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Nice to C_cU_s again: Commentary on the Government's reinvigorated CCUS ambition

With a new CfD/RAB split, have lessons been learned from the previous competitions?

What is CCUS?

The premise of Carbon Capture Use and Storage ("CCUS") is very simple – wherever possible, CO_2 produced in power generation and in industry (eg, steel and concrete manufacture) should be captured rather than released to the atmosphere. This is fundamental to the continued use of natural gas in a Net Zero world. At a high level, this requires four separate stages:

a) CO_2 capture: the CO_2 must be captured from the industrial process associated with its production. This could be by gasification and partial oxidisation of a natural gas fuel before its combustion (referred to as "pre-combustion capture") or by capturing the CO_2 from the exhaust of natural gas combustion through a chemical absorption process (referred to as "post-combustion capture").

b) CO_2 transportation: captured CO_2 is then compressed and transported through adapted or specially built gas pipelines, or alternatively, on ships or road tankers.

c) CO_2 storage: the best long-term storage solution for CO_2 is considered to be injecting it into deep underground rock formations, including depleted or disused offshore oil and gas fields or deep underground salt cavities/ saline formations.

d) CO_2 usage: there are a variety of uses for lower quantities of CO_2 once captured (if the intention is not to store it underground), and it would be reasonable to assume new uses will be found to reflect the increased enthusiasm for a circular and sustainable economy (including in synthetic fuels or building materials).

How does CCUS fit into Government strategy?

The Government's Clean Growth strategy (October 2017) (the "**Clean Growth Strategy**") introduced an intention to convene a CCUS Cost Challenge Taskforce to deliver a plan to reduce the cost of deploying CCUS (the "**CCUS Taskforce**"). The purpose of the CCUS Taskforce was to set out a cost reduction platform to support the "deployment pathway" of CCUS. Importantly, this was to facilitate the "ambition of deploying CCUS at scale during the 2030s, subject to costs coming down sufficiently".

That ambition was restated in the Government's CCUS Deployment Pathway - An Action Plan in November 2018 (the "**Action Plan**"). The Action Plan was intended to enable the development of the first CCUS facility in the UK, to be commissioned from the mid-2020s. Again, deployment at scale was conditional on substantial cost savings over the previous CCS competition (see below): "commissioning of the first CCUS facility from the mid-2020s would help the UK to meet our ambition of having the option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently".

The Action Plan also announced an intention to "commence detailed engagement with industry on the critical challenges to delivering CCUS in the UK, in particular the cost structures, risk sharing arrangements and the necessary market-based frameworks." It also committed to "consult on [its] findings in 2019, announcing the outcome of the review by the end of 2019". That consultation (the "**Consultation**") came out in July 2019, contemporaneously with the industry report referred to in the Action Plan, which was the CCUS Advisory Group's Final Report (the "**CAG Report**"). The CAG Report and Consultation both considered in some detail, and endorsed the basic proposal within, the CCUS's Taskforce report (Delivering Clean Growth), which was published in July 2018 (the "**Taskforce Report**").

The essence of the Taskforce Report's proposal, and how it was considered by the CAG Report and the Consultation, is considered in detail in the rest of this note, together with a discussion of how the main risks that come out of the proposal will apply to future CCUS projects.

Government policy aligns with a favourable Net Zero pathway

There is a clear determination running through the Clean Growth Strategy, Action Plan and Taskforce Report to launch CCUS projects in ambitious timescales, subject to the costs of deployment coming down. This ambition has subsequently had rocket boosters put under it by the Committee on Climate Change's ("**CCC**") Net Zero Report in May 2019 (which, if it didn't catalyse the launch of the Consultation, certainly gave it a healthy shove). CCUS was identified by the CCC as having a number of indispensable roles in the delivery of the Net Zero ambition by 2050. This was further supported by National Grid's Future Energy Scenarios 2019 ("**FES 19**"), which followed shortly afterwards.

The indispensability of CCUS reflects the continuing importance of natural gas in the energy mix, which is why the CCC stated that "CCS is a necessity not an option". They foresee CCUS having a fundamental role in industry, in hydrogen production (eg, for decarbonisation of heat and heavy transport), in combination with biofuels and in flexible fossil-fired power generation, potentially requiring 75-175 $MtCO_2$ to be stored annually by 2050. This is echoed in FES 19, where CCUS is regarded as being "essential in our Net Zero sensitivity to enable decarbonisation across several sectors, particularly: (i) the widespread production of low-carbon hydrogen in GB; (ii) the use of low-carbon heat for industrial processes; and (iii) the use of negative emissions technology to offset carbon emissions for processes that are very difficult to decarbonise".

One key conclusion of the CCC's report and FES 19 was that Net Zero requires high levels of sequestration, to compensate for sectors that cannot readily decarbonise (eg, certain industrial processes and agriculture). This means existing greenhouse gas emissions will need to be removed from the atmosphere to offset continued emissions from those activities. FES 19 anticipated that 37m tonnes of CO_2 will need to be removed from the atmosphere using techniques such as biomass power generation paired with CCUS (referred to as BECCS), alongside natural methods of sequestration, such as reforestation and rewilding. One tonne of CO_2 has a volume of around 500 m3, which is about the size of a hot air balloon, and stays in the atmosphere for around 100 years, so this is a considerable challenge.

The CCC were not particularly encouraging about CCUS's mixed track record, noting: "given the lack of progress to date… progress in deploying CCS in the 2020s is a crucial enabler to putting the UK on track to meeting a net-zero target".

CCUS and the cluster approach

In parallel with the work of the CCUS Taskforce, in COP 24 (December 2018) the Government announced its Industrial Clusters Mission. This set out the Government's ambition to establish the world's first Net-Zero carbon industrial cluster by 2040, with at least one low-carbon cluster available by 2030.

The idea of developing low carbon industrial clusters is central to the reinvigorated CCUS and hydrogen strategy. The principle is that significant cost savings and risk reductions can be achieved through co-developing carbon capture technology (the initial capture project is referred to as the "catalyst") with energy intensive industries users (referred to as "feeders", who join the transport and storage network after the catalyst project is operational) and off-shore storage facilities. Traditional industrial zones, including in particular those in Scotland (St Fergus and Grangemouth), South Wales (Port Talbot and Swansea), Humberside, Merseyside and Teesside are particularly appropriate for this purpose. Each of these is currently promoting CCUS, in some form, as being integral to their long-term survival and competitiveness.

There is now a wider recognition of the UK's strategic potential to store more than 78bn tonnes of CO_2, and in so doing become a world leader in CO_2 management services (eg, the St Fergus Acorn project anticipates developing the shipping port of Peterhead to become an international CO_2 storage hub). The ambition to deliver world leading technical expertise runs strongly through the Taskforce Report, and is perfectly complemented by the UK's existing oil and gas expertise (and, where possible, existing installed oil and gas infrastructure, which would otherwise have to be decommissioned).

Haven't we been here before? CCS 2011 v 2015 v CCUS 2019

This is not the first CCUS competition. The Government has previously run two competitions, the first was cancelled in 2011 and the second in 2015. The second cancellation occurred very late in the process, with two shortlisted projects having very advanced proposals. That ambition fell over for a number of reasons; chief amongst them was the requirement to adopt a "full chain" model. That approach required: (i) all project risk to be carried collectively by the project consortium; and (ii) one financial instrument (in that case, a Contract for Difference ("**CfD**")) to underwrite both the capture (referred to in this note as "**generation/capture**"), and transport and storage (referred to as "**transport/storage**") phases of the project.

That full-chain approach put an awful lot of pressure on the CfD's strike price as:

- it could only be paid when the generation/capture and the transport/storage facilities were both available and operating; and
- it had to be sufficiently robust to absorb the full-chain risk profile (including, construction risk in a very capex -intensive project; delivery risk for a value chain with no prior joint operational history; availability risk for technology that was at best only at pilot stage; and the risk of low probability/high impact events, such as leakage of CO_2 from the underground storage site.

That risk profile asked a lot from private sector investors, both in terms of underwriting the project's ability to deliver an integrated value chain and in accounting for the risk of extremely high impact events. Unsurprisingly, the outturn cost of those bids was not cheap, and the Government changed their mind about procuring the projects.

Learning lessons: an honest look at delivery risk and "irreducible" risks

Following the cancellation of the second competition, the **Public Accounts Committee** (April 2017) drew attention to how the architecture of the full chain approach exacerbated problems of risk sharing between parties in different parts of the CCUS project (particularly in relation to the inability to control the actions of other parties in the chain). They concluded that the Government did not allocate the risks appropriately in the second competition, as between Government (taxpayers), consumers, investors and developers:

"it is unclear whether the Department tested at the outset of the competition which risks the private sector could feasibly bear. Instead, the Department opted for its prevailing approach to energy policy, of shifting risks as far as possible to the private sector… In particular, it asked developers to bear the 'full-chain' risk, which created problems for sharing risks between investors in different parts of a CCS project, making one of the competition projects unviable".

Similarly, the **National Audit Office** suggested that the cost could have been significantly lower if Government had adopted some of the delivery risk, as the reduced risk profile would have resulted in lower returns to investors. The flip side of this, obviously, is that taxpayers would be exposed to those risks if they did materialise.

The Taskforce Report, learning from this criticism, identified that there are some risks "which should be initially shared by Government and industry and transferred to the private sector as the CCUS sector matures". One purpose of the Taskforce Report was to "identify the irreducible core of risk – those low probability but high impact risks – which the private sector, at least initially, cannot price or take and where, as a result, it may be better value for money for the Government to hold".

The thrust of the Taskforce Report was that the Government had to take a more active role in relation to these risks in the initial phase, at least until the combined

maturity of the CCUS industry, investor appetite and insurance markets allowed those risks to be either reduced entirely or otherwise capable of being transferred to the private sector. The thinking behind this is also reflected in the parts of the Consultation and CAG Report that explore hybrid private/public sector ownership models (which, broadly, is not the supported approach).

The critical conclusion of the Taskforce Report was that "managing the irreducible risks is crucial to starting the CCUS industry in the absence of any compelling commercial rationale for the private sector to take these risks now". This concept of these "irreducible risks" is summarised later in this note.

Splitting the chain

More recently, the BEIS Select Committee took evidence from a range of stakeholders who, almost universally, suggested that CCUS costs could be substantially lowered if the business models (including funding models) for generation/capture and transport/storage were separated.

The BEIS Select Committee therefore recommended that the Government separated the funding models for those activities. This approach also found support across industry and with the CCC.

This "split chain" approach was considered in some detail by both the CCUS Taskforce and the CAG. In particular, the CAG analysed the relative merits and risk profiles of different variants of a split chain approach. Both organisations fully endorsed the idea of splitting the CCUS chain into its constituent parts. The CAG noted that separating the ownership and operatorship of the two elements of the chain would allow "investors to invest in different parts of the chain, although that would obviously mean that investor class would need protection against "failure of the other part of the chain to perform".

Relatedly, a second consequence of splitting the chain was that risks that couldn't be allocated to either the generation/capture stage or the transport/storage stage could instead be isolated and treated differently. Both project risks and overall project returns could be reduced if "an irreducible core set of risks" was managed outside the CCUS project.

Unsurprisingly, this split-chain approach was subsequently endorsed by the Government in the Consultation:

"Our review so far would suggest that splitting the CCUS chain and establishing a new, separate, business model for CO_2 T&S could be a viable option. Under this approach a T&S operator would be responsible for developing and managing the T&S infrastructure in a specific region, with different users of the infrastructure charged a T&S fee.

This would enable the CO_2 T&S infrastructure to be considered as a different asset class with its own investors and would enable T&S operators to focus on

their core business function (i.e. transporting and storing CO_2 emissions from capture projects, whether industry, power, hydrogen, BECCS or direct air capture), while also looking for new commercial opportunities (for example from emissions in Europe)".

As the Taskforce and CAG identified, the consequence of splitting the chain is the introduction of "cross-chain performance risk", being the risk to an operator of one project of default by an operator of another project, most likely because either the capture asset or the storage asset becomes either temporarily or permanently unavailable (whether pre- or post- commissioning). Due to the magnitude of this risk, in terms of the cost consequences to that first operator, it constitutes one of the Taskforce's "irreducible risks" that should be mitigated and managed "outside the projects". This new category of risk is discussed further later in this note.

Challenges facing the new split-chain approach

Conventional (or at least unmodified) private sector business models present a number of challenges to deploying a successful CCUS industry. This is particularly the case in the context of the ambitious timeframes introduced by the Action Plan and Taskforce Report. Some of these issues are discussed in the CAG's report and include:

- The UK has higher carbon prices than many other countries, yet even in that context there is no economic incentive to develop CCUS. The significant capex associated with developing low carbon solutions immediately renders a project uncompetitive against the non-abated incumbents (at least until they are forced to pay a higher carbon price for their emissions).
- Relatedly, there are no widely accepted standards, or markets, for "low carbon products" that give them appeal over non-abated incumbents (this issue was promoted in the Taskforce Report).
- There is a tension inherent in the desire to quickly deploy the first CCUS project(s), with the strategic need to design a regime that allows a sustainable and scalable long term CCUS industry to deliver Net Zero.
- First-of-a-kind projects have a significantly higher risk and cost profile than subsequent projects in a more mature market. This often demands additional financial support to encourage the "first movers". The Government is clearly alive to this concern in recognising the need to offer more up-front support for the "irreducible risks", which it can reduce as the industry matures.
- Similarly, in a nascent industry there is a higher risk of failure at one point in the chain impacting other parts of the chain (referred to above as cross-chain performance risk). Cross-chain performance risk reduces as other assets and projects are brought forward, and is helpfully mitigated by the strong preference for developing CCUS on a cluster basis (defined by the Taskforce as regional groupings where several CCUS facilities share infrastructure and knowledge, and will generally also include hydrogen infrastructure).

Underlying values behind any new business model

The Consultation, and the reports preceding it, clearly show the Government is open to a revised and more nuanced approach to risk sharing, thereby avoiding the failures of the last competitions. This is reflected in the introduction of their "overarching parameters", which any proposed new CCUS business model must satisfy. These require that a new business model should:

- be market based and incentivise CCUS to provide value. It should drive decarbonisation and be compatible with existing market systems;
- be designed to instil investor confidence, and to attract innovation and new market entrants (hence the openness to a new approach to risk allocation);
- be cost efficient, by providing value for money for taxpayers and consumers. It should drive cost reductions and attract new investment;

- introduce appropriate and fair cost sharing between the Government and CCUS developers/investors, which may evolve as the CCUS industry matures; and
- have the potential to become subsidy free.

The "baseline" split chain proposal: CfD generation/capture and RAB transport/storage

The core "split chain" business model considered in the Consultation and CAG report is the one initially endorsed by the Taskforce. This model is motivated by the need to adopt existing funding mechanisms to support the ambition of delivering "at least two" operational CCUS clusters from the mid-2020s. The Taskforce proposed that:

- **Power generation fitted with CO_2 Capture technology** should be privately owned, financed and operated. The project's revenue should come mainly from the wholesale electricity market, supplemented by a modified "dispatchable" CfD. The CfD should be further adapted to incentivise flexible generation, which would ensure it is called on before unabated generation in the merit order. This is explained further below.
- **CO_2 Transport and Storage** should also be owned, financed and operated by the private sector, and funded under a RAB regime. The T&S revenue stream should come from the generation/capture operator, who is required to pay the transport/storage operator for processing the CO_2 it captures.
- **Risks**: "Business as usual" risks should be managed within each project and general "cross-chain" risks should be managed through the contractual relationships between the project operators. As above, the Taskforce recommended that the "irreducible risks" should be "initially shared by Government and industry and transferred to the private sector as the CCUS sector matures".

The Taskforce's proposal was intended to deliver an integrated, coherent CCUS package, albeit it one devised from individual split chain projects, which are themselves bankable and deliverable on an individual basis.

Main risks/irreducible risks

The "irreducible core set of risks" identified by the Taskforce are summarised below. The problem of these "highly unlikely events of large consequence" is that (as captured in the CAG Report) they "are very difficult for the private sector to price effectively [such that] they cannot therefore be borne by the private sector at reasonable cost".

This category of risk has direct parallels with the concept of "low probability but high impact risk events" referred to in the context of the Government Support Package in the nuclear RAB consultation, which was released at the same time as the Consultation. The common characteristic of these risks is that they cannot be borne by the private sector (or at least it would be incredibly expensive to ask the private sector to bear them). As such, they should be backed by government guarantee, ultimately through tax revenue.

The "irreducible risks" (for CCUS) identified by the Taskforce are:

- **Political risk (change in law or policy)**: As with any long term, high capex infrastructure project, the Government must provide a long term policy and regulatory stability to incentivise private sector investment. This should ideally be backed by the usual change in law relief.
- **Cross-chain risk**: As explained above, the interdependence of the different phases (capture, transport and storage) necessarily means that the failure of any stage will prevent the integrated project from performing as a whole. While the split chain model avoids the operator of one stage of the process being equally liable for the unavailability of another asset in the chain, it is nonetheless still reliant on the availability of those other assets for it to be able to generate its own revenue. This risk requires careful modelling from both an irreducible risk guarantee perspective, and in how it impacts the variable element of any revenue stream (particularly for the

variable element of a CfD stream for the generation/ capture stage, explained further below).

- **Stranded asset risk (permanent closure or prolonged shutdown)**: Each stage is only relevant if the other stages are in place and able to operate. Therefore if it becomes permanently impossible to capture, transport or store CO_2, the other elements of the chain become stranded assets, and may need to be decommissioned or fundamentally adapted. This should merit a termination compensation payment from the Government to the other assets in the chain, to cover their remaining exposure to debt and equity providers. The CAG regard this outcome as "an extremely remote risk" and it is not necessarily binary – for example the capture plant could operate unabated during a period of T&S unavailability, but this would still impact its CfD revenue as it would only be entitled to be kept economically neutral versus the abated running profile (which would deliver CO_2 to the transport/storage project). This would most likely mean the fixed element of the CfD would still be paid, but the non-abated CO_2 emissions would be taken into account through the variable payment.
- **CO_2 leakage risk**: Probably the most talked about risk, and possibly the most remote (the CAG point out that there has been no reported leakage of any significance across the existing 18 operational plants in the last 47 years of CO_2 storage). Nonetheless, CO_2 leakage (or "migration risk") is considered to be a "low probability, high impact" risk as there is a statutory requirement under the EU CCS Directive to pay for CO_2 leakage at the prevailing EU ETS allowance price. The lack of certainty over a future price (if a leak were to occur) makes this financial risk extremely difficult to quantify. It is exacerbated by the long time periods (20 years in the case of projects subject to the EU CCS Directive) over which security must be in place against the risk crystallising.

  One proposal to account for the leakage risk is to establish a contingency reserve account of ETS allowances, held centrally by the regulator, to which all operators of transport/storage infrastructure must contribute (as a percentage of total CO_2 stored). The Government would then act as insurer of last resort, to the extent there were insufficient allowances held to cover the volume of CO_2 leaked. There is an additional question, of course, over how the UK structures its own EU ETS regime once it leaves the EU.

  This is analogous to the problem of the long "insurance tail" for the extended liability for personal injury claims under the nuclear third party liability regime, once the 2004 Protocol becomes effective. Migration risk is therefore unlike the other irreducible risks, as it does not reduce as CCUS infrastructure scales up. A further analogy to the nuclear sector is the issue of liability for the long term storage of nuclear waste, although there is a sound precedent for managing that issue (again with the Government ultimately taking responsibility for the liability at a certain stage).

- **Un-insurability of CO_2 storage liability/ insurer of last resort**: Again, much like the concern that the nuclear third party liability insurance sector would not be able to accommodate the revisions to the liability regime, there is a parallel concern that the insurance sector will also not be able to bear the CO_2 leakage risk. Or, that the shallow capacity of the market and the short term nature of the policies would make maintaining a policy following a claim either impossible or exorbitantly expensive.

Rather than blindly passing these risks to the private sector (and absorbing the cost implications of doing so) per the second competition, the Taskforce advised that industry and Government, together with the finance community, develop an agreed risk allocation for CCUS projects.

Fortunately for all those involved in CCUS, the Government has picked up the challenge in the Consultation: "as a first of a kind technology, there are likely to be CCUS-specific risks that can have an impact on [the cost and investability of projects]. Ignoring or not taking account of these risks when considering the design of business models may result in the models not delivering the intended outcomes."

Generation/Capture stage proposal: Dispatchable CfD

a. Meeting the Government's "overarching parameters"

Any proposed delivery model must clearly be based on mechanisms that incentivise private sector investment with the lowest possible burden on consumers and taxpayers. The role of consumers and taxpayers, in the context of new CCUS projects, is to provide a broad base to absorb the additional costs of decarbonisation, in the absence of economic market drivers for investment.

The financial model favoured by the Taskforce (and adopted and promoted by the CAB and Consultation) for the generation/capture phase is a modified CfD, which is designed to incentivise an economic low carbon "dispatchable" generation profile.

b. Role of generation/capture stage

CCUS has important applications across a range of carbon intensive activities. These includes CCGT with post-combustion capture (which is the focus of this note – although the principles apply to all forms of gas fired generation); BECCs; hydrogen production through steam methane reforming, and various carbon-intensive industrial processes (eg, steel and concrete manufacture, chemical production and oil refining). These applications all feature in the Consultation, although they are not considered in detail in this note.

c. From baseload to dispatchable

The CCUS discussion accelerates an identity crisis that gas has grappled with for at least the last 20 years, namely, whether it is best suited to a baseload or flexible mode of generation. CCGTs are often forced to respond to today's more complex market conditions by operating flexibly (referred to as "peaking"), although they were generally designed for baseload or two-shifting operation. The proposal within the Consultation is to deliver CCUS CCGT as a "mid-merit" dispatch proposition, being called behind nuclear and renewables but ahead of unabated gas plants (and this design, much like the adoption of electric vehicle smart charging, would actually help integrate more renewables onto the system). The CCC

also see CCUS CCGT in this light – providing "firm low carbon power" alongside nuclear, to complement future higher levels of intermittent renewable generation.

Although outside the scope of this note, CCGTs are generally not designed to operate flexibility and there will be a number of technical challenges associated with ensuring this running profile does not introduce excessive wear on the gas and steam turbines (and that this is expressly modelled in the EPC performance warranties and the CSA/LTSA assumptions about the number of starts and running hours, and associated minor and major outages). That said, most turbine manufacturers now offer a number of plant upgrades to ensure faster, more fuel efficient and more robust starts and ramp ups. Similar considerations apply to the capture plant, particularly when running in the desired "dispatchable" regime if the plant has frequent cold starts and short running periods.

From an operating and "proving" perspective though, it would be preferable for the first-of-a-kind CCUS CCGT to operate as a baseload/ high load plant for an extended "commissioning" period. This would also complement today's more modest level of installed renewable generation. The advantage of running in a baseload profile is that it would provide operating stability and therefore an opportunity for the early plants to capture technological improvements, one of the most important being its capture efficiency (the proportion of the CO_2 generated in the CCGT's combustion that is sequestered by the capture plant). Estimates are that achieving a capture efficiency over 90% is unlikely.

d. Vanilla CfD

CfDs are obviously a very well tested mechanism for bringing forward both fuelled (nuclear and energy from waste) and non-fuelled (offshore wind) low carbon and renewable technologies. A vanilla CfD could apply in relation to the capture/generation stage, to introduce a fixed strike price that reflected: (i) the levellised cost of energy ("**LCOE**") of the capture facility; (ii) the fee payable to the transport/storage operator for disposing of the CO_2 (referred to in this note as the "**T&S fee**"); and (iii) the plant's decommissioning costs.

The Consultation also suggested introducing a "fuel price adjustment", which could be modelled to incentivise generators to dispatch at times of high fuel prices. Only "low carbon" power generated through the generation/ capture plant would be rewarded through the CfD, anything else (eg, non-abated generation when the transport/storage facility is unavailable) would be sold at wholesale market prices, to minimise the additional financial burden on consumers.

Although initially attractive, the concern with adopting the "vanilla" CfD structure is that the single strike price, which is paid on dispatch only, would not be sufficiently sophisticated to incentivise a dispatchable business model. It might instead simply incentivise dispatch at a higher level than that desired for overall system balance, in the same way that conventional CfDs incentivise offshore wind to generate at close to maximum output.

Building in this degree of designed flexibility is critical for CCUS CCGT. As a general observation, flexibility is an increasingly prized characteristic of today's electricity system due to the complex interdependencies of higher levels of intermittent renewable generation, lower levels of traditional centralised generation (making it harder to stabilise system frequency), and more sophisticated demand response activity.

e. Dispatchable CfD

It is therefore necessary to adapt the vanilla CfD to create a "dispatchable CfD". The difference here is that splitting out the price elements can help incentivise the plant to operate as a mid-merit player, being called ahead of unabated CCGTs. To model and incentivise that running profile properly, it is necessary to determine how a "reference plant" would operate in equivalent market conditions, with that reference plant being identical in all respects save for the capture facility. A key element in the economic comparison, in designing the level of revenue support, is to determine and reflect the wider energy system value of having dispatchable low-carbon electricity capacity available; it should not simply be a narrow focus on the LCOE of the plant (which does not factor the broader system benefits of flexibility). This will inevitably be a focus of the applicable CfD.

With this approach, incentives can be introduced to ensure the CCUS CCGT operates in circumstances where the reference plant would not (hence moving above it in the merit order), with the difference being remunerated appropriately. Achieving this outcome requires the different fee elements of the CfD to be split out, probably into a:

- **Fixed payment**: potentially covering: (i) the

"availability cost" of firm low power capacity being available to the system (including the plant's opex); (ii) the capital expenditure (including debt and equity service) and fixed costs of the capture equipment; and (iii) a direct pass through of the T&S fee (or at least the capacity reservation element of the T&S fee). This fixed revenue stream should in principle be modelled to provide sufficient certainty for investors in generation/capture projects. The availability element could have a Capacity Market style penalty regime for not being available when required.

- **Variable payment**: covering the low carbon electricity generated, calculated in comparison to the reference plant (referred to as a "dispatch incentive payment"). As with the unabated CCGT, most of the CCUS CCGT's output revenue should come from the wholesale market, but the CfD linked variable payment would reflect the additional costs to the CCUS CCGT operator of dispatching ahead of unabated generation, taking into account prevailing gas and carbon prices (and indeed, to incentivise it to do so). This should also include the associated start-up costs for the CCUS CCGT (which are not otherwise incurred by the reference plant in those circumstances).

An alternative to a variable fee would be to implement a "fixed top-up", with a maximum margin allowed to the CCUS CCGT operator (with any excess over the margin being return to LCCC). As with RAB element of the transport/storage project (discussed below), the anticipated rate of return for the generation/capture project's investors will be a fundamental consideration in determining the applicable level of support through the CfD.

There are various other models referred to in the Consultation (eg, a hybrid CfD, an interconnector type "cap and floor" model, a cost reimbursement open book approach and the use of tradable CCUS certificates). While the Consultation is open to all these models (and any others), the clear line coming through the CCUS Taskforce, CAG report and Consultation is that the dispatchable CfD model is favoured for the generation/capture stage.

The CAG suggests that a dispatchable CfD should run for at least 20 years, in recognition of the long operational life of CCUS CCGT and to facilitate project financing for the entire CCUS network (versus less capex intensive conventional CfD projects). While underpinning investment in the early infrastructure, a longer tenor CfD has the additional advantage of incentivising unabated operation for a longer period.

f. Getting the CfD right

The CfD provides the point of entry for the revenue support for the whole CCUS project (as it allows a pass-through of the RAB fee to the transport/storage operator). It is therefore obviously essential for the integrated project to structure the CfD correctly. It is still early days for a discussion on the precise structure of a CCUS CfD, but Cornwall Insight produced a useful analysis in 2019 ("Market Based Frameworks for CCUS in the Power Sector"), which looked at three possible models with varying operating flexibility (baseload with limited flexibility; hybrid with more flexibility; and flexible with a merit-order focussed running profile, not intending to deter renewables dispatch).

Cornwall concluded that a flexible CfD could in principle incentivise the development of more flexible CCUS technology, albeit the strike prices would likely be higher (partly reflecting wider system value of flexibility) and the short run times may limit the ability to make technology improvements relative to a baseload profile (hence the comment above about allowing early CCUS CCGTs to operate in an initial baseload regime). Cornwall emphasised that an availability element (constituting a floor price) should be included in the CfD to provide investors with a stable minimum level of return. From a "first of a kind" perspective, this could be set at a higher level for the initial projects to give investors (and their credit committees) greater confidence in the project. This therefore broadly supports the model adopted in the Consultation.

Transport/storage stage proposal: utility model RAB

a. Project similarities

The transport/storage project has some similarities to the generation/capture project. As with the high capex associated with new build gas-fired generation and capture technology, the transport/storage project also faces significant upfront capex to build the onshore and

offshore CO_2 pipelines (for the transport stage) and CO_2 storage sites, compressor stations and injection equipment (for the storage stage). Perhaps unlike the generation/capture projects though (which will still have high fuel costs and high carbon costs in relation to non-abated generation), the operating costs of transport/storage should be relatively low. The Government is also consulting on the ability to reduce initial expenditure still further by repurposing existing oil and gas infrastructure.

The transport/storage operator also faces the additional challenge of interfacing with a number of generation/capture operators (both the "catalyst" and the "feeders") who wish to use its network. These will typically have different operating profiles (eg, power generators, hydrogen producers and industrial carbon-intensive users). This could be a complex problem in the context of a RAB model that typically requires a long-term, creditworthy customer base (the concept of the "catalyst" becoming an "anchor" customer is likely to be key from the RAB's perspective).

b. Transport/storage business model: RAB and "low risk/low reward"

As with the generation/capture stage, there is a broad consensus between the CCUS Taskforce, the CAG and the Consultation on the appropriate business model for the transport/storage stage. The recommendation is that the transport/storage assets should also be privately owned and financed (other alternatives explored varying degrees of public ownership). But, unlike the generation/capture stage, the transport/storage project is rightly thought to be particularly appropriate for regulation through a "low-risk, low-reward" RAB structure, delivering typical infrastructure or "utility" levels of returns.

The main source of revenue in the RAB model would be the T&S fee charged to the users of the transport/storage infrastructure. The RAB approach is particularly attractive here (for all the same reasons as are considered in the nuclear RAB consultation), because: it widens the categories of potential investors (to include e.g. pension funds); it delivers a transparent, fair return on capital; and the regime sets out a clear allocation of risks between investors, consumers and taxpayers. This all helps to mitigate uncertainty on construction costs and (in this case) storage liabilities, that may otherwise limit the pool of potential investors and make it more expensive to raise finance.

Sharing risks with consumers and allowing a transparent RAB revenue stream signals to investors that they do not need to price in the risk of low probability but high value contingencies in advance. Instead, the RAB payment can be flexed in response to both actual expenditure and the occurrence of certain categories of risk (eg, the unforeseen need to drill a new well). As with the nuclear RAB consultation, this is all concerned with lowering the overall cost of capital and driving better value for the delivery of complex infrastructure projects.

This low risk/low reward approach to what is still a very capital intensive and potentially high risk activity (at least until the transport network is operating at scale and the stores are well established), can be achieved through designing greater certainty on the revenue streams for the transport/storage project and achieving clearer allocation of the "irreducible risks" that are considered too expensive for the private sector to bear. This is a

common approach to encouraging investment in capital intensive infrastructure assets.

The obvious consequence of delivering a low risk investment profile to the private sector is that the government, ultimately through the taxpayer, has to offer a support package to cater for the "irreducible risks" that have been removed from the risk/reward calculation (referred to in the nuclear RAB consultation and the Thames Tideway project as the Government Support Package). Nonetheless, the significant advantage of this approach is that the particular risk being considered may never materialise and accordingly the taxpayer has not borne the cost of the risk. The key point is that this category of risk is not priced into the project, and paid for under the revenue support, as a risk premium from the outset.

c. The revenue stream: the T&S fee

The core feature of the transport/storage RAB proposal is the design of the T&S fee. This is crucial as it must provide sufficient certainty to investors and sufficient transparency to generation/capture operators. As the T&S fee is charged on a monopoly basis, then (as is characteristic of all RAB projects) the Consultation emphasises that it is important the fee is "fair, transparent and equal to all potential users of [the] network". This is obviously an area that Ofgem has particular expertise in.

The principle of the fee is actually reasonably straightforward. It would most likely be charged on £/tonne CO_2 basis for use of the relevant regional network. As mentioned above, the T&S fee would constitute part of the cost of the overall CCUS project and so forms an important part of applicable generation/capture CfD. In order to provide adequate certainty to the transport/storage operator (and its investors), the fee would most likely have to be paid irrespective of actual delivery to the transport/storage facility, or at least a material part of the T&S fee would have to represent reserved capacity and be payable in most circumstances (even if the capture project were not operating properly). This is one of the various examples of how cross-chain risk remains important in a split-chain model (the T&S fee is explored in greater detail below).

d. Timing of the T&S fee

The Consultation leaves open the question of whether 100% of the transport/storage costs should be charged to the first generation/capture project (the "catalyst"), and then subsequently reduced as more capture projects join the network and the costs can be shared across a wider user base. Such an approach is obviously attractive to the transport/storage operator as it provides an obvious means of keeping its cost base (including debt serving and shareholder dividends) whole in the early stages of a CCUS project, as opposed to only receiving a proportion of the cost from the first generation/capture customer based on its actual utilisation. This would have to be modelled into the generation/capture operator's strike price so that it can afford the cost pass through.

If a 100% fee approach was not adopted, the same issues applies the other way around: the transport/storage operator would most likely require alternative funding for the difference between the utilisation of the catalyst and its own T&S system costs until a sufficient number of users joined the network to achieve full utilisation. It becomes obvious that the issue is simply at which phase (capture or storage) the overall project should be compensated for under-utilisation in the early stages.

As such, and for reasons of simplicity, the Taskforce favoured the approach of the first capture project being charged all the transport/storage costs until more capture projects join that network. Another approach is to simply compensate the capital investment in the first transport/storage assets through a Government grant. Either way, a clear driver behind the cluster approach is to minimise the amount of time when there are only limited projects at each phase (eg, an industrial cluster aims to exploit what is in effect an existing captive customer base, and then to quickly scale out to new forms of activity, such as hydrogen production through steam methane reforming). This approach helps to mitigate the above problems relating to setting the T&S fee and cross-chain risk.

e. Structure of the T&S fee

Relatedly, it is not necessarily a foregone conclusion that a vanilla £/tonne CO_2 basis is the most appropriate basis for setting the T&S fee, as the variability introduced by actual CO_2 delivery (influenced by operating profiles and running regimes) may undermine the effectiveness of revenue certainty that underpins RAB funding models. Again, like the CfD model for the generation/capture stage, it may be more appropriate to split the fee into a:

i) fixed capacity based fee (which could be a fixed annual or monthly fee and is likely to account for most of the overall T&S fee). This reflects the

"capacity reservation" element the generation/ capture operator must pay in almost all circumstances, and which will form a pass through of the dispatchable CfD strike price. This element of the T&S fee should in principle be payable from the start date of the transportation/storage services contract, irrespective of the volume of CO_2 actually delivered; and

ii) variable volume based payment for actual delivery of CO_2 (charged on a £/tonne CO_2 at the delivery point basis).

The advantage of this approach is that it provides greater certainty to investors in the transport/storage project (as they can take assurance the stable fixed element will be paid in most circumstances and from a specific date) and provides a more obvious solution to various permeations of the cross-chain issue. For example, there are various scenarios when it could be appropriate to maintain the obligation to pay the fixed element of the T&S fee but excuse the variable element when actual delivery to the system is prevented (due to the unavailability of the capture or storage facility).

Obviously, this will be one of the more complex areas to resolve in the new RAB model, and it relates to how the cross-chain risk (and certainty for investors) is managed in practice. It can be partially mitigated through close collaboration between the two projects and ensuring they take a final investment decision at the same time, and follow a closely synchronised construction programme.

f. Make-up of the T&S fee

Either way, the aggregate T&S fee will most likely follow the "traditional" RAB fee, with all agreed categories of "allowed" revenue (properly, economically and efficiently incurred) forming part of the RAB base (whether or not they were foreseeable), on top of which the agreed WACC (rate of return) would be applied. As with the Thames Tideway, the WACC for the construction and initial operation period could be competitively tendered. The usual additional categories of cost, including in this case, allowable operating costs, a decommissioning reserve cost, depreciation and financing costs adjustments would also be added to the T&S fee. The T&S fee would be periodically reviewed by the new regulator, with the usual adjustments being possible in relation to each regulatory review period (eg, as to the applicable target regulated return for the upcoming period and adjusting for actual expenditure).

It is obviously a fundamental characteristic of any RAB fee that it should be sufficient to allow the RAB operator to continue to operate, carry out further investments (eg in relation to additional pipeline investment or well enforcement work) on the regulated infrastructure and make a regulated return on its investment (subject to actual performance and the applicable investment regime). As mentioned above, the proposal in relation to transport/storage activity is that the operator should make a "utility" rate of return, taking into account the specific CCUS industry and project specific risks, and of course any contractual protections made available to it (again, with risk and reward going hand in hand). As with other RAB models, the regulator has an important role here in both licensing RAB operators and in setting and reviewing the relevant T&S fee.

g. Risks and structures of RAB models

The characteristics of a RAB funding model and some of the risks that apply in high value infrastructure delivery (including in particular the role of the government support package) are considered in a separate note (in relation to the nuclear RAB consultation), so are not repeated here.

h. Conclusions on the RAB approach for the transport/storage phase

The underlying success of this model requires there to be a: (i) RAB model that offers a sufficiently attractive investment proposition for the transport/storage investor base; and (ii) the willingness of Government to offer revenue support in relation to some of the non-irreducible risks and a support package for the irreducible risks. Other approaches are referred to in the Consultation, including an interconnector type "cap and floor" mechanism and the OFTO model, but the similarities with other RAB network projects and the potential to drive much better value and bring forward a wider investor base means the Consultation is understandably supportive of the RAB approach.

As mentioned above, some risk could also be more directly mitigated by the use of a government grant to cover the initial network and storage capital spend (a

proposal that is also relevant to the application of CCUS technology to energy-intensive industrial processes).

Final thoughts

The Government came in for plenty of criticism after its first two forays into launching CCUS in the UK. Following the closure of the last competition in 2015, there has been a long line of careful analysis that has explored the implications of the central criticism, that the Government expected the private sector to take on risks that it was simply not efficient for it to manage. A review of those risks suggests some are better managed outside the CCUS project entirely (the "irreducible risks"), while others can be better mitigated through splitting the delivery chain and applying a RAB model to the transport/storage phase.

As set out in this note, many of the issues faced by developers in the last competition do not go away and will still require careful management (particularly in relation to the practical challenges of new build power generation, commissioning capture technology, gas transportation and storing CO_2 in underground rock structures). However, the Government is now clearly indicating a greater willingness to engage on the efficient management of these risks, and to help design a business model that will bring forward private capital and unleash the significant ambitions of the Action Plan. This has been given all the more impetus by the CCC's Net Zero report and the subsequent adoption of the Net Zero ambition by the Government. These issues all have relevant parallels in the move from a CfD funded Hinkley Point C to a potentially RAB funded Sizewell C, which hopefully indicates a new era of RAB funded infrastructure is about to be launched.

Hugo Lidbetter
Partner, Energy & Natural Resources
+44 (0)121 210 6246
hugo.lidbetter@fieldfisher.com

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