UKERC
UK Energy Research Centre

CCS: New enthusiasm, old uncertainty, and the need for a Delivery Body

Response to recent policy advice on Carbon Capture Use and Storage including the CCUS Cost Challenge Task Force and the Parliamentary Advisory Group on CCS

Ian Temperton (UKERC Advisory Board)

Introduction to UKERC

The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems.

It is a focal point of UK energy research and a gateway between the UK and the international energy research communities.

Our whole systems research informs UK policy development and research strategy.

UKERC is funded by The Research Councils UK Energy Programme.

For information please visit: www.ukerc.ac.uk

Follow us on Twitter @UKERCHQ

Acknowledgements

The views and opinions expressed in this document are those of the author and do not necessarily reflect the views of UKERC.

Contents

CCS: New enthusiasm, old uncertainty, and the need for a Delivery Body

There was another new independent report to the UK government on carbon capture use and storage (CCUS) published in July this year. After six months' work the CCUS Cost Challenge Task Force (CCTF) reported under the heading "Delivering Clean Growth"[1].

There have also been new pronouncements on CCS in the Committee on Climate Change's (CCC)[2] annual update to Parliament and in the National Infrastructure Commission's (NIC) National Infrastructure Assessment[3].

In this policy response, Ian Temperton, who sat on the CCTF and the previous Parliamentary Advisory Group (PAG)[4] on CCS which reported in 2016, takes a critical look at what these eminent bodies have said this year and puts them in the context of the many previous reports on the subject.

He finds little to suggest that CCS policy in the UK has become any clearer, and makes the case for a Delivery Body to fill the gap left by the private sector and uncertain policy.

Does the government want to have its CCS cake and eat it?

The Clean Growth Strategy (CGS)[5] published by the government in 2017 and the terms of reference for the CCTF[6] both state that the government wishes to take actions in the 2020s which provide it with the option of scale deployment of CCS in the 2030s. Such scale deployment is stated to be subject to achieving cost reduction. This is also reiterated in the foreword to the CCTF report by the Minister, Claire Perry[7].

What was shown by the Cost Reduction Task Force (CRTF)[8] in 2013 and has been supported by both the PAG[9] and the CCTF[10] since, is that much of the reductions in unit cost for CCS come from scale (c.50% as calculated by the CRTF).

One can interpret the CGS's objective for action in the 2020s in two ways. Either the government wishes to have low total expenditure in the 2020s, meaning almost certain high unit costs in whatever is developed in that period, or it wishes to prove low unit costs in the 2020s which almost certainly means deploying CCS at large-scale.

Everyone including the government knows that the former will not prove that unit costs have come down and will achieve little more than the previous cancelled competition projects

---

[1] Delivering Clean Growth: CCUS Cost Challenge Taskforce Report, July 2018
[2] Reducing UK emissions – 2018 Progress Report to Parliament, Committee on Climate Change, June 2018
[3] National Infrastructure Commission (2018) National Infrastructure Assessment: An assessment of the United Kingdom's infrastructure needs up to 2050
[4] Oxburgh (2016): Lowest cost decarbonisation for the UK: The critical role of CCS. Report to the Secretary of State for Business, Energy and Industrial Strategy from the Parliamentary Advisory Group on Carbon Capture and Storage.
[5] BEIS (2018) The Clean Growth Strategy. Leading the way to a low carbon future.
[6] Terms of reference for the CCUS Cost Challenge Task Force https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/721755/CCUS_Cost_Challenge_Taskforce_terms_of_reference.pdf
[7] CCTF page 2
[8] CCS Cost Reduction Task Force Final Report, May 2013
[9] Oxburgh (2016) paras 175-179
[10] CCTF page 9 "… scale is key to driving cost reductions".

would have. The latter means that at any given hub/cluster we will need to build an infrastructure of meaningful scale (5, 10, 15mt CO_2 p.a. perhaps) and in doing so we might deliver all the CCS capacity ever needed at that cluster (i.e. no need to scale up at least at that cluster).

All the evidence is that you cannot prove low unit costs in CCS without scaling up (at least at one place) and so a policy which makes a scale up of CCS contingent on proving unit cost reduction is circular (having one's cakes and eating it).

The PAG[11] was clear that unit cost is king at the expense all of other considerations. It further rejected the idea that CCS needed to cut costs by learning-by-doing or through deployment[12]. The PAG said that CCS in power should cost no more than £85/MWh on a baseload CfD equivalent basis from the first project[13]. The PAG suggests hubs /clusters should have storage capacity of at least 5mt p.a. from the start[14].

The CCC suggests that two clusters should be operational in the 2020s with the target of 10mt p.a. being stored by 2030[15].

The CCTF endorses the CCC's target of the development of two clusters by 2030[16]. However, the CCTF is silent on the size of those clusters.

The CCTF actually suggests seven possible options[17] for the development of clusters. A number of which explicitly do not involve getting to scale and hence are not consistent with the CCC's recommendation or proving unit cost reduction. The case studies in the CCTF report range from smaller starting points[18] to large-scale first projects[19].

The CCTF is also more equivocal on where this gets costs. In places it agrees with the PAG assertion that costs can be competitive from the first project[20,21]. In other places it tends more towards the traditional view that early projects will be more expensive, and costs will fall as new ones are brought online[22,23,24]. This is presumably reflective of the fact that the CCTF includes both large-scale and small-scale options for the 2020s and doesn't recommend one over the other.

The reality is that the government does indeed want to have its cake and eat it, and it will continue to do so.

---

[11] Oxburgh (2016) para 220 and 228
[12] Oxburgh (2016) para 226
[13] Ibid para 221
[14] Ibid para 237
[15] Reducing UK emissions – 2018 Progress Report to Parliament, Committee on Climate Change, June 2018
[16] CCTF (2018) Recommendation 1
[17] CCTF page 45
[18] CCTF page 25 – the Acorn project in Scotland starts small
[19] CCTF pages 27 and 41 – illustrate the large-scale power plants proposed by Summit Power and the OGCI
[20] CCTF page 40 talks about £80-90/MWh for an electricity contract for difference strike price as does the case study on page 27
[21] CCTF – fourth key message on page 6 for instance.
[22] CCTF page 6 says "Project concepts being proposed are comparable on cost with other *first of a kind low carbon technologies*" (emphasis mine). The CCTF is not explicit about what "first if a kind" technologies have cost, but it is well documented that offshore wind started above £150/MWh and others have been higher.
[23] CCTF page 40 says "… deployment of CCS if key to driving cost reductions"
[24] CCTF Case Study on page 41 talks only about " …kicking off the cost reduction curve"

The justification for the cancellation of the last CCS competition in 2015 was that costs were high[25]. However, the costs were consistent with known projections from bodies such as the CRTF[26].

It is hard to avoid the conclusion that the criteria by which the last attempt at CCS was judged were not determined until after it was cancelled.

Given the long project timescales and current political volatility in the UK, any assurance given today on the criteria the government will eventually apply to the final decision on a CCS project may be of limited value when that final decision finally comes around. Whatever today's Secretary of State, Minister, Special Advisor or even senior official assures you of, few would bet on them being around to stand by that assurance in the four- or five-years' time.

It is therefore unrealistic to expect the government to give reliable clarity on what the assessment metric is, what form of option it wants, the metric by which it will judge cost reduction, or which of the seven approaches identified by the CCTF it will eventually want to take.

This is just life for the CCS community and CCS policy-making. The government does want to have its cake and eat it on CCS and the logic of the CGS is circular. It is better to understand this and plan for it, than to seek worthless assurances.

A technology of the whole system is a technology of nowhere

Despite what appears to be new enthusiasm in government for CCS, there are increasing challenges in making the case for renewed CCS policy at all.

While both the CCTF and the PAG before it set out an enthusiastic case, it is important to note that they have done no new energy system or economic analysis, and hence are in effect groups of people with an interest in CCS who quote (perhaps selectively) the case for CCS made by people like the CCC and ETI[27,28].

At the same time it is becoming less and less clear what we need CCS for, at least in the medium term.

While supporting the CCC's proposal for two clusters being operational by 2030, the CCTF makes a virtue of being agnostic as to which sector or sectors (electricity, hydrogen production for heat or transport, or industry)[29,30], should capture and store this CO_2. This leads to an interesting logical conundrum.

Storing carbon dioxide is clearly not an end in itself, and so if you don't care whether it happens in electricity, hydrogen production or industry by 2030 then there can't be a particularly compelling or urgent case in any of those individual sectors.

---

[25] National Audit Office (2017) Carbon capture and storage: the second competition for government support
[26] CCS Cost Reduction Task Force Final Report, May 2013
[27] Oxburgh (2016) paras 40-46
[28] CCTF page 11 and 22
[29] CCTF page 9 says "We do not recommend what should be a catalyst project for any cluster"
[30] CCTF page 44 "The Taskforce is impartial as to the type of Catalyst project, instead each cluster should decide this based on the make-up of industry and its potential investors"

The CCC[31] itself is largely agnostic as to where the CO_2 for the 10m tonnes p.a. comes from in 2030, again leaving the impression that there isn't a compelling and urgent case for any of that target, at least for its own sake. This is despite the CCC's assessment of the CGS being very clear that the government should not even consider pathways to the UK's 2050 targets that don't include CCS[32].

This latter assertion is solidly founded, by the way, on the need for negative emissions technologies to meet existing, never mind potentially enhanced, targets for mid-century. The medium to long-term case presented by the CCC is very robust, the problem is that the short-term case is much less so, and you need to pass through lots of short-terms to get to a long-term.

In one of the few new assessments of the case for CCS, a report produced for the GCCSI[33] by UCL and UKERC[34] says that the risk of not developing CCS outweighs the risks involved in developing it. This sets out a case based on whole systems thinking but does not plot a course through that system necessarily. Such a course starts with that awkward first project.

The PAG[35] does set out a pathway through this conundrum: electricity first, industry to follow, and hydrogen if it proves to be an option we want for heat and/or transport. In doing so it sets out a much more robust case for CCS and the urgency of that case, but it commits the sin of picking winners (i.e. electricity first).

Herein lies a challenge for all people looking at the energy system on a whole of system basis: you have to start somewhere, you have to lay a path through the whole system, and if one sector needs to be an early adopter to open up the whole system benefits then this can present policy-makers with a very unpalatable early decision.

This is the case for CCS. While the long-term case is clear and is built on the almost certain need for, for instance, negative emissions technologies, the case for the first and perhaps hardest decision is not being robustly made, in its own right, by any of the recent interventions (i.e. the CCC and the CCTF).

In real life, people (that is politicians, officials or executives) simply don't make big and difficult decisions in order to be ready to make bigger and more difficult decisions in the future. If CCS is to advance, and the long-term need is to be satisfied, someone needs to come up with a compelling and urgent case for the first application.

What do we need to know before we go back to the 1970s?

A big part of this conundrum for CCS is whether we need to produce low carbon hydrogen as a replacement for natural gas in our heating system. This is part of a much wider and ongoing debate about the decarbonisation of the UK's heating system

---

[31] Reducing UK emissions – 2018 Progress Report to Parliament, Committee on Climate Change, June 2018
[32] Committee on Climate Change (2018) An independent assessment of the UK's Clean Growth Strategy
[33] Global Carbon Capture and Storage Institute
[34] The role of CCS in meeting climate policy targets. Understanding the potential contribution of CCS to a low carbon world, and the policies that may support that contribution. A report commissioned by the Global CCS Institute Produced by:UCL Institute for Sustainable Resources, UCL Energy Institute, UCL Faculty of Laws, University of Edinburgh, UKERC
[35] Oxburgh (2016) paras 92-96

It involves in large part reversing the transition from town gas to natural gas that was made in the 1960s and 1970s.

There is close to universal agreement that if we did make this change then we would create hydrogen from fossil fuels using CCS at least for the foreseeable future[36,37,38].

While many in the CCS community view hydrogen as the saviour of CCS after too many failures in electricity, others see the widespread use of hydrogen in heating as an option created largely by special interests[39].

The question for policy-makers then is how confident do they need to be in the technical, commercial and regulatory arrangements for CCS in the UK before they are prepared to take the plunge on hydrogen, or, for that matter, reject it for what might turn out to be a more costly or inferior solution.

The CCTF and the NIC seem not to need to prove CCS before taking a hydrogen decision. The CCTF is sector agnostic, meaning that a first UK CCS project could be producing hydrogen for heat or transport, and the NIC[40] rejects the need for CCS in the electricity sector while considering it as a serious option for future decarbonised heat.

Interestingly the NIC explicitly rejects the idea that electricity consumers should fund the development of CCS for any reason other than if it benefits them solely as electricity consumers in the future[41]. Even more interestingly, it then uses whole systems thinking to suggest that total energy costs for consumers will fall in the future as more expensive heating is compensated for by cheaper transport. This again highlights the difficulties in achieving "whole systems" thinking and achieving consistency in its application.

Arguably, there are lots of other big infrastructure decisions where we don't get to "try it out first" and so we could simply go straight to hydrogen with CCS.

However, others would argue that the UK has successfully proven that CCS is too expensive in the electricity sector three times over the last decade or so, and hence for hydrogen with CCS to even be an option we need to disprove the accumulated negative evidence base.

For policy-makers to determine that the evidence garnered from three attempts to do CCS in electricity is meaningless for the purposes of making one of the biggest UK energy decisions of the coming decades (how to decarbonise heat) would be quite something.

---

[36] Imperial College for the Committee on Climate Change (2018) Analysis of Alternative UK Heat Decarbonisation Pathways
[37] PAG paras 63-64
[38] Element Energy & E4tech for the National infrastructure Commission (2018) Cost analysis of future heat infrastructure options
[39] UKERC Working Paper (2018) Incumbency in the UK heat sector and implications for the transformation towards low-carbon heating
[40] National Infrastructure Commission (2018) National Infrastructure Assessment: An assessment of the United Kingdom's infrastructure needs up to 2050
[41] National Infrastructure Commission (2018) National Infrastructure Assessment: An assessment of the United Kingdom's infrastructure needs up to 2050 (page 43)

The CCC[42] is largely of the view that we need progress on CCS to take hydrogen seriously as a heat option, although it is not clear that its timetable for CCS and heat proves that much in the former before deciding on the latter[43].

The PAG, as noted before, is clear that there is no option on hydrogen with CCS for heat and transport unless it is proven at scale in electricity first[44].

The view the government takes on this issue will largely determine the urgency with which it needs to pursue CCS and the credible timetable for a decision for hydrogen with CCS in heat and transport.

It's like a sewer for CO_2

The vogue model for financing complicated infrastructure projects in government these days is the regulated asset base (RAB) model. This is far from new and is used in many industries in the UK and elsewhere. However, it recently was critical to financing the London "Super Sewer" (Thames Tideway Tunnel) which a bit like CCS looked at one point - like an expensive and unpalatable decision that might need direct government investment.

It is also widely known that it is the preferred model of EDF for financing its next nuclear power station at Sizewell C[45].

In short RAB models aim to give investors a fair return on the capital they invest and the way they do that is to allocate risk between investors in the project, customers and potentially tax-payers[46]. In the case of the Super Sewer this is credited with delivering a cost of capital only 1% or so higher than the government can borrow over the same time period[47] and cutting the anticipated cost to London's water consumers by two thirds of the original estimate[48].

So it delivered for the Super Sewer, it is in favour, and it is what EDF want. No surprise then that the government asked the architects of the Super Sewer – the law firm Linklaters - to run the CCTF.

What is very surprising is the limited extent of the application of the RAB model proposed in the CCTF report. While the exposition of the model is detailed[49], as one might expect, the only new application of the model proposed in the CCTF report is to the transport and storage (T&S) part of the CCS chain[50]. Arguably this is where the most risk lies and so the RAB

---

[42] Reducing UK emissions – 2018 Progress Report to Parliament, Committee on Climate Change, June 2018

[43] Reducing UK emissions – 2018 Progress Report to Parliament, Committee on Climate Change, June 2018 – this states that a first CCS cluster should be operational by 2026, but it also states that a decision on the future of the gas grid is needed in the early 2020s. This means that the decision on the gas grid will be made with no CCS project having been completed in the UK and no operating history (unless 2026 is redefined as the "early 2020s").

[44] Oxburgh (2016) para 67

[45] FT (June 2018) Private investors raise hopes of new model for UK nuclear plants

[46] RAB models generally allocate to consumers, but can allocate risk and cost to the taxpayer either by the RAB being supported by the government (which is unusual) or through a separate "Support Package" as is done in the case of the Super Sewer.

[47] The cost of capital was 2.497% and long-term UK gilts yield between 1.5% and 2.5%

[48] National Audit Office (2017) Review of the Thames Tideway Tunnel

[49] CCTF pages 49-52

[50] CCTF page 8, 20-21 among others

model might work well in that regard, but it is not where most of the investment and cost of CCS lies, meaning the impact of the lower cost of capital will not be so great[51,52,53].

The CCTF does recommend incentivising hydrogen production through the existing RAB mechanism of the gas network companies[54]. However, there is no mention of using it for electricity or industrial CCS.

The PAG on the other hand, had the implementation of what it called a "regulated return approach" (same as a RAB with a more slap-dash approach to legal definitions) across all aspects of CCS including, in effect, the contract underpinning the application of CCS in electricity and industrial applications[55] as well as hydrogen production and T&S.

The extent of the application of a RAB-style approach, and the ability to implement it in relevant sectors in a timely manner is a key issue for the development of CCS.

The government has only ever cancelled the first project. More haste, less speed?

Not only is the CCTF a little shy about the application of a RAB or regulated return type model, it is also quite equivocal about whether this new business model and its associated cost impacts can be in place for projects operating in the mid-2020s[56,57,58].

This is concerning, as so far, it has always been the first CCS plant that has been rejected for its high costs. Surely therefore any new model which underpins cost reduction must be there for the first project.

The PAG, in contrast, is very clear that the first projects must be delivered at or below £85/MWh on a baseload CfD equivalent basis and that this should be entirely possible.[59]

While we all must recognise that reports like the PAG and the CCTF are always a "call to arms" and hence are likely to present the most optimistic end of plausible timetables it does look as if the delivery targets in the CCTF may not be entirely compatible with putting the business model and regulatory structures which it proposes in place.

---

[51] The 2016 study for BEIS and the ETI by a consortium lead by Pale Blue Dot entitled Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource concluded that T&S costs were £11-18/tonne CO_2 or £5-9/MWh based on a gas-fired power station counterfactual. As noted elsewhere in this piece full costs of CCS in electricity tend to be quoted between £70/MWh and £90/MWh hence T&S is between 5% and 13% of total costs (page 7).

[52] Another recent report for the ETI by SNC Lavelin, AECOM and the University of Sheffield shows T&S capital costs representing only 13% of total capital cost for a full-chain post combustion CCGT powered by natural gas (5-train example used) –ETI (2018) (ETI Number: D5.2) (page 38)

[53] The CRTF report of 2013 showed approximately 20% of the cost of a post combustion CCGT CCS project being related to T&S capex (page 57)

[54] CCTF Recommendation7 page 10, and page 54

[55] Oxburgh (2016) Recommendation 2 paras 253-290

[56] CCTF page 8 says "To meet timescales of CCUS clusters being operational from the mid-2020s, projects may have to be initiated using funding mechanisms that *largely exist or could be implemented quickly*….." and "*In parallel* we recommend a new business model for CO2 T&S….." (emphasis mine)

[57] CCTF page 49 "… the first capture projects may need to be supported via existing mechanisms"

[58] CCTF page 50 talks about the need for primary legislation to implement the RAB model with a footnote which suggests that this may be able to be re-assessed. Time for primary legislation is obviously a scarce commodity, probably always, but certainly these days.

[59] Oxburgh (2016) para 221

While no-one is going to accuse any recent government of racing ahead on CCS, perhaps, at least in terms on focusing on getting the first project right, there is more of a case for haste over speed.

Selling low carbon cement to the Chinese

Probably the biggest news in the CCTF report is the potential for new value to be realised in industries that produce their products with CCS and hence in a decarbonised way[60,61,62,63].

The CCTF even talks about the significance of making these industrial products from CO_2 and the ability to brand[64] these industrial products as low carbon and hence command a premium price in the marketplace[65].

Traditionally the accepted position has been that the kind of industries which might apply CCS (cement, steel, refineries and bulk chemical production such as ethylene and ammonia) are trade exposed sectors where there is no benefit for being low carbon as customers buy an undifferentiated (and hence unbranded) product based solely on price, and there are competitors who are not exposed to the same level of environmental regulation.

This latter, seemingly dated, logic underpins a £100m p.a. compensation scheme for heavy industries in the UK[66], the continued allocation of free allowances under the EU ETS, and other reliefs from environmental regulation, which are each intended to insulate such industries from the impacts of UK environmental costs and regulations which are not imposed on their international competitors.

In the current world described by the CCTF some of this is now presumably available to fund CCS.

Only two years ago, the PAG report firmly maintained the traditional approach[67]. Note however that the CCTF had a considerably greater representation of the relevant industries[68] and so any reasonable person would go with the new CCTF view of the world.

It is worth noting that the CCTF is not entirely unequivocal about this low carbon premium point with the section on finance giving a much more downbeat assessment of the incentives for people to invest in CCUS for such reasons, at least today[69].

---

[60] CCTF pages 2 and 3 both the Foreword by the Minister and the Chair of the CCTF talk about "…. improve productivity and competitiveness…" and ".. improved productivity and competitiveness in a future low carbon economy" respectively.
[61] CCTF page 7 Key Message 2
[62] CCTF page 24
[63] CCTF page 26
[64] CCTF page 59 "Decarbonised Product Mark"
[65] CCTF page 24 "Many of these uses also support decarbonisation through sequestering the CO2 in decarbonised products such as cement and building aggregate. The value of such products has *significant* potential as a route to cutting UK emissions ….." (emphasis mine)
[66] https://www.gov.uk/government/news/100-million-a-year-boost-for-energy-intensive-industries
[67] Oxburgh (2016)para 136
[68] While members of the PAG had all been around there was no explicit representation of any of the potential industrial users of CCS. In contract the CCTF included representatives from the Energy Intensive Users Group, the Mineral Products Association, BOC LInde, Tata Steel as well as a number of the owners of UK refineries and industrial equipment suppliers to heavy industry. This means you really have to go with the CCTF on this point.
[69] CCTF page 37

The idea that low carbon industrial products yield a premium price in these markets today (present tense is used[70]) and that this will grow over time to represent an independent revenue stream for industries applying CCS, potentially changes how CCS is incentivised in key industries, the extent of incentive needed, and the way the UK government looks at environmental costs for trade exposed sectors[71].

Could this US import work?

No-one is suggesting however that this new-found value in low carbon industrial products will fill all the gap required to fund CCS in heavy industry, at least for the moment.

The CCTF therefore proposes copying the US 45Q CCS incentive policy and hence filling this gap with a tax credit[72].

This is another radical departure with the past. No-one can argue about the effectiveness of tax credit incentives in the US system. As well as 45Q there have been the Production Tax Credit and Investment Tax Credit in renewable energy which have worked well.

However, the UK tax system is simply not capable of giving the kind of long-term visibility that these US systems do. People will surely look to the fuel duty escalator and the carbon price support as examples of UK environmental tax policy where to have invested on the policy trajectory signaled at the time of their implementation by the Treasury would have looked very foolish.

Interestingly, one of the merits presented for this system in the CCTF report is the fact that the tax credit will not pay out until CO_2 is actually being stored and only when it is stored[73]. The RAB proposed by the CCTF for investors in the T&S system provides them with the exact opposite risk profile (i.e. payment prior to operation and payment whether or not CO_2 is stored).

Why industrial capture applications of CCS are singled out for this special treatment in the CCTF report or why the many members of the group from industry accepted a much harsher incentive regime than those investing in T&S remains a mystery.

It certainly contradicts the approach suggested by others such as the Tees Valley Collective[74].

The PAG[75] report is very clear that it considers both the business case and the risk appetite in industrial CCS investors to be low (potentially non-existent) compared to other applications and suggests more lenient terms on payment and access to T&S[76], not more stringent.

---

[70] CCTF page 7 and 59 among others
[71] CCTF (2016) page 53 "… support … could reduce in line with the value attributed to these low carbon products by the consumer"
[72] CCTF (2016) page 53
[73] CCTF page 53 states "The benefit of this approach is that no funding is required until projects are capturing and permanently storing or utilising CO_2"
[74] Teesside Collective (report by Poyry) (2017) Teesside Collective Report: A business case for a UK Industrial CCS support mechanism
[75] Oxburgh (2016) paras 135-153
[76] Oxburgh (2016) paras 300-306

It is not clear that UK industrial CCS projects will be able to take a low-carbon premium in their product price or a UK tax credit to their banks and investors. Let's rephrase that. Forget taking either idea to banks or investors.

The PAG[77] suggested a tax-payer funded, regulated contract that would support investment in industrial CCS. It would be able to adapt to the circumstances of individual plants as well as to changing circumstances in the relevant industries. Those circumstances might involve the increasing prominence of a price premium for low carbon products which could lead to the contract being revised to reflect that premium and reduce the cost to the tax-payer.

It would be a contract, not a policy, that you could take to the bank.

Whatever your view on a price premium for low carbon products such as steel, cement and bulk chemicals to be reflected in the marketplace now and over time, the PAG approach to industrial CCS is undoubtedly superior to the suggestion in the CCTF report.

Why splitting up is so hard to do

The CCTF[78,79], the PAG[80] and others such as the CCC[81] agree that in some way the CCS chain should be split so that capture and T&S are separate businesses. They also agree that delivery of a full-chain project (capture and T&S together) is simply not something that the private sector will deliver, at least not at an acceptable cost[82].

There is agreement that in the long-term, where there are multiple sources and multiple sinks, T&S and capture are different businesses and should be treated as such.

Where there is a disagreement is on the first project at any given hub or cluster. Here the CCTF has the energy consumer and/or tax-payer taking the risk that the full-chain of capture and T&S is delivered. Private investors in each component (i.e. capture and T&S) will get their return whether the other part of the chain works or not[83].

The CCTF rightly says that CCS can be privately financed because the government (via consumers or tax-payers) insulates those private investors from the risk of failure of the full-chain. Whereas the PAG rightly says that CCS will have to start as a state-owned enterprise because the private sector cannot deliver a full-chain project and the PAG believes that the first project must be a full-chain[84].

Both are definitely right. Public versus private finance is not the question. The question is full-chain versus split-chain for the first project(s).

Here are the four things you have to believe one way or another, to decide whether your position is consistent with that of the PAG or the CCTF. If you side with the PAG on these four issues it is simply a logical corollary that CCS must start with full-chain projects which must

---

[77] Oxburgh (2016) Recommendation 3
[78] CCTF page 5 "A new business model for CO_2 transport and storage infrastructure"
[79] CCTF page 44 "Project delivery through CCUS clusters"
[80] Oxburgh (2016) paras 215-216
[81] Committee on Climate Change (2016) A strategic approach to carbon capture and storage (letter to the then Secretary of State at DECC Amber Rudd)
[82] Oxburgh (2016)para 162
[83] CCTF page 35
[84] Oxburgh (2016)para 207-209

therefore begin by being state financed. If you side with the CCTF then similarly it is logical that split-chain is the answer and it can begin by being privately financed[85].

Firstly, you need to decide if you think delivering a full-chain project is technically prohibitive. The PAG would say it is not, and that the concerns about full-chain risk are not reflective of the physical reality of the project. The CCTF would appear to take the opposite view.

Secondly, you need to decide if you think split-chains will be allowed. Will political and civil society allow the fossil fuel industry to burn (say) natural gas in newly built plants (power stations or hydrogen production facilities) on the promise that they will safely and securely sequester the CO_2 only to see them let off the hook at the cost of consumers and tax-payer? The PAG would say such an approach is bound to be stopped as it was for CCS on coal in Europe. Veterans of the CCS debate in the UK will remember the Kingsnorth coal-fired power station, for instance. The CCTF would say that people will see it as a price worth paying to get this important green technology off the ground with private investment.

Thirdly, you need to decide if the energy consumer or taxpayer are the right people to take the risk. It is a risk that they simply have no ability to monitor and manage. You also need to ask if insulating private investors from the very core of the risk management in a CCS project represents the UK leading the world, and whether it is a precedent we want to set for the rest of the world. The PAG would say that it isn't. The CCTF would say that the reduced cost of capital and hence burden on consumers and taxpayers, along with the reduced investment burden on the public finances make this a price worth paying.

Finally, you need to ask yourself if you think the split-chain is deliverable. It requires a Minister and/or civil servant to potentially sign off on a white elephant project (a CCS project that has no obligation to have either capture or T&S) paid for over many years by the tax-payer or consumer. Do you believe that those people are going to take the career risk which comes with such a decision, or do you think they will insist on such high levels of assurance that they will not be embarrassed that they will, in effect, insist on a full-chain project? The PAG clearly is of the latter view. The CCTF is of the former view, although it has to be said that the CCTF report goes to some lengths to reassure the government that they will not be embarrassed[86].

While the long-term separation of capture and T&S is a matter of broad consensus. A new CCS policy needs to consider carefully the prospects of successfully splitting the chain for the first projects and what this implies for financing of those first projects.

What makes the sewer super for investors

As noted above despite getting the Super Sewer people in to run the CCTF, the CCTF report is far from liberal in the application of the Super Sewer model to the CCS problem.

Given the vogue for the Super Sewer model in Whitehall however, it is worth imagining for the moment that the CCTF had read its script fully and hence briefly comparing a privately financed Super Sewer model to the PAG's proposal of initial state financing followed by privatisation.

---

[85] Please note that the PAG and the CCTF do not necessarily address these four issues explicitly. I am proposing that these are the issues which determine whether you fall on the PAG or CCTF side of the argument on initial full-chain versus split chain.

[86] CCTF page 46 "in each proposal we would anticipate a strong level of collaboration between …. the T&S Enabler and the CCUS Catalyst project, so that the two projects could be dovetailed and become operational concurrently".

The Super Sewer is a £4.2bn investment in a major one-off construction project which takes nine years to go from final investment decision to first operation[87]. There are many risks to be borne through those years of construction, some of which could be catastrophic, and if your plan is to sell or refinance the project once it is operational then you have no guarantee of what the markets will be like so far out in the future.

However, the risk presented to investors in the Super Sewer is quite different. A combination of risk allocation in the RAB model and a separate (temporary) "government support package" means that investors are insulated from some of the risks of construction, including some catastrophic risks; they start to receive a return on their investment from the start of construction; and in the event that the markets are closed when they come to refinance the government has offered to step in[88].

In other words, the investment profile of the Super Sewer investor is quite different from the fundamental profile of the underlying project. In fact, arguably the investment profile is much closer to that of a sewer that has already been built and is operating than one that will be in construction for close to a decade.

Consumers and tax-payers fill the gap between the fundamental investment profile of the underlying asset and the investment profile offered to investors. In return, the cost of capital of those investors has proved to be extremely low: at 2.497%[89] being only 1% or so above the rate at which the UK government could borrow over a similar timescale[90].

In fact the reality is almost certainly that there would not have been private capital available, or at least not at any remotely reasonable cost, if investors had been presented with the fundamental underlying investment profile of the project.

There has been much written on the Super Sewer and its financing arrangements, and I am not going to repeat all the arguments here. Some question if the government has been too kind to investors while others see the model as a way of successfully raising capital at a cost comparable to the state without the need for direct state financing.

The recent NIC report was somewhat negative on the use of the model for CCS and nuclear, suggesting that such arrangements might simply be a way of hiding costs and in effect that every pound of risk taken by consumers and taxpayers is a pound of reduction in the effective cost of capital[91].

At first blush this is a fair criticism, but it is not necessarily true. The portrayal of these arrangements as a zero-sum game relies on the assumption that risk and return price linearly over a wide range, and hence every pound of risk offloaded is a pound of reduction is return ("hidden costs" as quoted in the NIC report). This is almost certainly not true. It is highly likely that return prices non-linearly with risk and hence every pound of risk taken on through the RAB and government support package could potentially lead to a multiple of that pound in cost saving to the consumer.

---

[87] National Audit Office (2017) Review of the Thames Tideway Tunnel
[88] National Audit Office (2017) Review of the Thames Tideway Tunnel
[89] National Audit Office (2017) Review of the Thames Tideway Tunnel
[90] UK long-term gilts yield between 1.5% and 2%
[91] National Infrastructure Commission (2018) National Infrastructure Assessment: An assessment of the United Kingdom's infrastructure needs up to 2050

The NIC does make the very important and correct point that any assessment of the merits of financing models must take account of the full costs and risks of the underlying project.

Honestly, in the specific case of the Super Sewer the cost of capital looks very low and it looks to me like a good trade to the benefit of consumer and taxpayers. Obviously, there are a few years of construction left before we see the final result and the National Audit Office is, for instance, clear that the final cost remains uncertain[92].

Now the PAG and the CCTF state, that as with the Super Sewer, the investment profile of a full-chain CCS project will not attract private financing, likely at all, but certainly not at an acceptable cost[93,94].

The PAG does however state that once a full-chain CCS project is operational and construction and refinancing risks have been overcome, then under an ongoing RAB style model the project will represent an attractive proposition to private investors and hence the delivery body proposed by the PAG will be able to be privatised in whole or part[95].

This is no different to the Super Sewer and hence when it comes to financing the construction of a full-chain CCS project the government has a choice. Either do as the PAG suggests and finance it by the state, hence retaining construction and financing risk until the project has entered operation, and then privatise it; or apply the Super Sewer model and through a combination of the risk allocation in the RAB model and direct government support retain those same risks in the public sector, and present the private sector with an investment profile which is privately financeable but different from the underlying asset.

The PAG implies that a full-chain CCS project cannot be privately financed until it is operational and under the Super Sewer model, the fundamental profile of the investment is made to look very much like the project is already operational even though it is still being built. In fact, in the Super Sewer model the taxpayer support falls away after a period of operation[96].

The trade-off in the Super Sewer model is quite simple. You allocate risks inappropriately (it is hard to argue that consumer and taxpayers can observe, manage, measure or control construction and financing risk), you pay investors as if the project is already operating and in return you get private capital (which might not otherwise be available) at a potentially very low cost.

There are a number of questions as to whether the trade-offs inherent in the Super Sewer model are appropriate for CCS (or nuclear or anything else for that matter). The bottom line however is that the investment challenge is the same for a full-chain CCS project as it was for the Super Sewer.

My belief is that the PAG would have found it rather odd to introduce financial engineering of the sort inherent in the Super Sewer model in order to mask its conclusions on the fundamental underlying investment risk.

As the NIC states, judge a project on its fundamentals, and then assess the benefits of financial engineering separately.

---

[92] National Audit Office (2017) Review of the Thames Tideway Tunnel
[93] Oxburgh (2016)paras 188-194
[94] CCTF page 35 “Allocation of risks”
[95] Oxburgh (2016)paras 206, 246-247
[96] National Audit Office (2017) Review of the Thames Tideway Tunnel

In the case of CCS which many climate models expect to be deployed around the world at massive scale one also has to be particularly concerned about the precedent the Super Sewer model sets. However, my view is that most in the industry, including members of the PAG (including me), would prefer to see CCS done and if that means a Super Sewer model because of the pressures on the UK public finances then so be it.

In the long-term we are all dead

Both the CCTF[97] and the PAG[98] set out the belief that after what is an inevitable period of state intervention in CCS there will come a time when the technology is supported by investment from the private sector under a more market-style regime. The two reports however set out very different visions of how this will be achieved.

For the CCTF[99], it is the ever increasing premium placed by the market on industrial products produced in a low carbon way. This progressive realisation of the value of low carbon products in the price paid by consumers and traders for those products will be supported by the development of low carbon product marks and public and private procurement strategies which increasingly shun high carbon products in favour of low carbon ones[100].

The UK is proposed to lead the way in both the development of low carbon product marks and the change in procurement strategy to a low carbon one[101].

This in many ways is how anyone contemplating a low carbon future would like to see the world evolve and it has much to commend it. It has, however, three flaws.

Firstly, it has the potential to be fiendishly complicated. The likelihood of everyone in the world moving to recognise low carbon value in products at the same time is low, and so such developments will need to backed up by measures such as border tax adjustments to protect low carbon UK industries from "unfair" high carbon competition. This could open a Pandora's Box of trade policy issues.

Secondly, there is no guarantee of outcome. We don't know that the evolution of the premium for low carbon production will drive investment in CCS and other low carbon production methods in a manner consistent with the UK legislated carbon budgets and its international commitments on emissions.

Thirdly, you can't take it to the bank. Investors and finance providers are going to need a lot of certainty in the enduring nature of the low carbon premium in order to lend against it.

The PAG[102] used two of its six recommendations to propose what is commonly known as a CCS Obligation / Certificate System. This is a system where companies who supply fossil fuels into the UK are obliged to capture and store a growing percentage of the CO_2 associated with that fossil fuel use.

This is a more interventionist approach and would require more legislation, regulatory infrastructure and bureaucracy, and so it is far from an easy option. However, if robustly

---

[97] CCTF page 35 "Allocation of risks"
[98] Oxburgh (2016) para 247
[99] CCTF page 53 "Industrial projects" and page 59 "Decarbonised product mark"
[100] CCTF page 10 Recommendation 16 and page 59 "Decarbonised product mark"
[101] Ibid.
[102] Oxburgh (2016) Recommendation 5 and 6

implemented in law like the Renewables Obligation was, it would provide an eminently financeable revenue stream and the targets for captured and stored CO_2 could be set to mirror the legislated carbon budgets and the overall target enshrined in the Climate Change Act.

A CCS Obligation / Certificate system could be a national scheme, but it is true to say that while it has less overt connection with trade policy, all environmental schemes risk scrutiny from trading partners and there is a likelihood of needing to compensate some of those upon whom the burden of the policy would fall.

The first question for CCS policy is whether a long-term, less interventionist policy signal is needed at all, or whether muddling along under effective government direction actually works just fine for the amount of CCS we need.

If such a policy is needed, the choice is between a world of a low carbon premium recognised in prices in international markets, which we all want to see, but we all also know may not happen in a timely or robust way, or an intervention in the form of an obligation which requires more bureaucracy but prioritises certainty of outcome and financeability over economic purity.

The "C" Word

Projects of the size and complexity of CCS projects need quite a lot of investment in design and development even before the final investment decision is made. This phase is very risky. If the project doesn't get to a final decision, then you lose all the money you have invested to that stage. For most previous attempts at developing CCS projects this money has come substantially from the government in the form of grants[103].

The PAG[104] makes the statement that all future development funding will need to come from government and suggests that a CCS programme of sufficient scale will need £200-300m of such funding to develop between three and six clusters to investment decision.

The CCTF does not give a figure or an ultimate payor, but while it couches it in lots of good politically acceptable language about partnership between industry and government, anyone who has been around knows that the CCTF really means that a substantial amount of development funds (if not all) will have to come from government[105].

The evidence from the past two competitions[106] plus BEIS's own published estimates[107] put the amount of high-risk investment needed for each project in this phase to be around £50m.

This implies an overall budget of £100m for the two-cluster target suggested by the CCTF or £250m if all five cluster plans identified by the CCTF are indeed "fully costed" and "detailed"[108] as the CCTF states but almost certainly doesn't mean.

This is also consistent with the PAG budget proposal for a plan across three to six clusters.

---

[103] National Audit Office (2017) Carbon capture and storage: the second competition for government support
[104] Oxburgh (2016) paras 212-214
[105] CCTF page 10 Recommendation 5 and page 46 "Development funding"
[106] National Audit Office (2017) Carbon capture and storage: the second competition for government support – showed the government spending £100m on competition 2 - £29m to fund 75% of Shell's costs and £52m to fund 75% of White Roses costs. This means development costs were between £40m and £70m for each of the projects.
[107] BEIS (2016) Cost of electricity generation gives the pre-final investment decision costs of CCS on new gas CCGT in the £30m to £80m range
[108] CCTF page 46

Note this assumes that there is only one project at each cluster which is certainly not the intention of the CCTF or the PAG.

This raises the vexed question of how government allocates such money to projects and raises the spectre of a competitive award process.

The CCS industry view, backed by the CCTF[109], is that the last competition failed and so competitions are bad. Don't ever mention the "C" word in the presence of CCS people.

However, while it's a nice try, it doesn't stack up.

Of the three serious attempts to make CCS projects happen in the UK, one was a bilateral negotiation between the government and BP and SSE, and two were "competitions" (of sorts). All three failed. Neither competition nor bilateral negotiation have worked.

There are, in my view, two common themes to the three failures: the first is that in none of the three cases did the government really decide what its objectives and targets were before it embarked on the process, and in all three cases it made major design decisions very early in each process in the absence of any evidence on which to base those decisions. Those decisions in order being: to decide on a project (Peterhead-Miller) upfront, because BP told them to; to decide on a technology (post combustion capture), perhaps because the Germans asked them to[110]; and to decide on a commercial structure (full-chain delivery) without any evidence that it could work.

None of this has anything to do with whether the process was competitive or not, and in each case, arguably, more competition might have revealed the error of their ways more quickly (i.e. considering more than one project, or more than one technology, or more than one commercial structure).

The CCTF suggests that the government selects the first two CCS clusters from the five most likely cluster locations (Scotland, Teesside, Humberside, Merseyside, and South Wales). These regions are to produce "cluster plans" which will be assessed against the criteria in the CCTF report, and two selected to be taken forward in a process which is not a competition. The report sets out some proposed selection criteria.[111]

Remember that the government is making no commitment to scale deployment in the 2030s until it has seen evidence of cost reduction. This means that if you are not one of the two selected clusters, you might never get a CCS infrastructure, while a competing region of the UK will get one in the 2020s. If you believe in the opportunity for premium value from making low carbon industrial products and the industrial regeneration that CCS brings to your "Clean Growth Regeneration Zone" as stated in the CCTF report then the prize here is at least several years head start on competing regions of the UK and possibly an enduring structural competitive advantage.

---

[109] CCTF page 10 Recommendation 3 and page 46 – no mention of competition.

[110] It is entirely hearsay and conspiracy theory (and hence almost certainly true) that the decision to only permit post combustion projects in the first UK Competition was taken in an informal deal with the German government where they were supposed to "demonstrate" pre-combustion technologies and the UK was to demonstrate post-combustion in projects that happened to be sponsored by German utilities in the UK. It is also worth saying that at the time there was a perception that China, and other countries with large fleets of coal-fired power stations, represented a large potential market for exports of UK-developed post-combustion capture CCS technologies.

[111] CCTF page 46

If you are one of those five regions (or perhaps the Thames Estuary or the South Coast which didn't make the CCTF list) and you do not already have your local MPs, Lords, Ladies, Mayors, captains of industry and assorted dignitaries buttering up Ministers at every conceivable opportunity to get one of the two awards of CCS infrastructure recommended by the CCTF then you are already losing.

There are a number of obvious details that need to be worked out in this process.

Firstly, who is responsible for developing the plan at each cluster? There is no CCS incumbent really at any of the clusters. There are indeed past and present efforts to develop projects but even if it were possible to simply appoint a private sector entity to be the effective monopoly developer of CCS at a given cluster, no reasonable commercial person would suggest that any company's work to date is enough for them to merit simply being appointed to a monopoly position over a piece of critical UK energy infrastructure.

This means that there will need to be a process for the award of the right to develop the cluster plan before there is then the process to decide between clusters.

Another approach would be for the government to create publicly owned entities at each of the clusters, perhaps in partnership with local authorities (or Local Enterprise Partnerships as suggested in the CCTF report[112]). We know however that public ownership is not popular in the corridors of power, at least at the moment. The CCTF does suggest that each cluster (Clean Growth Regeneration Zone) has an "Oversight body" but it is not clear what the status of this body is[113].

There have only ever been five or six viable clusters in the UK (the CCTF has them right) but the evidence from the past two competitions is that the number of independent first projects exceeds the number of clusters. There were nine[114] and eight[115] first round entries respectively into the previous two competitions and they did not cover all five clusters in the CCTF report (there were none in South Wales for instance) hence showing there were around two separate bids for each obvious cluster.

It is also worth noting that the previous two CCS competitions were restricted to electricity and in the case of the first competition a certain type of CCS power station configuration. These new cluster plans will be open to electricity, hydrogen and industry. There are 11 case studies in the CCTF report[116].

There is likely to be (say it quietly) competition to lead the development of at least some of the clusters.

Having appointed people to be responsible for cluster plans without having a competition, the two winning clusters need to be selected in some way. Presumably the people in charge of cluster plans will be given a small grant to develop the first plan which will be assessed against the criteria. Note the CCTF does say that they will be given sufficient development funding to

[112] CCTF page 9
[113] CCTF page 58
[114] National Audit Office (2012) Carbon capture and storage: lessons from the competition for the first UK demonstration
[115] National Audit Office (2017) Carbon capture and storage: the second competition for government support
[116] CCTF

come up with a "comprehensive and fully-costed business plan"[117] but it does not define what this means.

How this will not become a de-facto competition is honestly a little baffling.

More concerning for BEIS is the nightmare presented to them by the three losers, who as noted above will all have mobilised all the political resources at their disposal. Remember the three losers have no guarantee of getting a CCS infrastructure in the future unless the winning regions can deliver theirs cheaply enough.

The politics of the selection decision are a nightmare. All five clusters can and do host power stations and hydrogen production facilities or the like. All present an excellent case for regeneration and maintenance of industrial skills. Four of the five are near known stores and all have a good, but different, industrial story.

So if the government wants to give the steel industry an edge in a low carbon world it should pick Humberside and South Wales (the locations of our two remaining primary steel facilities); if it thinks that chemicals are the most enduring part of the fossil fuel industry in a decarbonising world then it should pick two of Teesside, Scotland and Merseyside; if it is minded to promote industry in the devolved nations of this great Union then it should pick Scotland and South Wales; if the Northern Powerhouse is in vogue that day then it should pick two from Humberside, Merseyside and Teesside.

What if they pick one of the two obvious steel locations and not the other? Or one of the chemicals hubs, say Scotland, and not the others? Won't new investment in either existing or new facilities be naturally attracted to the region which has the CCS infrastructure and hence the ability to guarantee low carbon production. If you buy the CCTF story on CCS as a means of industrial regeneration then they surely will.

This could even split companies. CF Industries, the US company, owns fertiliser production facilities at Teesside and Merseyside. What if one is given a CCS infrastructure and access to the value it brings, and the other does not?

I could go on. You get the point.

But once you have ridden out the headlines about abandoning the hopes of three of the UK's industrial heartlands, presumably on a day with lots of other news, the nightmare does not end.

Money is hard to come by and so BEIS is almost guaranteed to commit another sin of past processes and under-invest in those cluster plans before deciding to select the two. Industry will also continue its rational approach of doing the minimum needed to get to the next stage.

The likelihood is that much will then change between the first award of a cluster based on a plan produced with a small amount of money and what might turn out to be a multi-billion pound investment decision. However, BEIS will have to be constantly looking over its shoulder at the criteria it used for the original decision and the risk of challenge if it changes the rules ex-post. The flexibility that all parties need to deliver the right, cost-effective solution will be traded away very early in the process.

---

[117] CCTF page 46

We have been here before. By the time the last project fell in the first competition I am not sure anyone could remember what question sending a slipstream of the Longannet power station's emissions the length of Scotland was an answer to; and in the second competition it is not at all clear that the White Rose project fulfilled the selection criteria long before the competition was cancelled[118].

One more point, in case you are not bored of this issue yet, capture and T&S are separate in the CCTF model. Hence there is another question, once the people responsible for the cluster plan have been selected they will presumably need to select initial catalyst capture and T&S projects. Again, there could easily be a multiple of each.

The PAG roundly rejected the idea of competition between clusters[119].

However, the PAG does generally embrace competition to the greatest extent possible; and it recognises the need for a delivery body which co-ordinates the competitive development of CCS.

The PAG says that hubs / clusters competing is silly and while those hubs/clusters are unlikely to all be built at the same time, that if CCS is going to be needed at one of them it will be need at all of them[120].

The PAG sees no way of delivering the required cost reductions needed without fully embracing competition, but it states that competition works best when it is addressed at markets which are actually competitive. This is clearly not in full-chain CCS development in which there are effectively no players, and is instead in the component parts of CCS (capture, transport and storage or even their sub-components) which all form parts of existing and competitive industries[121].

To fully realise the benefits of competitive markets while delivering the full-chain project which the PAG insists is necessary requires the formation of a delivery body or company (the CCS Delivery Company) whose role is to coordinate the development of CCS across all the relevant hubs / clusters in the UK[122] and to maximise the effective use of competitive pressure in the components of CCS.

This delivery body is to be judged by one criterion: unit cost[123].

There is a theme in CCS policy and that is that the first bit is the hard bit, and the government and the industry continues to come to regret getting the first bit wrong. The CCTF leaves many questions unanswered and on deeper analysis its approach looks a lot like the last two competitions, whereas the PAG provides the unpalatable answer of capitalising a state-owned delivery body.

The government will need to pick its poison, but remember, just don't mention the "C" word.

---

[118] National Audit Office (2017) Carbon capture and storage: the second competition for government support
[119] Oxburgh (2016) para 90
[120] Ibid
[121] Oxburgh (2016) paras 168-169
[122] Oxburgh (2016) Recommendation 1
[123] Oxburgh (2016) para 220

The future ups and downs of CCS and a big opportunity missed

Among the many mistakes people always make in CCS, here are two. First, while saying how many sectors CCS can be applied to, people only ever talk about costs in electricity (£/MWh) and second, while always expounding the virtues of CCS as a flexible technology, people only ever talk about baseload operation.

The fact is that by the time any CCS power station is operational there will be so much zero marginal cost renewable (and possibly nuclear) generation on the UK power system that a CCS generator cannot conceivably operate in baseload. Also, applications in the production of hydrogen for heat will require the management of the highly seasonal and unpredictable demand for energy for heat in the UK[124], and industrial applications will have to deal with both short-term and long-term production uncertainties in the industrial product markets.

2018 will long be remembered as the long hot summer of potential fizzy beer shortages as a number of facilities supplying CO_2 to be purified for use in drinks shutdown, leading to the risk that we would need to be sober to watch England's inevitable exit from the World Cup.

Both the CCC[125] and the NIC[126] seem to still consider CCS to be a baseload technology and as far as I can tell anyone still doing any development work on CCS projects is largely progressing on this assumption. Let's be clear: it is a wrong assumption.

The reason this matters is simply that it changes everything!

The technical solution particularly for CCS in electricity could be radically different depending on the anticipated operating regime. One might choose an entirely different configuration for a 30%, 60% or 90% load factor plant, for instance.

The case for CCS also changes substantially as it now has to be assessed, on a variety of timescales, against alternative forms of storage and flexibility in the future energy system and not just on a levelised cost of energy (LCOE) basis. This has not been done nearly sufficiently.

The support and financing arrangements also need to be very different. Revenue is the product of price achieved and volume dispatched. Financiers often say they don't like price uncertainty, but in reality, they often take that risk, but financiers really don't like dispatch uncertainty and in any normal market projects will simply not attract finance if material dispatch uncertainty exists over the financing term (which fundamentally it will).

Finally, it makes the work required pre-investment decision much more complicated. There are more technical and operational options to assess. The commercial and financing arrangements are more complex.

This means there will need to be a lot more investment in options assessment and optimisation before any investment decision can be made, and in reality, before any project or cluster selection can be made. If it was ever plausible, rehashing work done for previous competitions

---

[124] UKERC Briefing Note (2018) Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018

[125] Reducing UK emissions – 2018 Progress Report to Parliament, Committee on Climate Change, June 2018 – all the power scenarios in this report that include CCS have those CCS power stations running at >90% load factors

[126] National Infrastructure Commission (2018) National Infrastructure Assessment: An assessment of the United Kingdom's infrastructure needs up to 2050

and the assorted consultants reports on CCS simply won't be good enough to design a CCS project fit for the late 2020s, the 2030s and beyond.

Every issue identified in this piece is amplified by this fact.

While neither the CCTF nor the PAG had any resources to address this issue in detail and hence in each case resorted to bland statements about the ability of CCS to deliver flexibility to the energy system[127,128], it is great disappointment that this issue has not been addressed properly in 2018. It is an essential prerequisite for getting CCS policy on track.

There is lots of work still to do: the case for a Delivery Body

While there appears to be renewed enthusiasm in government for CCS, it is not at all clear that the foundations of that enthusiasm are any more robust. This final summary section looks at the issues remaining and suggests that steady forward momentum, combined with significant amounts of optionality for government come best from the formation of a Delivery Body.

A Delivery Body in the form of the CCS Delivery Company (CCSDC) was proposed by the PAG[129]. It suggested a state-owned body which would develop CCS projects across the UK. The development phase would be state-financed, as would initial construction, followed by a privatisation of the CCSDC once projects were operational. It would focus initially on electricity and T&S.

Now long before there was the Oxburgh Report (the PAG) there was, of course, the Oxburgh report. In 2009 a Working Party on "the arrangements needed to develop the infrastructure for carbon capture and storage in the UK"[130] again under the Chairmanship of Lord Oxburgh recommended setting up a National Carbon Storage Authority or a Delivery Body as some might call it.

If you look closely, even the CCTF report calls for a "…UK-wide oversight body responsible for ensuring overall efficiency, cost-effectiveness, and fairness…".[131] Hence there appears to be some enthusiasm for such a body in the CCTF report too although it has nothing like the prominence it has in the PAG report.

Let's review the characteristics of a Delivery Body in light of the above discussion of policy.

The first characteristic of a Delivery Body like the CCSDC is that it is initially state-owned and its development activity (up to final investment decision) is state financed. There is no argument that this phase of development has always been and will continue to be substantially taxpayer funded.

The case for CCS and the approach to delivering it have become less certain in recent times. Neither the CCTF nor the CCC provide a compelling or urgent case for the first project for its own sake. The CCTF describes seven different approaches, and it is entirely unclear what policy-makers think they need to know about CCS in order to inform their decisions on heat and hydrogen.

---

[127] CCTF page 27 "Decarbonising power"
[128] Oxburgh (2016) para 53
[129] Oxburgh (2016) Recommendation 1
[130] https://www.geos.ed.ac.uk/ccs/Meetings/industry-readiness-June-2011/NCSA_Oxburgh_2009.pdf
[131] CCTF page 59

There is also the inherent circularity of CCS policy as expressed in the CGS and a lack of clarity on how CCS will be judged in the future.

Given this uncertainty and the need for government to retain optionality and to be able to adapt as much as is practical in project development to changing circumstances, it would seem that a Delivery Body owned, funded and directed by government is a far superior approach than a cycle of apparent decision, followed by change of direction, followed by hiatus and review, which we have been in for the last decade or so.

This is a particular problem for the first project.

I am afraid that eventually someone will have to decide what the first project is for and why we need it, whether that be in electricity as the PAG suggests or not.

There is also consensus that the fundamental investment profile of a full-chain CCS project cannot be financed by the private sector. If the government wishes to financially engineer that profile through a combination of regulation and contract so that it could be financed by the private sector, then that is a decision for later. Whether state-financed or engineered to be privately financed, there will need to be a Delivery Body to be the focus of those financing or support arrangements, as indeed there was for the Super Sewer[132] and other similar infrastructure projects.

Whatever support package and regulatory arrangements are put in place need to be ready for the first project and preferably need to be developed with that project. This includes determining the extent of the application of the RAB model. This is a situation crying out for a Delivery Body.

The co-ordination of the roll-out of CCS across the relevant UK hubs/clusters, the realisation of the benefits of competition in the supply chain and the development of scale and synergies all seem to point to a national Delivery Body.

Finally, CCS plants are indeed going to have to be flexible, and while there is a considerable body of academic work on flexible CCS solutions[133], this issue represents a gaping hole in the policy discussion on UK CCS, not to mention the mindset of those in the industry. This hole needs to be filled and the government needs to be able to understand the associated work to a depth that is only possible if it owns the entity doing it.

There are other issues for policy-makers to deal with. How fast will the low carbon price premium for heavy industry emerge and how does this influence how trade exposed industries are treated generally in the future; what arrangement is right for industrial CCS; and what should the long-term incentive arrangement be for CCS.

However, if there is one thing that will make an enduring difference to the development of CCS in the UK, it is the formation and financing, by the government, of a Delivery Body.

If such a body were formed in early 2019 it might be able to resolve a number of the issues laid bare in this analysis and from that produce a real business plan for CCS in the UK which would

---

[132] Bazalgette Tunnel Limited was the entity in this case

[133] By way solely of example (and this is by no means an exhaustive list) Mechleri E, Fennell PS, Mac Dowell N, 2017, Flexible operation strategies for coal- and gas-CCS power stations under the UK and USA markets, 13th International Conference on Greenhouse Gas Control Technologies (GHGT), Publisher: ELSEVIER SCIENCE BV, Pages: 6543-6551, ISSN: 1876-6102; Chalmers, H, Gibbins, J and Leach, M (2011) *Valuing power plant flexibility with CCS: the case of post-combustion capture retrofits* Mitigation and Adaptation Strategies for Global Change, 17 (6). pp. 621-649.

be ready to bid for funding in the 2019 Budget and/or the government Spending Review expected around the same time.