildings, this makes it easy to finance. Deploying major energy saving and renewable supply options requires entities with a long time perspective, and access to long term, low cost finance. In some countries, such as Denmark and Sweden, DH was and is the responsibility of the local councils. However, in the UK, energy service companies are the most likely candidates - as is already the case in Germany.

Almost all the boilers in place have low efficiencies of about 60 to 70 %, with little prospect of improvement while in private ownership. No energy service company would wish to commit to meeting a carbon Reduction target with such plant that they do not own. However, with the prospect of major (e.g. 80 %) savings in energy for heating - and hence carbon emissions - from CHP, they would be prepared to replace the individual boilers with connections to DH. As well as the current owner or occupier of buildings, they could expect to have subsequent owners or occupiers as customers. Most probably, the ESCos would offer connection to the DH system street-by-street, (much as a cable TV company), together with a scheme for removing existing boilers, and replacing them with DH 'consumer units'. These comprise the heat meter, various control valves, and sometimes a heat exchanger between the DH water and the building heating system. DH should be very attractive to landlords, tenants, and owner-occupiers, in that no capital outlay would be involved, and future maintenance costs would be greatly reduced. Also, by displacing bulky boilers, it would often release space in homes and offices. Yet with such large energy savings, it should be possible to guarantee lower heating bills for all customers. This is the common practice in Denmark.

Unlike the present electricity and gas networks, the DH networks would not be linked together - at least initially. Like the electricity and gas networks, the DH networks would first be deployed at the centres of cities and towns, where the load density is greatest. Hence, the present option of choosing any electricity or gas supplier (with the freedom to change within 28 days) could not apply to DH - any more than it does for water and sewage. It could be replaced with open publication of the various heat tariffs (as with present gas and electric tariffs). This should ensure that no company was unduly more expensive than any other. (In any case, water and sewerage costs still differ somewhat across the country). Yet DH networks should be linked wherever economic. For example, industrial and services sites may have heat or electricity to sell, or could offer plant capacity for peak demands and emergencies. Alternatively, they may prefer to become customers.

Although building the DH networks would involve a great deal of construction work, it would be widely dispersed across the UK. This would mean that it could proceed at a great many sites at once. Moreover, the workers would preferably be local, and could therefore live at home (rather than in remote construction camps). This would give them a local association, and mean that they would be much less likely to strike, and hold up the programme.

3.2 Heat and Electricity - Renewable Energy Supply

The Energy Service Companies could also substitute for some of their fossil fuel burn with municipal waste, agricultural and forestry wastes, biogas, and other (energy crop) biomass, and connect large scale solar heat collectors and thermal stores to the DH network. (See Part I).

3.3 Heat and Electricity - Taxation Policy

The Climate Change Levy rates in effect establish carbon tax rates for the fuels concerned for the service and industrial sectors. Thus at 0.43 p/kWh for electricity, which with the present fuel mix, has a carbon intensity of 121.3 gC/kWhe, it is £ 35.4/tC. At 0.15 p/kWh for gas, with 51.8 gC/kWh gas, it is £ 28.9/tC. At 1.17 p/kg for coal, with 0.659 kgC/kg, it is £ 17.7/tC. At 0.96 p/kg for LPG, with 0.82 kgC/kg, it is £ 11.7/tC. [Ref. DETR, E & E Mgt, 1-2/01, p F4]. Hence the effective carbon tax rate varies from £ 11.7 to £ 35.4/tC - i.e. by over 3:1.

The Government has recently auctioned carbon 'certificates' under the UK Energy Trading Scheme. [Ref. DEFRA, E & E Mgt, 5-6/02, p 6]. This has established a carbon price of £ 53 per tonne C - different again from those of the CCL. (In Sweden, the carbon tax for domestic consumers is about $ 180 per tonne). [Ref. KFB, 'R-00-35.pdf', p 22]. Logically, there should be a single carbon tax rate - with derived rates for each fuel. Only that for electricity would need to be updated periodically due to the changing mix of fuels burnt.

Shortfalls under the Renewables Obligation can be paid for via the 'buy-out' price of £ 0.03/kWhe. [Ref. DTI, 'energymaster.pdf']. With the carbon intensity of electricity for the current fuel mix being about 121 gC/kWhe, and for gas firing 109 gC/kWhe, this is equivalent to £ 248 to 275 per tonne C. However, this is evidently intended as a deterrent, rather than a tax.

CHP that meets certain criteria is relieved from payment of the Climate Change Levy. However, as shown in Part I, the present criteria do not ensure meeting the policy objective - of reducing net carbon emissions. To ensure that the policy objective (and intent of the Climate Change Levy) of a net carbon saving is met, the present CHP QA criteria should be changed. Logically, the relief should be directly proportional to the net (national) carbon savings. This requirement is independent of the capacity of the CHP unit. Also carbon savings are maximised when all the cogenerated heat is used, and this was assumed when determining the new criteria. When displacing electricity from the generators fuelled by the current mix, just to break even requires a minimum electricity efficiency of 0.23. In future, when displacing electricity from generators that are (almost) all gas-fired, it would require a minimum electricity efficiency of 0.26. Furthermore, to achieve the full potential carbon saving would currently require an electricity efficiency of 0.45, and in future of 0.50. Relief from the CCL would vary directly with the carbon saving, and thus linearly between the lower and higher figures. (See Part I, Fig. 14). This new criterion could be termed the CHP Carbon Criterion (CHP CC). In practice, the threshold efficiency and the relief rate would have to be set for the year ahead. However, demonstrating compliance would still require (as now) proper monitoring and reporting.

Since DH-CHP is such an effective option for carbon reduction, that fair and consistent treatment of CHP in respect of the CCL would be an essential pre-requisite for the utilities to turn themselves into Energy Service Companies, with franchises and Carbon Reduction Obligations, selling heating, electricity, and transport fuel services.

4 Transport Fuels

4.1 Transport Fuels - Energy Service Company Responses

All transport fuel suppliers should also operate under Carbon Reduction Obligations. Thus, in line with an agreed timetable, they would be required to meet progressively lower carbon emission targets in respect of their processing operations and the fuels they sell - although again the means would be left open. Again they could buy and sell carbon certificates in the Carbon Trading Market.

4.2 Transport Fuels - Energy Saving

The European (and Japanese and Korean) vehicle makers have agreed to reduce the average CO2 emissions of their new vehicles by 25 % from 1998 to 2008. (See Part I). However, in a free society, it is difficult to limit vehicle usage.

4.3 Transport Fuels - Renewable Fuels

Hence, to ensure meeting the targets even if the total transport fuel consumption increases, it is necessary to reduce carbon intensity. Effective means include the production and supply of biofuels, such as biodiesel and bioethanol, and of carbon-neutral synthetic fuels, such as ethanol. (See Part I). To ensure that the carbon savings were as claimed, the production chains would be subjected to energy audits.

There is ample experience from abroad that bio-fuels can be introduced progressively, without severe impacts on the vehicle fleet (which is worth many billions). For example, in the USA, up to 10 % of ethanol is blended with petrol as an 'oxygenate' - to reduce noxious emissions. Also, Brazil has shown over many years that up to 23 % of ethanol may be blended with petrol, and used in standard engines. Moreover, motor spirit containing 85 % ethanol (E85) may be used in 'Flexible Fuel Vehicles'. These have sensors in the fuel pipe, that adjusts the engine fuelling and ignition, so that any mixture between straight petrol and E85 may be used (depending on availability and price), all being held in the one vehicle tank. Such FFVs have been offered for some years by the major vehicle manufacturers in the USA. Prices are no higher than for standard vehicles, and some two million have been sold. Last year, Ford introduced a Flexible Fuel 'Focus' in the Swedish market, and expects to sell some thousands a year. (See Part I).

Ethanol-based fuels, in blends up to 95 %, can be used in compression ignition (diesel) engines. Indeed, they have been so effective at reducing pollution in Swedish cities, that several - including Stockholm - have standardised on such fuels for their bus fleets. (See Part I).

It would be prudent to start building up the UK output of bio-ethanol and synthetic ethanol well before 2050. Indeed, on the Campbell thesis of oil (if not gas) output peaking about 2005, R & D and planning a pilot plant should start very soon.

4.4 Transport Fuels - Taxation Policy

To help meet the carbon reduction targets, every effort must be made to reduce the demand for (fossil-based) transport fuels. The Government should press for the international agreement needed to tax aviation fuels. Logically, these should be taxed as heavily as road fuels (and on a carbon content basis). This would also improve the competitive position of rail transport, which is less energy intensive. Also, much rail transport can use electricity, which could eventually be from renewable sources, such as wind turbines.

In the case of road transport, the use of large cars should be discouraged. They could still be permitted, but become more expensive to run. The annual Vehicle Excise Duty (VED) should reflect much more strongly the carbon emissions per km of the vehicle, and rise steeply for vehicles emitting say 170 gCO2/km (i.e. with engines above about 1.5 litre). In addition, all transport fuel tax should reflect carbon content, and be set at a higher level than now. (Perhaps part or all should be ring-fenced for public transport provisions - both capital and operating). Both VED and fuel tax should be harmonized within the European Union - to remove a bone of contention from protesters.

The Government and the transport fuels industry should encourage the vehicle industry to produce flexible-fuel vehicles - much as they have encouraged them to produce LPG vehicles. As well as petrol and diesel fuels, these would be able to use ethanol blends up to E85 and E95 respectively. The Government should provide inducements to buy FFVs, as part of the PowerShift programme - even before the biofuels become available in quantity. This would help to overcome the ‘chicken and egg’ problem. In the USA, a high

proportion of the passenger vehicles purchased by State and Federal Governments must be FFVs. This is helped by the prices being no higher than for standard cars, and there are already about two million.

Transport fuels should be relieved of tax to the extent that they save carbon emissions. (Precedents include the introduction of 'lead-free' and 'low-sulphur' petrol). Thus, relative to that on petrol and diesel fuels, the tax on LPG and CNG should be less - though not to the present extent. The tax on biofuels and other carbon-neutral fuels should be much less - rather than only 20 p/l less. It should reflect their lower fossil fuel inputs (net - with credits for by-products that displace other fossil fuels). This would provide appropriate incentives to produce carbon-neutral fuels, such as bioethanol, and synthetic fuels, and have them compete in the marketplace. This should be done to ensure a smooth transition when the oil 'runs out' - i.e. the oil prices rise steeply for the last time - the terminal rise. The maximum tax rates could be adjusted to maintain revenue - but see EU harmonization above.

5 Verification of Carbon Reduction Obligations

Just as international obligations and national targets on carbon emissions require monitoring for verification, so do the legally binding obligations on the carbon emissions of energy service companies. Measuring the fossil fuel used is easy, because much of it is already measured in connection with taxation. This is at the point of extraction for North Sea gas and oil, and at the point of sale for motor fuels. Also, the Climate Change Levy, on all non-domestic users of gas, oil, coal, and electricity, requires comprehensive returns of fuel use.

Monitoring the effectiveness of energy saving and renewable energy supply requires only measuring the smaller amount of fossil fuel used. Any decline in fuel saving would be gradual, and could be rectified by maintenance or upgrading.

Conversely, continued high fossil energy supply would require carbon capture and sequestration. Determining the net carbon release would then be much more difficult because, as well as the larger amount used as fossil fuel, it would require the measurement of the carbon sequestered. This might be done by growing trees, or by injection below ground or deep in the ocean, and all are difficult to measure. Moreover, the net carbon release is the difference between two large quantities, each of which is subject to appreciable uncertainty. This means that the difference is subject to great uncertainty, which would make compliance very hard to verify – even initially.

Furthermore, there are real questions as to the permanent effectiveness of such sequestration. Monitoring for possible long-term releases from e.g. forests or deep oceans would be even harder. Any failings would be hard to detect and rectify, and could be catastrophic - leading to rain forest dry-out etc. Since they would only show as an increase in atmospheric CO2, it would be impossible to identify the guilty – whether parties or techniques – and too late to do anything about it. Hence solutions that are easily verifiable, and where any failings involve no regrets, are obviously preferable in principle. However, capture of CO2 for use in the synthesis of ethanol is a special - and hence preferable - case. This is because the ethanol produced is proof of capture, and no sequestration is required.

The Government should also press for all 'bunker' fuels - for international shipping and aviation - to be included in national carbon emissions totals. At present, they are excluded. If this had to be contained within national totals, it would have major consequences. [Ref. IAG, 'greenhouse.pdf', p 25, para. 2.23]. According to this, the '-60 %' carbon target for 2050 for the rest of the UK would be tightened from 62 to 48 or 41 MtC/y. The only consolation is that - with oil production (not discovery) peaking around 2005, it is most unlikely that such oil volumes as these numbers imply would still be available by 2050.

6 Danish Precedents and Plans

In Denmark, more than 50 % of the demand for heating is met by DH. Of this, about 70 % comes from CHP plant. [Ref. Danish Bioenergy Solutions, p 16]. Denmark intends to reduce CO2 emissions relative to 1988 by 50 % by 2030. [Ref. Wood for Energy Production, p 6]. Denmark plans to increase the production of

biogas by eight times over the next 20-30 years. About 12 % of Denmark is covered by forests, and it is planned to double this before 2100. [Ref. 'Danish Bioenergy Solutions', p 34]. By 2030, renewable energy supply should reach 35 %. Of this, about 44 % will come from biomass wastes and 19 % from energy crops, and most of the remaining 37 % from wind electricity. [Ref. Straw for Energy Production, p 5].

The Danish Government has realised that the environmental disadvantages of wind power are at the local level, so it has promoted the private ownership of wind turbines by e.g. farmers or co-operatives of e.g. 20 to 100 families. Denmark had 1500 MWe of wind power installed by 1999, generating 3.3 TWh. Because they use mostly coal for generation, the carbon intensity is 231 gC/kWhe, and the corresponding carbon saving is 0.76 MtC/y. Denmark has scope offshore (in five areas) for 7 GWe, generating 15-18 TWh/y. Compared with the 1997 total of 32 TWhe, this would be about 50 %. [Ref. Caddet Offshore Wind Report, p 61].

Denmark has already required the power companies to comply with CO2 quotas - albeit with only a modest penalty of DKK 40/t CO2. [Ref. "Wind Power in Denmark", September 1999, p 8]. It is expected that the major part of the offshore (wind turbine) development will be carried out by the (two large) power companies as a Public Service Obligation to provide lower CO2 emissions. [Ref. 'soren.pdf', p 10, para 7, "Public Service Obligations", and 'enbal.pdf', p 9. http://wwwwindpower.dk]. This is very nearly a Carbon Reduction Obligation, except that the ESCos are being 'guided' into making a specific kind of investment, and it is not (obviously) backed or enforced by any penalty.

Denmark has recognised the importance of an independent testing laboratory in "sparking comprehensive product development among the manufacturers" (of biomass boilers and wood stoves). [Ref. "Danish Bioenergy Solutions", p 12]. The Danish Gas Centre performs the same function for gas boilers. Indeed, they lead many of the most advanced European R & D programmes in this field. [Ref. http://www.dgc.dk]. Likewise, Risoe National Laboratory carried out extensive research and testing on wind turbines. [Ref. http://www.risoe.dk]. (See also Part I).

7 Sustainability

Energy saving and renewable energy supply options avoid some fossil fuel use and carbon emissions each year – and are therefore sustainable. Hence energy saving and renewable energy supply measures are inevitable in the end. Therefore they should be adopted sooner rather than later. The reason is that for fossil fuels, we are in a 'zero-sum' game. When there is only so much to go around, to have extra yourself is to deny it to another. This is the way it was for most of the time we have existed. However, humankind now covers the globe, and we are consuming oil at four times the discovery rate. Within say 100 years, we will have to live off income - i.e. sustainably. Moreover, to minimise conflicts, the limited resources - both fossil fuels and carbon emissions - must be shared out fairly, both within and between nations. This is often referred to as 'contract and converge'. Furthermore, for all forms of renewable energy, accessing it is not a 'zero-sum' game. However much is harnessed (as opposed to used) in the UK, there is still the same left for everyone else. Indeed, the better we are at doing so, the more others could gain through technology transfer.

8 Conclusions to Part II - Delivery of the carbon reduction objectives

1) The UK Government has accepted a number of national and international obligations on carbon emissions reduction, yet is in no position to ensure their delivery. This position could be rectified by requiring energy suppliers in the UK markets to accept Carbon Reduction Obligations. The Government should first satisfy itself and the energy suppliers that suitable solutions exist. It could then invite the latter to take up franchises to UK energy markets - each with sales of billions a year.

2) There should be a Carbon Reduction Obligation for all heat and electricity suppliers. Since Thermodynamic Heating from the best CHP plant offers fuel and carbon savings of 80 %, the analysis of CHP should be changed accordingly. Also, the CHP QA criteria should be changed to reward only net carbon savings. (See Part I). CHP and District Heating could then be deployed with the private sector providing all the funding and taking all the risk.

3) As major corporations, such companies have access to low cost, long term finance, and could deliver energy saving and efficiency and renewable supply options symmetrically with fossil energy supply. In the event that the City of London failed to finance it, Continental interests would finance it, since they have ample experience of financing such energy technologies.

4) There should be a Carbon Reduction Obligation for the transport fuel suppliers, and a rational regime for taxing transport fuels on their carbon intensity. Biofuel and synthetic fuel production would then commence, with the private sector providing all the funding and taking all the risk. Also, ample renewable electricity will be required, probably from wind turbines, notably for the synthesis of ethanol as a transport fuel.

5) For the Government's part:

a) National, Regional, and Local Government should be required to facilitate the implementation of effective energy technology options.

b) Aviation fuel should be taxed - logically at the same rate as petrol and diesel.

c) Vehicle Excise Duty should rise above say 170 g CO2/km - to discourage the purchase of large cars.

d) All transport fuel taxes should be directly proportional to their carbon intensity - so encouraging the production and use of biofuels and synthetic fuels made with captured CO2. The maximum rates could be adjusted to maintain revenue.