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Assessing issues of financing a CO_2 transportation pipeline infrastructure

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Abstract

For carbon dioxide capture and geologic storage to be deployed commercially and in a widespread manner will require well thought out approaches for transporting the CO_2 in a pipeline system from the capture facility to the injection site. Establishing a widespread CO_2 transportation infrastructure will require strategic long-term planning, taking into account the potential magnitude of future deployment scenarios for CCS, up to a scale of infrastructure that could be comparable to the scale of oil & gas infrastructure. This paper outlines the results of a study, commissioned by the CO_2 Capture Project (CCP) and completed by Environmental Resources Management (ERM) that evaluated the benefits and risks of two approaches to developing CO_2 pipeline systems. The two basic approaches are described in the paper as:

1. On a point-to-point basis, which matches a specific source to a specific storage location; or
2. Via the development of pipeline networks, including backbone pipeline systems, which allow for common carriage of CO_2 from multiple sources to multiple sinks.

An integrated approach to pipeline infrastructure approach offers the lowest average cost on a per ton basis for operators over the life of the projects if sufficient capacity utilization is achieved relatively early in the life of the pipeline. Integrated pipelines also reduce the barriers to entry and are more likely to lead to faster development and deployment of CCS. Without incentives to encourage the development of optimized networks project developers are likely to build point to point pipelines because they offer lower costs for the first movers and do not have the same capacity utilization risk.

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1. Introduction

For carbon dioxide capture and geologic storage (CCS) to be deployed commercially and in a widespread manner will require well thought out approaches for transporting the CO_2 in a pipeline system from the capture facility to the injection site. This paper outlines the results of a study, commissioned by the CO_2 Capture Project in Phase 2 (CCP2) and completed by Environmental Resources Management (ERM) that evaluated the benefits and risks of developing CO_2 pipeline systems.

The approach of the research is based on a view that pipelines for CO_2 transport could evolve in two basic ways:

1. On a point-to-point basis, which match a specific source to a specific storage location; or
2. Via the development of pipeline networks, including backbone pipeline systems, which allow for common carriage of CO_2 from multiple sources to multiple sinks.

A combination of the two will likely prove to be the most optimised approach, with individual projects driving the scope for development on a network basis. However, establishing such a network of CO_2 transportation infrastructure will require long-term planning and adopting a strategy that takes into account the potential magnitude of future deployment scenarios for CCS (i.e. 100's $MtCO_2$ being transported over long distances).

2. Strategies for deployment of infrastructures

Future strategies for private business and policy-makers should take account of the following:

- That while point-to-point pipelines may be readily funded on a project-by-project basis by individual developers, there may be a need for public policy that encourages the development of optimized networks. Development on this basis can help to reduce costs, broaden participation and deepen deployment of CCS;
- The incremental cost of building optimized networks ahead of point-to-point pipelines may not pass project-specific commercial evaluation criteria;
- Consequently, other forms of financial support which overcome commercial barriers may be needed to ensure optimized development of CO_2 pipelines networks.

Two further elements were also considered to influence the way pipeline networks are promoted and deployed, namely: geography and geo-political factors; and, the nature of policy tools used to incentivise CCS.

The approach taken to address these issues was as follows:

- To review the rationale, models and mechanisms used to promote and finance large oil & gas backbone pipelines;
- To review public/private infrastructure project financing models via case studies, such as large rail or road transport projects
- To undertake economic analysis of the relative risks and opportunities associated with developing point-to-point pipelines or backbone pipeline networks; and,
- To hold discussions with a range of potential financiers for CO_2 pipeline development.

3. Results

Point-to-point pipelines will be funded on project-by-project basis by individual developers because of certainty over capacity utilization. The study found that integrated backbone pipeline networks may be the most efficient long-term option. At the same time, such integrated backbone pipeline networks will need "guaranteed" capacity utilization in order to be economically viable. Therefore, public policy that encourages development of optimized networks with some support of capacity utilization will be needed. Government support in the first years when capacity is ramping up will be important to commercial viability. Government incentives or loan guarantees are also needed to support a backbone infrastructure.

In interviews with staff from banks and financial institutions[2], the key conclusion is that CO_2 pipeline projects, if they can be reduced in terms of carbon price risks, will become the same in terms of risks similar to any other oil & gas pipeline project. At the same time, these same banks and financial institutions view such projects as having significant regulatory and market risks associated with the carbon price, in addition to the typical geopolitical and commercial risks associated with other oil and gas projects.

4. Point to Point Pipelines Compared With Backbone Pipeline

In this study, economic modeling was done to attempt answering some basic questions potentially posed to a project developer (or project consortium) in considering the option of developing a backbone CO_2 pipeline infrastructure. The key question faced by a developer is whether to develop a backbone system ahead of a point-to-point pipeline, and what are the commercial considerations in this context. Thus, the questions that the modeling exercise aims to answer include:

- Is a backbone system the most optimized way of deploying CO_2 pipelines?
- Are there technical and commercial advantages to deploying a backbone system?
- Are there commercial barriers to deploying backbone pipelines?
- Are there options to overcome any commercial barriers?

In order to try and answer these questions, a methodology was developed based on several potential deployment scenarios, with each scenario tested using a pipeline financing model to test the most appropriate option, as described below.

The modeling approach adopted to undertake the analysis consists of two core components, namely:

(1) The modeled scenario: consisting of the physical (i.e. sources of CO_2, storage site availability; and distance between the two) and temporal (i.e. the timeline for development) aspects of a hypothetical CCS value chain development. This also includes the different options for connecting sources and storage sites; and
(2) The economic assumptions: in terms of the construct of the underlying economic model used to appraise the two options (i.e. the basis of the pipeline cost model).

4.1 The modeled scenario

The hypothetical scenario consists of possibly 10 new coal-fired power plants being developed over a seven year period, by four different independent power producers. Developer “One” will bring on stream four new plants together in year one, with subsequent tranches of plant following in later years. All operators are assumed to be suitably incentivised to deploy CCS under the types of policy regimes described above. Each tranche of deployment is assumed to be clustered close together, although collectively, the tranches are dispersed over approximately a 60-120 mile radius.

A saline formation suitable for CO_2 storage has been identified within 600 miles or so of all the power plants. The formation has an estimated 2000 million tonnes (Mt) CO_2 storage capacity, sufficient to take all the CO_2 from all the plant for 40 years.

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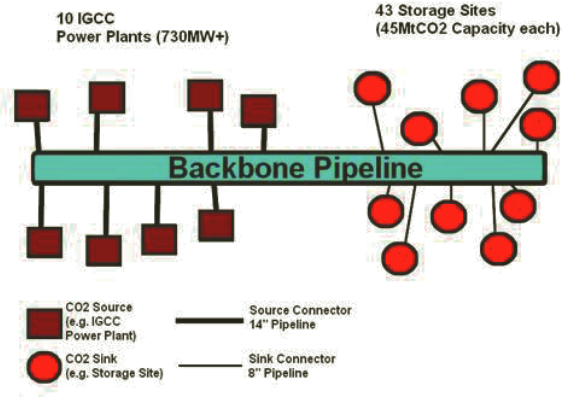
[2] Staff from six financial institutions was interviewed. One institution has a charter to carry out strategic investments for the European Union.

Figure 1. Scenario Overview -- Showing the Backbone Pipeline Option



In terms of connecting the power plants to the storage formation, two options exist, namely:

(1) Point-to-point pipelines: each tranche of power plants independently develops a pipeline, designed to only take the CO_2 from that tranche to the storage formation at 98% capacity utilization.

(2) Backbone pipeline: the developer of tranche 1 develops a backbone network with the option for subsequent tranches to connect, so as to reach 95% capacity utilization after year 7 when the final tranche of plants are completed. See Figure 1.

Details of the characteristics of the hypothetical scenario are outlined below (Table 1). While what is described here will not necessarily play out in reality, the scenario provides a useful basis with which to test the two options for pipeline development in the context of advantages and barriers, as well as options to overcome those barriers.

Table 1 Summary of the Scenario Characteristics and the Two Options

Feature	**Characteristics**
CO_2 source	10 x 730MW Integrated gasifier combined cycle (IGCC) coal-fired power plants, ~5MtCO_2/year/plant (3)
Timeline for deployment	The projects will be developed over an 8 year period as follows: • Year 1. Tranche 1: 4 x IGCC in close proximity completed • Year 3. Tranche 2: 2 x IGCC in close proximity completed. • Year 5. Tranche 3: 2 x IGCC in close proximity completed. • Year 7. Tranche 4: 2 x IGCC in close proximity completed. Each tranche is being developed by different developers.
Timeline for operation	• All plants are assumed to operate for a 40 year+ period. • During design of tranche 1, it is not assured that subsequent tranches will be realised i.e. there is uncertainty over whether new power plants will come on stream.
Total CO_2	• Tranche 1: 20 million tonnes CO_2/year • Tranche 2: 10 million tonnes CO_2/year • Tranche 3: 10 million tonnes CO_2/year • Tranche 4: 10 million tonnes CO_2/year Total CO_2 per annum in year 7 = ~ 50/year Total CO_2 following 40 years operation = ~2000MtCO_2
CO_2 store	• Large saline formation with around 2000 MtCO_2 storage capacity. • Each injection well has a capacity of 1 Mt/year, which means 45 injection wells will be needed in total.
CO_2 pipeline	All plants with an average distance from the formation = 600 miles Interconnectors detailed below.

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(3) IPCC, Special Report on Carbon Capture and Storage, Table 3.10, new IGCC power plants using current technology.

Feature	Characteristics
Options for pipeline development	*Option 1. Point to point:* Each new tranche of plant seeks to connect directly to the storage formation in isolation of earlier or subsequent tranches. Tranche 1 builds a backbone pipeline (operating at 97.5% capacity utilisation), operating with an inter-connecting hub on average 60 miles away. In addition, a centralised receiving hub is built at the storage formation, with inter-connectors built to individual wells with an average distance of 10 miles from the hub. Tranche 2 builds a small backbone pipeline to take-up CO_2 from the two power plants in year 3 and with an interconnecting hub similar as the one for Tranche 1. Tranche 3 and 4 follow the same pattern as Tranche 2. *Option 2. Backbone:* Tranche 1 builds a backbone pipeline system in year 1 (operating at ~40% capacity utilisation), with a view to take up CO_2 from all the new potential tranches coming on stream through an inter-connecting hub, on average 120 miles away. In addition, a centralised receiving hub is built at the storage formation, with inter-connectors built to individual wells with an average distance of 20 miles from the hub. This is necessary to avoid interference between each injector.

Economic assumptions

The pipeline economic model includes three key elements:

- Construction and operating costs (Capex/Opex): details underpinning the pipeline cost model for Options 1 and 2 are outlined in Table 4.5 and Table 4.8 respectively.
- Financing characteristics and structure: this covers the metrics used to estimate both the cost of different types of capital used to finance the project, and the economic metrics used to appraise the different investment options. Further details on the assumptions used are provided below.
- Project revenues: project revenues have been estimated by calculating the cost of service for each different pipeline option, based on achieving a break-even tariff charge for a 20 year net present value (NPV) using cash flow analysis. The financial analysis assumptions are outlined below.

The project revenues form the basis for comparing different options. A summary of financing assumptions is provided below (Table 2).

Table 2 Assumptions Underpinning Financial Analysis

Feature	Characteristic and assumptions
Project financing structure	Debt to equity ratio: 70:30 Based on analysis of oil and gas pipeline case studies also conducted as part of the study. The ratio used here is a reasonable one based on interviewing staff from these projects.
Timeline for financial appraisal	20 years (financial)
Cost of equity	15% - typical rate
Cost of debt	9.57% (US libor + 4%) – London Interbank Offered Rate (LIBOR) is the interest rate at which banks can borrow funds, in marketable size, from other banks in the interbank market.
Discount rate	7.5% - Discount rate is the weighted average cost of capital (WACC), a combination of equity and debt for this scenario that also accounts for inflation

4.2 Comparative Analysis

In this section we compare the two options using as metrics the cost of service associated with their use and the capital investment required for their development.

4.2.1 Cost of service (Tariff charge to breakeven)

Table 3 shows the average cost of service for Option 1 and Option 2 for the whole system (i.e. for all tranches) and from a first mover perspective (i.e. in year 1).

Table 3 Average Cost of Service for Option 1 and Option 2

	Cost of Service (for all tranches)	**Cost of Service (in year 1)**
Option 1	$10.5	$8.1
Option 2	$7.7	$11.3

Key findings of the research can be summarized as:

- The cost of service for Option 2 (i.e. backbone pipeline) presents the cost effective scenario for the system.
- Cost of service for the system is higher for Option 1 than Option 2 because additional smaller pipelines are developed separately for Tranches 2, 3 and 4.
- From a first mover perspective the reduction to the cost of service for the operator of Tranche 1 (cost of service in year 1) that follows Option 2 is small $0.4 ($8.1 vs. $7.7).
- There is a risk that if the first mover opts for Option 1 then additional tranches may not be able to carry out CCS due to prohibitive costs, absent of a backbone pipeline (i.e. Option 2).

4.2.2 Capital Expense

Table 4.11 presents the capital required for the development of Option 1 and Option 2 for the whole system (i.e. for all tranches) and from a first mover perspective (i.e. in year 1).

Table 4 Capital expense required for the development of Option 1 and Option 2 ($thousand)

	Capex (for all tranches)	**Capex required (in year 1)**
Option 1	$3,112,747	$1,030,942
Option 2	$2,321,779	$1,560,622

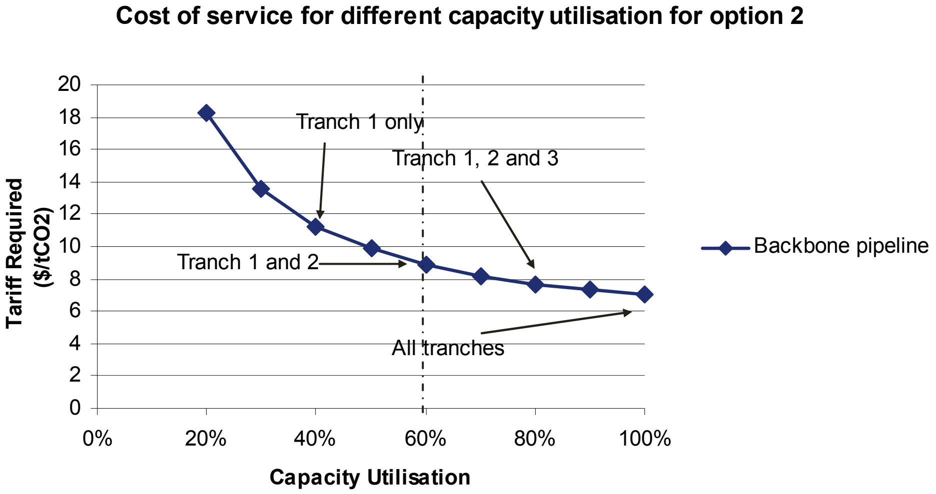
Key findings of the research can be summarized as:

- The capital required for the deployment of the Option 1 system is almost 35% more when compared with Option 2.
- From a first mover perspective the operator of Tranche 1 would need to raise an additional $500 million in year 1 to develop Option 2.

4.3 Capacity Utilisation

A sensitivity analysis was undertaken in order to understand the economic risks for a first mover (i.e. Tranche 1) pursuing a backbone pipeline with excess capacity (Option 2), when some or all subsequent tranches are not deployed. Figure 2 shows that the above scenario effectively results in an increase in the cost of service due to under-utilization of the backbone pipeline capacity.

Figure 2 Cost of Service for Different Capacity Utilisation for Option 2



The above results are summarized along the equivalent cost of service for Option 1 in Table 5 in order to understand the risk in the context of the both scenarios.

Table 5 describes the following:

- Under Option 1: The cost of service for Tranche 1 and for the system when more tranches needed then build separate pipelines.
- Under Option 2: The cost of service for the backbone pipeline depending on how many tranches eventually connect to the system.

Table 5 Average Cost of Service of Deployment of Option 1 and 2 (in $/tCO2)

	Tranche 1 only	**Tranches 1 and 2 only**	**Tranches 1, 2 and 3 only**	**All Tranches**
Option 1	$8.1	$9.2	$9.8	$10.5
Option 2	$11.3 (40% capacity utilisation)	$9.2 (60% capacity utilisation)	$8.2 (80% capacity utilisation)	$7.7 (Full capacity utilisation)

Table 5 shows that it would be cheaper for a first mover (i.e. Tranche 1) to pursue Option 1 for $8.1/tCO_2$ over Option 2 unless they are sure that all tranches will eventually connect to the backbone as this will bring the cost down to $7.7/tCO_2$ for Option 2.

In this sense, the Tranche 1 operator would need to weigh the probability of future capacity realization, along with the marginal cost benefit that will be received in this scenario, versus the probability of non-realization along with the associated costs. The results from this analysis indicated that the integrated pipeline is the preferred approach if an average lifetime capacity utilization of 60% or greater is achieved.

4.4 Financing Structure

Different financing structures influence the cost of capital and can subsequently affect the cost of service. For this reason the model was run for alternative financing structures in order to evaluate the cost of service in relation to Option 2.

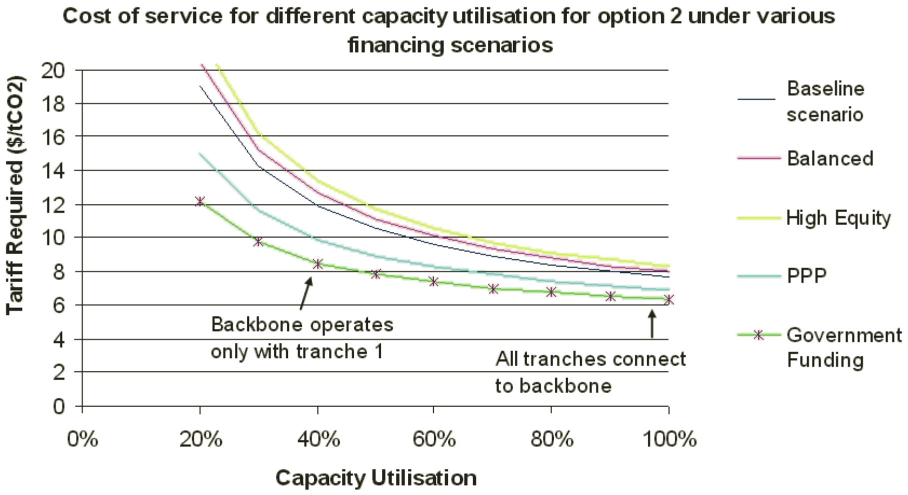
The alternative financing scenarios that were studied are presented below in Table 6.

Table 6 Financing Scenarios

Scenario	Financing Sources	Comments
Baseline Scenario (typical)	70% Debt, 30% Equity	Projects are typically leveraged with 70/30 debt to equity ratios or higher.
Balanced	50% Debt, 50% Equity	Similar to the base scenario the medium scenario is structured with less debt and more equity.
High equity	30% Debt, 70% Equity	As the cost of debt is usually cheaper that that of equity this can be considered as the pessimistic scenario where the project company could only partially raise the necessary debt to finance the project.
PPP	40% Debt, 10% Equity, 50% Government Guaranteed Bonds	Public private partnership scenario where the government would agree to guarantee bonds issued by the project company in the capital markets.
Government funding	100% Government Guaranteed Bonds	Government entirely funds the project.

The cost of service for different capacity utilisation for Option 2 under various financing scenarios is presented in Figure 3.

Figure 3 Cost of Service for Different Capacity Utilisation for Option 2 under Various Financing Scenarios



Government funding can enable the project to operate commercially at a comparative cost of service (~8$t/$CO_2$) to Option 1 even when Tranches 2, 3 and 4 are not realised (i.e. see Figure 4.4 at 40% capacity utilisation). In this sense, governments through favorable financing or other types of support can provide security to first mover over future capacity up-take and mitigate risks in order to promote optimised deployment options for a CCS scenario such as the one modelled.

5. Acknowledgement

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