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Overview of Carbon Capture and Storage (CCS) demonstration project business models: Risks and Enablers on the two sides of the Atlantic

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Abstract

There are 15 large-scale CCS projects operating globally. Ten out of these fifteen projects, are located in North America [1]. The European Union's (EU) stated ambition was to have up to twelve operating CCS projects by 2015 [2], however this goal was not accomplished. The two projects currently operating storage in the European Economic Area, Sleipner and Snøhvit, are located in Norway. Because of this disparity in the number of projects operating in North America and in Europe – ten vs. two – we have analysed business models of major CCS projects in North America and in Europe, with an aim to identify risks and enablers in CCS project financing development on both continents. We find that successful CCS project development depends on multiple factors, such as (i) clarity of regulatory frameworks, (ii) efficiency of permitting processes, and (iii) early and sustained stakeholder engagement for public acceptance. However, project finance remain the most challenging piece.

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Keywords: CCS; Business; Demonstration; Europe; North America; Risks; Enablers.

Nomenclature

A	radius of
B	position of

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1. Introduction

Businesses invest capital (capex) and incur operating expenses (opex) in anticipation of receiving income. For a business to be viable, the cumulative income must exceed the cumulative opex and capex. Regulatory requirements may also mandate that companies make provision for decommissioning or, abandonment expenditure (abex). This can also generate costs in terms of capital that must be held on the balance sheet, or the costs of buying a form of financial security from a third party [3]. A business model has to take into account the above elements among others. One challenge is to find a business model which shares risks and rewards in such a way that acceptable returns are earned by each individual party involved as well as by the project as a whole.

Business models for CCS are vital to ensure the viability of CCS, as they describe how risk and reward will be allocated. For policymakers, viable business models may incentivise more companies to enter the market, while for CCS developers it can provide competitive advantage. Inappropriate business models are unlikely to have the desired results. For this reason, business models have attracted much attention within the CCS community and have been a subject of continuous discussion. Herzog [4], inter alia, highlighted the importance of CCS business model evolution.

In the late 2000s, studies [5, 6, 7] identified barriers to commercial deployment of CCS. This current analysis of the "real life" experiences gained by project proponents in their pursuit to CCS, shows such barriers are still relevant. More recently, Kern et al. [8] explored reasons why it has been so difficult to get demonstration projects off the ground by assessing different initiatives to develop CCS projects in the UK and Canada. The paper introduces an analytical framework that considers sets of factors that influence outcomes based on a political economy perspective.

In a previous paper, we focused on the European CCS Demonstration Project Network developments [9]. This paper expands previous work to discuss and analyse different business models from different CCS projects in North America and Europe. It is based on project proponent information gathered within the knowledge sharing activities of the European CCS Demonstration Project Network (http://ccsnetwork.eu/).

The European CCS projects studied are the European CCS Demonstration Project Network members, Don Valley Power Project, Peterhead CCS Project and Rotterdam Opslag en Afvang Demonstratieproject (ROAD). North American projects examined are the Boundary Dam Carbon Capture and Storage Project, Illinois Industrial Carbon Capture and Storage (ICCS) Project, Petra Nova Carbon Capture Project (formerly NRG Energy Parish CCS Project) and Texas Clean Energy Project (TCEP).

The models presented are notably different from each other, confirming the uniqueness of CCS projects in this aspect too. Different designs, selection of technologies throughout the CCS chain as well as market conditions and regulatory frameworks are, inter alia, factors contributing to the variance of business models. While the projects' models differ on funding sources, commercial structure and contractual arrangements, the vast majority, if not all projects, have acknowledged the importance of public funding for the development of their business model and business case.

2. Incentives for action

Observing the incentives of the projects examined to develop CCS, a clear remark can be made: in Europe, CCS initiatives are primarily driven by climate objectives; in North America, the view is more pragmatic, oriented on specific target such as, for example, gaining revenue from CO_2 sales.

From our analysis, we observe that projects are set up on "case-by-case" basis, depending on their commercial structures, market conditions and the regulatory environments they need to operate in. This mainly due to the fact that during their development, CCS projects have to face some unique challenges: they are evaluating financing

prospects for an industry that is still developing, in markets where support and policy mechanisms are still evolving and for projects where, in many cases, structures and risk allocation is still being defined.

Boundary Dam CCS is the only operational project among the ones we included in our study. This project may be a unique combination of environmental and financial incentives. In the late 2000s, power requirements were continuing to grow in the province of Saskatchewan, where the project is located. Electric power would have to come from either a retrofitted unit to the already existing infrastructure or from an alternative source of power. As Boundary Dam Units were approaching retirement, clear business decisions were necessary for Boundary Dam. Units 1 and 2 were retired in 2013 and 2014 respectively, so a decision on the future of Unit 3 had to be made quickly, particularly in anticipation of upcoming federal GHG emissions regulation. The Kyoto agreement changed the perceptions internally at SaskPower – the project proponent, promoting the idea of CO_2 capture and EOR. This way, there was an opportunity to produce lower cost electricity by combining EOR and credits from removing carbon.

3. Revenue streams

The necessity of revenue stream(s), either with EOR activities or other incentives is a topic of consensus for CCS projects on both sides of the Atlantic. Projects proponent have continuously expressed the importance of subsidies of any form for their development. According to projects, a form of "surety", i.e. the organization or person that assumes the responsibility of paying the debt in case the debtor policy defaults or is unable to make the payments on revenue stream, is necessary. Sureties are necessary to expedite project development, even if subsidies in their current form are replaced. Contract for differences (CfD) were mentioned as an example that could practically support projects and promote CCS further. The Don Valley project has primarily based its business model to the potential of benefiting from a CfD, complementing its existing EEPR grant.

Peterhead was one of the two projects selected within the UK CCS Commercialisation Program to receive funding to proceed with a Front End Engineering and Design (FEED) study. The objective of the UK competition was for DECC to grant £1 billion capital to project(s). Peterhead proceeded under the assumption that the grant would be available for the project's capital expenditure, with balance equity from Shell –the project's proponent. All revenues for the project would come from selling electricity. Under these terms SSE, the power plant owner, would receive income for producing green energy and then pass on to Shell.

The business case for the Boundary Dam's retrofit centred on making valuable by-products, namely CO_2, sulphuric acid and fly ash, for off taker markets. Electricity though remains the most valuable product.

Texas Clean Energy project business model is based on private finance. Financing is secured by all project asset and revenue generating contracts. The project has multiple revenue streams including sales from power, CO_2 and Urea.

The ROAD project originally based its revenue stream on credit from EUAs within EU ETS. Launched in 2005, the EU-ETS is the largest carbon trading market in the world. However, due to the significantly lower EUAs prices than forecasted, the ROAD project had to modify its original revenue stream plan. ROAD revenue stream is currently based primarily on public funds.

4. Enabling factors

CCS projects presented in this study have received some form of public support which all have acknowledged as being a major enabler for their project development. Given that projects rely heavily on such support, an unstable policy environment or withdrawal of support can transform this factor from a key project enabler to a key business risk.

The Don Valley project for example, based their business case upon the EEPR grant on the European level, for pre-FID development costs, and the potential of operation support through a CfD, post construction. Don Valley project has relied on a commercial scale multi-user transport and storage cluster with White Rose (WR) project to realise cost benefits from economy of scale and reduction of development time, cost and risk premia for follow on projects. White Rose project was one of the two preferred bidders within the UK CCS Commercialisation Program. On November 2015, the UK government announced that the £1bn ring fenced capital budget for the carbon capture

and storage competition was no longer available. Having been considered as a significant enabler, failure of this initiative entails further risk for the project.

4.1. Policies and Government Support

Government support has been reported to have played significant role in the development and diffusion of low carbon technologies [10, 11]. All projects included in this overview have acknowledged the crucial role of government support for CCS as well.

In North America, CCS projects have been supported by different policies, or, in some cases, blends of policies at Federal, State and local levels. One such example has been the Texas Clean Energy Project - while its business model is based on private finance, it benefits from a DOE grant and an Investment Tax Credit award resulting from the Energy Improvement and Extension Act of 2008 and the American Recovery and Reinvestment Act of 2009. The project also received support through the Texas House Bill 469. This bill provides tax incentives, for the first three "clean energy projects" built in Texas that achieve a minimum of 70 percent carbon capture and storage.

Similarly, the Industrial Carbon Capture and Storage (ICCS) project received DOE funding from the American Recovery and Reinvestment Act of 2009. The project proponents wanting to respond to the potential the project had demonstrated on phase 1 (Decatur Illinois project), considered EOR. However, with the falling oil prices, the option of generating amounts of CO_2 sufficient to qualify for US tax credit for carbon capture activities, known as 45Q tax incentives appeared more viable.

In the case of the Canadian Boundary Dam CCS, the timeline from the decision to go forward with the project to FID was approximately four years, with the project receiving CAN$240M of government funding in 2008. While in the meantime there was a change of governments, both supported the project.

The DOE was to provide up to $167 million in financial assistance to the Texan Petra Nova CCS project, through the Clean Coal Power Initiative (CCPI) Round 3. This includes funding to demonstrate the addition of a commercial-scale, post-combustion carbon capture technology to the existing coal-fired W.A. Parish Generating Station. Due to the 2016 Omnibus appropriations passed in December 2015, The Petra Nova CCS projects is now getting up to $190M in grant funding.

In Europe, the EU's CCS Directive (2009/31/EC) has been the main piece of legislation to provide a clear regulatory framework. Furthermore, the EC's proposal for a 2030 climate and energy policy framework acknowledges the role of CCS in reaching the EU's long-term emissions reduction goal.

In terms of financing, the EU ETS was to be an important incentive mechanism for CCS in Europe, but various weaknesses associated with it have surfaced during its implementation. ROAD is one example of projects that based their business model on the EU ETS. The 2008 economic downturn, in addition to the initial over-allocation of the market, led to a surplus of emission allowances. This resulted in a low price of the allowances and consequently, in reduced investment incentives. Having to reconsider its original business model, ROAD has now a phased approach (Figures 1, 2). In ROAD's new approach, all existing grants are for construction, with no obligation to operate beyond commissioning and testing. The project can also benefit from a new grant co funded by Norway, Germany, the Netherlands and the EU via ERA-NET for early operation and further testing and use future grants (e.g. EU Innovation Fund) for future operation.

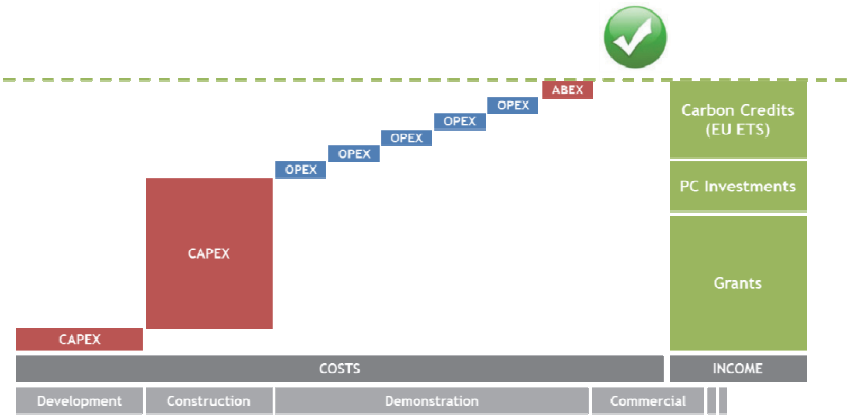

Fig. 1. ROAD original business model.

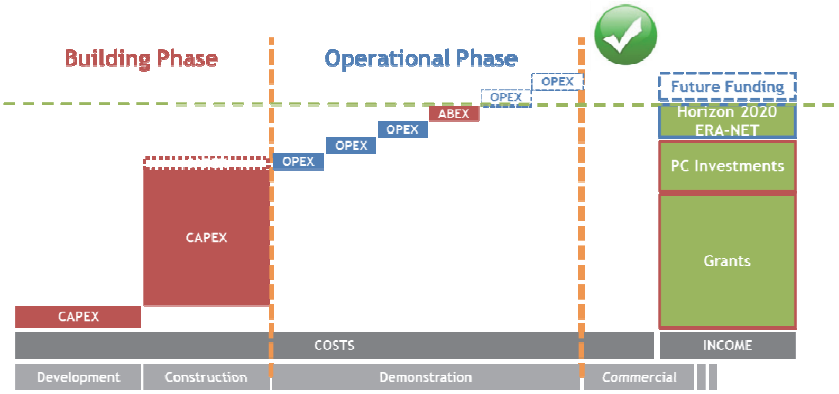

Fig. 2. ROAD current business model.

4.2. Synergies with the Oil Industry

CO_2 sales for EOR has been a major incentive for North American projects. Except from ICCS, all North American project included in this study plan to, or, receive revenues from EOR. In Texas, CO_2 is preferred option for EOR over water, as CO_2 moves oil off of rocks whereas water does not. Petra Nova project is driven from oil production, with 90% of its revenue stream coming from CO_2 sale for EOR. Therefore, oil prices are of utmost importance in this project. According to the project, oil price needs to average $75/bbl over 2018 – 2027 in order for the project to be viable. With oil prices as low as they have been in the last couple of years, funding for the project would not have been available.

At present there are no applications of CO_2-EOR in Europe, although projects have considered it as a storage option. Don Valley project examined EOR as a storage option, but finally opted for geological storage. After deselection from the UK CCS Commercialisation Program, the project underwent restructuring from its original form. Under the new project structure, the CO_2 supply would be insufficient for a full-scale EOR project.

4.3. Infrastructure

In 2013, the UK's CCS Cost Reduction Taskforce outlined significant cost reduction potential from infrastructure toward economies of scale [12]. Shared infrastructure has been noted as a crucial enabler for European CCS projects. The Don Valley project business model has relied on this concept, planning to connect to the Yorkshire and Humber CCS Cross-County Pipeline. This project would involve the construction of a cross-country pipeline and a sub-sea pipeline to transport carbon dioxide from fossil fuel power stations and industrial plants in the region to a permanent geological storage site beneath the North Sea.

5. Risks and Uncertainties

5.1. Costs

CCS project proponents need to take up various cost components during project development. These include prominent costs such as capex, opex and abex but also costs such as financing, insurance, storage characterisation, monitoring, etc. While operating costs are not insignificant, CCS projects have been associated primarily with large upfront capital cost. Projects from both sides of the Atlantic agree on this being a significant barrier for CCS project development. Petra Nova project has specifically identified this cost being its greatest cost barrier, not the operating cost. All projects acknowledged the importance of receiving public funds to support their costs.

5.2. Access to funding

Access to funding is usually a challenging exercise adding uncertainty to CCS projects. The nature of CCS development in each region differs substantially which may help to explain the varied engagement of financial institutions [13]. CCS projects financing activity in North America has been more dynamic. According to projects, in order to gain access to financing, it is important to be able to show working facilities that are viable. Operating pilot plants could provide the certainty required to allow for scale up to demo scale and access to financing. Tested technologies throughout the CCS system are much more likely to move forward on future CCS projects, but cost reduction is also essential for future developments and business decisions.

5.3. Permitting

The permitting process has been reported by projects to often be challenging and lengthy, adding uncertainty to project development. In Europe, CCS projects have faced a complex and time consuming permitting process, linked to the provisions of the CCS Directive and the wide range of permitting authorities involved. In North America, permitting timelines can also be prolonged, even if the process is significantly different. Permitting for the ICCS project for example, took longer than anticipated, affecting the starting date of the project. The project submitted a permit application in 2011. The process included a draft permit issued by the US Environmental Protection Agency (EPA) in 2014, a public hearing and comment period at the same year, before getting an Underground Injection Control (UIC) Class VI final permit granted in late 2014.

5.4. Public acceptance

Lack of public acceptance has caused project delays and in some cases even cancellation. On the other hand, acceptance of a project and support from the local community appears to play a vital role on its progress. In the case of Boundary Dam for example, the local community was a catalyst for the project, as supporting the plan, the company pursued and received external funding, with the project eventually going forward.

TCEP proponents recognise that support from the people of Odessa, Texas, has been unwavering. National environmental groups support has also been essential towards to realisation of the project.

Table 1, while non exhaustive, includes major enablers and barriers reported by projects.

Table 1. Enablers and barriers by project

Project	Enabler	Risks/Barriers
Boundary Dam	Federal GHG emissions regulation, government support, revenue stream, public acceptance	Cost
Don Valley	EU support, shared infrastructure	EU support, Government support, shared infrastructure
Illinois Industrial Carbon Capture and Storage	Government support	Permitting
Peterhead	Government support	Government support
Petra Nova (formerly NRG Energy Parish CCS Project)	Government support, revenue stream	Oil price
ROAD	Government support, EU support, private support	EUA price
Texas Clean Energy	Government support, revenue stream, private finance, community support	Oil price

6. The project experience

Projects from both sides of the Atlantic agree on the necessity of reliable revenue stream for their projects, either with EOR activities or other incentives. Projects highlight the importance of subsidies of any form for their development. As a matter of fact, a form of "surety" on revenue stream is necessary to expedite project development, even if subsidies in their current form are replaced. Contract for differences are underlined as an example that could practically support projects and promote CCS further.

CCS projects are not insensitive to current market conditions. In Europe, the EU ETS was to provide incentive for green investment and business models were, in some cases, built around it. Current EUAs prices have not been sufficient to drive investments, leading some projects to revise their plans. North American projects, given their activity on EOR are often linked with the oil index, inevitably exposing projects on the risk of oil price volatility and affecting their business case.

Project experience has shown that access to financing can be challenging. It is important to be able to show working facilities that are viable. Support for small to medium scale installations could help get across the "valley of death", paving the way for bigger facilities and commercial operation. Pilot plants, could provide the certainty required to allow for scale up to demo scale and access to financing. Tested technologies throughout the CCS system are much more likely to move forward on future CCS projects, but cost reduction is also essential for future developments and business decisions.

Projects have identified factors enabling their development but also risk and barriers posing challenges and delays. Putting these two in a relatively organized manner, revealed that under certain circumstances, specific factors can be transformed from enablers to barriers. This has been the case with Peterhead project - financial support through the UK CCS Commercialization Program enabled the project to go through their FEED. Yet, shortly after the announcement of the Program's cancellation, Peterhead decided to discontinue pursuing the project. Similarly for Don Valley, sharing infrastructure with one of the two UK CCS commercialization program preferred bidder, the White Rose project, has been anticipated to be an enabler towards reducing project cost. Cancellation of the program exposed Don Valley to unforeseen risk and further uncertainty.

7. Conclusions

In the EU, CCS project development has not been progressing as planned. Lack of economic rationale to invest in CCS projects was recognized as one of the main barriers. While North America has seen substantially more CCS activity in the last years, projects still face uncertainties and challenges.

As, in general, strategic interest is required to pursue CCS activities, replicating incentive models on technologies and adopting approaches that have worked elsewhere, could have a positive effect on CCS development. According

to North American projects and given the current market conditions, a form of support that could cover oil price risk would also provide some degree of confidence. Support for small to medium scale installations could help get across the "valley of death", paving the way for bigger facilities and commercial operation.

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