Developing a Regulatory Framework for CCS Transportation Infrastructure (Vol. 1 of 2)

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Executive Summary

The Department of Energy and Climate Change (DECC) has commissioned Parsons Brinckerhoff (PB) and NERA Economic Consulting (NERA) to analyse the regulatory options for developing carbon capture and storage (CCS) transportation infrastructure in the UK. DECC has also asked us to consider the required role for government in promoting efficient developments of CO₂ transportation infrastructure. This report contains the results of our analysis and our conclusions.

In order to recommend an appropriate regulatory framework for the development of CO₂ transportation infrastructure in the UK, we have conducted a survey of regulatory frameworks in other industries and jurisdictions. Volume 2 of this report contains these detailed case studies, which we summarise in Appendix D of this document (Volume 1). In developing our recommendations, we have drawn on PB’s accompanying technical study which describes the likely characteristics and costs of developing a CO₂ transport network in the UK. We have conducted our own theoretical economic modelling (see Chapter 3) to inform our conclusions.

The Rationale for Government Intervention

In the absence of market failures, decentralised deregulated markets will produce an efficient pattern of investment. The academic literature on CCS, and some recent reports to the UK government, suggest that there are two sources of market failure which may create a rationale for government intervention in the provision of a CO₂ transportation network: externalities and economies of scale.

Externalities arise in respect of CCS investments if investors cannot capture all the benefits of their investments, i.e. the external environmental benefits of CO₂ abatement. Without government intervention to internalise this externality, there would be an inefficiently low level of investment in all low carbon generation technologies including CCS. This problem is being addressed in part by incorporating CCS into the EU ETS, which creates a market for CO₂ emissions by assigning long-term property rights over the ability to emit CO₂. However, given the short duration of the EU ETS, there may still be a rationale for government intervention to provide private investors with long-term assurances over the value of CO₂ abatement into the future. Moreover, the UK Government has more ambitious goals for CO₂ abatement than those incorporated in the EU ETS (and may wish to lead by example). The UK Government would then have grounds for implementing a support scheme for CCS like that currently in place for renewables, or alternatively by offering CCS investors a guarantee on the price of EU Allowances (EUAs) in the future.

By way of contrast, our review of other network industries and our theoretical exploration of pipeline economics show that private investors have strong incentives to form “coalitions” to exploit economies of scale in the construction of pipelines. Genuine uncertainties about the future size, location and timing of investment in CO₂ sources and sinks mean that it is not always economically efficient for either government or private investors to provide capacity ahead of demand even if the average cost of capacity is lower as a result. Since investors have strong incentives to coordinate their investments, governments do not have to play a major role in overcoming economies of scale. However, a potential role for government may be to facilitate coordination between private investors to reduce transaction costs. This may
be done, as in the case of US interstate gas pipelines, by mandating open seasons when new pipeline projects are proposed.

The Design of a Regulatory Framework

Providing that the UK Government allows CCS developers to capture the value of CO₂ abatement, i.e. to internalise the externality, a market-driven system will promote efficient construction of CO₂ pipelines, both off- and onshore. Our review of regulatory frameworks in other sectors and jurisdictions showed that the regulatory regime for the transport of hydrocarbons on the UK continental shelf is a well-functioning, decentralised and market-driven model of infrastructure development. We have therefore based our suggested regulatory framework on this regime, although we have identified a number of possible improvements that could be applied to the regulation of CO₂ pipelines:

1. Promoting efficient investment in new pipeline capacity by:
   - Defining transportation capacity on a point to point basis to provide clear price signals and to avoid the weak and distorted investment incentives provided under entry-exit regimes;
   - Requiring the use of open seasons before new infrastructure is developed to remove incentives on prospective developers to be “late comers” and to ensure efficient and timely expansion of the network; and
   - Incorporating CO₂ pipelines into existing planning rules used for other kinds of energy infrastructure (such as power stations) to avoid distorting incentives;

2. Promoting efficiently integrated networks by introducing an obligation on pipeline owners to provide taps, i.e. connections to other pipelines:
   - The obligation to provide taps removes the ability of incumbent pipeline operators to prevent new entrants from constructing new pipeline capacity;
   - It also ensures that capacity is developed by the party who can provide it at the lowest cost, by enabling pipeline developers to compete with each other for the right to construct pipelines;
   - Without this rule, incumbents may be able to foreclose the market for new pipeline capacity;

3. Promoting efficient use of existing capacity by:
   - Requiring unbundling to prevent foreclosure, to prevent access disputes by allowing a market price for capacity to emerge and to remove any perceived advantage incumbent pipeline owners might have over capacity;
   - Setting tariff structures such that variable usage charges must be set equal to variable costs to ensure the efficient use of pipeline capacity; and
   - Requiring infrastructure developers to provide platforms for secondary capacity trading where transfer between users is feasible, so that the parties who most value pipeline capacity can get access to it.
In principle, the UK Government can choose to implement different rules in stages, as and when the government considers them necessary. However, it should be borne in mind that each set of rules makes some contribution to the first aim, that of promoting efficient investment. Some of the rules that might be introduced later need a foundation (such as formal accounting for costs) to be laid down from the start.

We assume that efficient investment will be an objective from the start, but recognise that efficient integration and efficient use may become important only as the CCS sector grows in size and attracts multiple users. Nevertheless, the UK Government may wish to signal these possibilities in advance, in order to help investors manage their risks efficiently.

**Conclusion**

Externalities and economies of scale provide theoretical reasons for concern about the efficiency of market outcomes. Our review of the case studies and our theoretical modelling suggest that as long as the UK government allows CCS investors to capture the value of CO₂ abatement, a market-driven system can promote efficient construction of CO₂ pipelines. In the course of this study we have identified three central objectives which the design of the regulatory regime should try to achieve:

- Promoting efficient investment in new pipeline capacity;
- Promoting efficiently integrated networks;
- Promoting efficient use of existing capacity.

The precise nature of the regime may vary over time according to which of the three objectives is most important. For example, as a new UK CO₂ transportation network is developed, promoting efficient investment will be more important than promoting efficient use of existing capacity. Later, as CCS networks become more established, the need to promote the efficient use of existing capacity may become more pressing. As we discuss in this review, however, it is essential to provide clear incentives from the start and some regulations require foundations earlier on in the evolution of the system. Therefore it is important that future changes to the regulation of pipeline development are made clear at an early stage.
1. Introduction

The Department of Energy and Climate Change (DECC) has commissioned Parsons Brinckerhoff (PB) and NERA Economic Consulting (NERA) to analyse the regulatory options for developing carbon capture and storage (CCS) transportation infrastructure in the UK, although this report was not commissioned to translate the EU directive on the geological storage of carbon dioxide into UK regulation. DECC has also asked us to consider the required role for government in promoting efficient developments of CO$_2$ transportation infrastructure. This report contains the results of our analysis and our conclusions.

Much of the discussion of investment frameworks concerns the appropriate incentives for investors to exploit economies of scale and, therefore, to invest ahead of demand. Appendix A sets out the economics of investment with economies of scale. Appendix B describes how regulation affects the incentive to invest and Appendix C lists some non-UK sources of public funding for investment in a CO$_2$ gas network.

As part of this study, we conducted a number of case studies that describe the regulatory and commercial arrangements operating in other network industries. We draw heavily upon the lessons in those case studies when describing options for the development of a CCS transportation network. Volume 2 of this report contains these case studies and we summarise the main findings in Appendix D.

The remainder of this report is structured as follows:

- Chapter 2 describes the drivers behind CO$_2$ pipeline investment incentives;
- Chapter 3 describes the economic theory of CO$_2$ pipelines, focussing on externalities and investors’ incentives to exploit economies of scale;
- Chapter 4 describes possible measures to ensure efficient investment in pipelines;
- Chapter 5 describes possible measures to ensure efficient integration of pipeline networks;
- Chapter 6 describes possible measures to ensure the efficient use of pipelines; and
- Chapter 7 summarises our conclusions.


2. \textbf{CO}_2 \textbf{Network Investment Incentives}

2.1. Introduction

A number of previous studies and academic papers have examined the potential for CCS in the UK and around the world. Many authors, having examined the cost conditions of the technology, have concluded that there is a need for government intervention to promote the development of a \textit{CO}_2 transportation network. However, the reasoning behind these conclusions merits closer examination.

A common justification for this conclusion is the observation that \textit{CO}_2 pipelines (like other gas pipelines) exhibit economies of scale and the fear that private investors would not be able to exploit these economies of scale efficiently, due to the lack of coordination. For instance, Chrysostomidis et al (2009)\textsuperscript{1} analysed an investment decision for the strategic deployment of \textit{CO}_2 pipelines (in the United States). They concluded that integrated backbone pipeline networks can be more efficient, but that such projects needed guaranteed capacity payments to be economically viable and that upfront government assistance was likely to be necessary to enable their construction. In another example, a recent report to the UK government stated the following:

\begin{quote}
"Shorter term commercial pressures may prevent the oversizing of transport infrastructure. Additional infrastructure would then be required to handle the increased volumes of \textit{CO}_2, which leads to higher lifetime system cost of capture. Even if interest rates were very low, the risk of \textit{CO}_2 capacity increases not occurring on time (or at all) is a barrier to private firms oversizing \textit{CO}_2 transport infrastructure. Some regulatory oversight or government investment would be required to ensure that effective transport system oversizing (as measured by lifetime cost of carbon abated) occurs."\textsuperscript{2}
\end{quote}

Closer examination of these reports and papers show that the authors often confuse two separate and distinct problems: (1) the presence of externalities (i.e. the environmental benefits of CCS); and (2) economies of scale in pipeline construction. Some discussions also identify a lack of information as a constraint on efficient coordination. Each of these separate problems merits a different policy response.

As with all environmental policies, there is a case for government intervention due to the presence of externalities. CCS provides a means of reducing – or rather abating – emissions of \textit{CO}_2 to the atmosphere. If investors in CCS cannot capture the benefits of \textit{CO}_2 abatement through some financial reward, the incentive to invest in CCS will be less than is economically efficient.


Given an incentive to invest in CCS, investors can minimise costs by exploiting economies of scale. However, it is not efficient to exploit all potential economies of scale in the construction of pipelines, if the result is either an excessive risk of asset stranding or the creation of diseconomies of scale in other parts of the process. An example of such a diseconomy might be the need to construct longer electricity transmission lines to transport power to centres of demand from CCS power stations clustered near to CO\textsubscript{2} hubs.

Some of the previous studies and academic papers we have reviewed do not distinguish fully between externalities and economies of scale when presenting a case for government intervention in the development of a CO\textsubscript{2} transportation network. Externalities seem to represent a genuine problem for incentives, requiring some government action. By contrast economies of scale may or may not merit government action.

Extreme economies of scale result in the evolution of natural monopolies, where a regulated monopolist can meet market demand at a lower cost than a number of smaller competing firms. Examples of natural monopolists include electricity, gas and water distribution networks. However, if economies of scale are limited, a market can exploit them efficiently. As we describe in Chapter 3, the cost information we have examined suggests that the provision of offshore pipelines is not a natural monopoly industry. Hence, government intervention is not needed to overcome economies of scale, and can be targeted at resolving problems of externalities.

In sections 2.2-2.4 we assess the case for government intervention in the development of a CO\textsubscript{2} transportation network. We consider separately the need for government intervention due to (1) the presence of externalities, (2) imperfect information and (3) economies of scale.

2.2. Externalities

Investment in natural gas pipelines is driven by consumers’ demand for gas and the benefits they receive from consuming it. Markets translate this demand into a price for gas and a reward for investing in the delivery of gas to consumers. However, CO\textsubscript{2} pipelines have no such customer base. Instead, the demand for CO\textsubscript{2} sequestration derives from a benefit to the environment, i.e. reduced CO\textsubscript{2} emissions. This benefit has a value to the global population as a whole, but the benefit is an “externality”, meaning that no investor in CO\textsubscript{2} pipelines will be able to capture the benefits of their investment without government intervention.

2.2.1. The theory of externalities

According to economic theory, any equilibrium created within and between competitive markets will be efficient, as long as property rights are defined and enforceable (i.e. markets are complete), and all market participants are “price takers”, i.e. they cannot exercise market power.$^3$ However, this result does not hold in the presence of externalities because property rights are not defined, so markets cannot be complete. This failure to meet the necessary conditions can cause inefficient outcomes, as we describe in this section.

An externality may be defined as follows:

“an economic situation involves a consumption externality if one consumer cares directly about another agent’s production or consumption… Similarly, a production externality arises when the production possibilities of one firm are influenced by the choices of another firm or consumer… The crucial feature of externalities is that there are goods people care about that are not sold on markets”.

If externalities are present, a market mechanism will not ensure an economically efficient distribution of resources between economic agents because some firms or consumers do not take account of the effect their actions have on others. For instance, in many jurisdictions the CO₂ emitted by power generators is a consumption externality because generators do not have to buy the right to emit CO₂. The market for CO₂ emissions cannot exist if nobody owns the right to emit CO₂ into the atmosphere. In these conditions, generators do not face the environmental cost of their emissions, and they will burn more fossil fuel, or more carbon-intensive fuels, than is economically efficient.

The costs of generating electricity from low carbon sources like CCS and renewables are high relative to the costs of conventional thermal power generation technologies. The additional costs of investing in such technologies are borne by private investors. However, without government intervention, they cannot own the external benefits they create by abating CO₂ emissions. This “missing market” distorts incentives by encouraging less investment in low carbon generation than is economically efficient.

2.2.2. Internalising the externality

Externalities arise when the consumption or production of a good or service gives rise to costs that the consumer or producer does not pay, or benefits that no individual consumer or producer can capture. Externalities derive from “market failure” – meaning that a market is absent (not just performing poorly), usually because some resource is not privately owned. In market economies, externalities cause inefficient allocation of resources between different uses, because producers or consumers have incentives to over-use resources that they do not pay for. This tendency can only be corrected by “internalising the externality”, i.e.

- by establishing some kind of property right over the resource so that the owner can charge for its use, or
- by bringing the resource into a form of state ownership, so that anyone using it must pay a tax or fee to the government for using it.

Either of these methods stops people from using a resource for free and discourages excessive use of it. Examples from history show that such policies arise when overuse of a resource

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5 There are other reasons. Externalities arise also if transactions costs prevent a market from coming into existence. However, it is unusual for the level of transactions costs to be prohibitive in a market between large-scale investors. The current problems in sustaining some financial markets may stem from the difficulty and cost of assessing credit risk, but similar problems do not seem relevant to pipeline investments.
threatens efficiency. The Enclosure Movement of the 18\textsuperscript{th} and 19\textsuperscript{th} centuries gave individuals a property right over land that was formerly held in common and was intended to prevent overgrazing of common land. The rather more modern London Congestion Charge obliges drivers to pay a local authority for using scarce road space and is intended to reduce the extent to which drivers block each other on the roads. Recent concern over CO\textsubscript{2} emissions is intended to prevent overuse of the atmosphere’s ability to absorb greenhouse gases.

CO\textsubscript{2} emissions constitute an externality, in that they harm or pollute the atmosphere, thereby reducing the planet’s ability to shed heat. If the people responsible for CO\textsubscript{2} emissions can avoid the environmental costs of their emissions, they will emit too much CO\textsubscript{2} and will use up too much of the atmosphere’s ability to absorb CO\textsubscript{2}. Recent developments in environmental protection have focused on replacing the “common” right to emit CO\textsubscript{2} with a new property right – the right to emit a tonne of CO\textsubscript{2} into the atmosphere.

2.2.3. Putting a price on CO\textsubscript{2} emissions

Within the EU, the “EU Emissions Trading Scheme” (EU ETS) removes – for a limited period of time – the externality associated with the right of large combustion plants to dump as much CO\textsubscript{2} as they want into the atmosphere. Instead, large emitters of CO\textsubscript{2} must have an “EU emissions allowance” (EUA) for each tonne of CO\textsubscript{2} they emit. Governments allocate or sell these EUAs to large installations that emit CO\textsubscript{2}, but EUAs are tradeable. A market has grown up to let emitters buy and sell EUAs, as and when their forecast emissions change, and a price for EUAs has emerged in that market. Each tonne of CO\textsubscript{2} emitted to the atmosphere costs the emitter the market price of an EUA, either as the cost of buying an EUA or as the revenue foregone because the emitter cannot sell one of its EUAs. For participants in the EU ETS, the price of an EUA represents the opportunity cost of emitting CO\textsubscript{2} and the marginal value of reducing CO\textsubscript{2} emissions.

At present, the market price of EUAs is effectively defined by the marginal cost of CO\textsubscript{2} abatement, i.e. the cost of the most expensive method of reducing CO\textsubscript{2} emissions down to the required level. Currently, the price is varying in the range €10-20 per tCO\textsubscript{2} (per tonne of CO\textsubscript{2}).\textsuperscript{6}

The UK government has introduced legally binding CO\textsubscript{2} emissions reductions targets that are lower and longer lasting than those in the EU ETS. The UK has unilaterally enacted legislation requiring an 80\% reduction in CO\textsubscript{2} emissions by 2050, which is a more demanding target than set at the EU level.\textsuperscript{7} Such tighter targets will incur higher marginal costs of abatement. They imply that the UK government attributes to CO\textsubscript{2} emissions a cost (an implicit or “shadow” value) that is higher than the EU ETS price. The relationship between tightening targets and raising the marginal cost of abatement was illustrated by

\textsuperscript{6} This EUA price may reflect directly the marginal cost of abatement. However, in Phase I of the EU ETS (2005-2007), EUAs had to be used up and could not be transferred to later Phases. The market price of an EUA therefore reflected a probability-weighted value, dependent on whether the system was likely to be short (in which case the price would reflect the costs of abatement or more) or long (in which case EUAs would have no value). The market price now reflects the possibility of transferring EUAs between Phases, so that long-run marginal costs of abatement play a more important role.

\textsuperscript{7} See the Climate Change Act 2008: http://www.defra.gov.uk/environment/climatechange/uk/legislation/provisions.htm
recent Markal-Med modelling carried out for the UK government. This study estimated that a 60% reduction in UK emissions of CO\textsubscript{2} by 2050 would shift the marginal cost of abatement to £61/tCO\textsubscript{2}, whilst an 80% reduction by 2050 would raise the marginal cost of abatement to £140/tCO\textsubscript{2}. This higher shadow value provides a necessary, but not a sufficient, condition for incurring the costs of CCS and other CO\textsubscript{2} abatement techniques, as long as the price of an EUA remains at the current low level. We presume the UK Government has other reasons for adopting higher cost techniques, such as its desired role in international policy debates.

2.2.4. Centrally planned investment decisions

Putting a price on an externality has two important consequences: investment decisions can be decentralised in response to the (revised) market signals; and prices reflect the full costs of service, including the cost of the externality.

In one of our case studies, the British rail sector, the UK Government chose to provide investment incentives by providing a direct subsidy to investments that avoid the externality, instead of making users pay for causing the externality. The externality in question is a combination of pollution and congestion caused by motor vehicle traffic. The result of the subsidy is to reduce the price of rail transport (externality-abatement) instead of raising the cost of a road transport (externality consumption). The justification for providing such subsidies may be the short duration of franchise agreements (relative to the life of assets provided through infrastructure investments) and the difficulties in defining and allocating capacity on a rail network. However, as a consequence, prices do not reflect the cost of the externality and the UK Government is closely involved in planning rail sector investment, through the procedures for passenger service franchising and through Network Rail’s price control review process. (See Appendix D section D.5.)

In the case of a CO\textsubscript{2} network, a market-based approach to internalising externalities, such as the EU ETS, minimises government involvement in investment decisions. It allows private investors to choose where and when network capacity should be provided. It also permits the use of competition between competing pipeline developers, as a tool for encouraging efficient investment planning and implementation.

2.2.5. Investment Drivers for CCS

Private investors in CCS would bear all the costs of constructing and operating the plants and pipelines. However, at present they have little incentive to incur these costs, because there is little demand for CO\textsubscript{2}.

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8 AEA Energy and Environment (2008), MMARKAL-MED model runs of long term carbon reduction targets in the UK Phase 1: Final report to Committee on Climate Change, November 2008.
9 AEA Energy and Environment (2008), page v.
10 As long as the price of an EUA remains low, the UK Government could achieve its own targets for CO\textsubscript{2} abatement at lower cost by buying up and retiring EUAs (or by not auctioning EUAs in the first place). The result would be tighter limits on all producers within the EU and lower CO\textsubscript{2} emissions in the UK and/or other countries.
**Benefits**

The surge in oil prices to over US$100 per barrel during 2007 and 2008 raised interest in the use of CO$_2$ for “Enhanced Oil Recovery” – injecting CO$_2$ into North Sea oil wells to extract a greater volume of oil.\(^{11}\) That source of revenue is no longer likely to promote investment in CCS, now that the value of the recovered oil has fallen to around US$50 per barrel. PB found that other techniques such as in-fill drilling and water injection may prove more economic than using CO$_2$ for EOR.\(^{12}\) Instead, the value of CCS is driven largely by the environmental benefits of CO$_2$ sequestration. However, investors in CCS cannot capture the long-term benefits of CO$_2$ abatement, for a variety of reasons:

- CCS abatement of CO$_2$ emissions has not been recognised in the EU ETS in the past;
- Although the market for future EUAs exists beyond 2012, Platts (among other agencies) has commented that these markets remain illiquid;\(^{13}\)
- The UK government’s long-term targets for CO$_2$ reductions have yet to be converted into explicit or legally binding constraints or charges on emitters of CO$_2$.

Including CCS in the EU ETS involves recognising that sequestered CO$_2$ is not emitted to the atmosphere and does not require an EUA. It also requires a method of monitoring the amount sequestered and assignment of liabilities for any leakage from pipelines and storage reservoirs.) As of May 2009, these changes seem to be imminent.\(^{14}\) However, there is still no deep and liquid long-term market for EUAs, which weakens incentives for investment in CCS (and for any other long-term investment in CO$_2$ abatement).

**Long-term incentives**

The UK government could internalise the long-term positive externalities created by CCS generators by creating a long-term policy framework. To extend the effect of the EU ETS, the UK government could offer investors in CCS a long-term guarantee that they will capture the benefits of the EU ETS, or an equivalent in the event of the EU ETS coming to an end. This guarantee could be either an “annuity” or a “securitisation”.

Under the “annuity”, the government commits to give the project a certain volume of EUAs (or the equivalent value in cash even if the EU ETS comes to an end) during each year of the project’s life. The benefits accruing to the project may take the form of actual EUAs, which

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\(^{11}\) See for example: Analysis of Carbon Capture and Storage Cost-Supply Curves for the UK, Poyry (prepared for the DTI), January 2007, page 11.


\(^{13}\) “Platts’ EU Emissions Allowance assessments and indices are based on trade in EU Emissions Allowances (EUAs) of carbon dioxide equivalents, as traded under the EU Emissions Trading Scheme (ETS). One EUA is equivalent to 1 metric ton of carbon dioxide. Prices are quoted for EUAs valid for the remaining Compliance Period in Phase One of the ETS scheme (2007) and all five of the compliance periods of Phase Two (2008)…Further price assessments for Phase Three (2012 onwards) EUAs are envisaged as those products become actively traded and as arrangements and regulations for Phase Three become concrete.” See Platts, Emissions Methodology: http://www.platts.com/Electric%20Power/Resources/Methodology%20&%20Specifications/methodology_emissions.pdf?m

\(^{14}\) An EU Directive that recognises CCS within installations covered by the EU ETS had, at the time of writing, received a 1st reading approval from the European Council. Another draft EU Directive covers the permitting and monitoring process for underground (“geological”) storage of CO$_2$. 
the owners can sell in the market, or cash payments of a fixed amount, or a commitment from the government to buy EUAs from CCS operators at a fixed price. The benefits may also be bundled with similar commitments to pay for electricity output from a generator – in which case the scheme becomes a “feed-in” tariff.

Under the “securitisation”, the investor agrees to hand over to government each year any EUAs or equivalent benefits accruing to the CCS project for CO₂ sequestration, in return for the government paying a fixed sum to the investor at the start of the project. The government’s willingness to pay for receiving these benefits indicates its own degree of confidence in future policy and the value of the project. To select which projects receive such payments, and to minimise the amount involved, governments might auction off a contract (in this case, a contract obligation to hand over EUAs).

In principle, such “annuity” or “securitisation” schemes could be funded in a number of ways, including through general taxation or through a levy on electricity consumption.

B Additional value in the UK

As the UK government’s policy targets are tighter than those implied by the EU ETS, even a long-term commitment to the EU ETS may not be enough incentive for efficient investment in CCS projects. These commitments might therefore have to cover other schemes as well.

For other types of low carbon generators, the UK government has expressed its higher shadow value of CO₂ abatement, relative to the EU ETS, through subsidy schemes such as the Renewables Obligation. Without incorporating CCS into existing schemes or designing an equivalent mechanism for CCS, the incentive to invest in CCS will appear to investors to be unduly low, compared with other forms of low carbon power generation. This imbalance would not encourage efficient choices between CCS and other technologies. The UK government may therefore need to bring CCS within the remit of the ROC scheme or some equivalent (and this scheme may require a long-term guarantee similar to that required for the EU ETS).

2.3. Information and Government’s Role in Investment

The lack of long-term commitments to EUAs and other renewable incentives means there will be inefficiently low investment in all low-carbon technologies and there is a case for government intervention to correct this market failure. However, this does not necessarily justify government intervention to offer specific support to CCS rather than any other technology, such as renewables. The question is whether the government knows more about the future value of CCS than the private sector. If the government possessed “private information” (i.e. information available only to the government) about the costs and benefits of investment in CCS, then the government might be better placed to select such investments than the private sector. However, if the government can put the relevant information into the public domain (e.g. by publishing all known information on the costs and benefits of CCS and any policy commitments), public sector investors will have no advantage over private investors.
Of course, while a government can publish its future policy commitments to support low carbon generation, in order to remove any information advantage it may have, published information may suffer from a problem of credibility. For example, any government can announce its intention to support CCS and other CO\(_2\) abatement for the next 40 years. However, investors know that governments (and government policy) can change. They may therefore require a firm commitment to such support – in the form of a long-term contract enforceable in the courts. By offering such a contract, the government would be expressing its faith in the long-term existence of the policy and allowing the private sector to transfer policy risk to the public sector.

However, the UK government may not have any more information, or any better information, about future policies on CO\(_2\) than the private sector. Genuine uncertainty surrounds the future costs and benefits of investment in CCS – including uncertainty over future policies – and hence over the value of alternative methods of CO\(_2\) abatement in the future. The UK government would then have no additional private information to share with the private sector and no basis for taking over risks from the private sector. Other things being equal, public and private sectors would be equally well equipped to make choices about future investment in CO\(_2\) abatement (although there are several reasons to favour investment by the private sector). Thus, genuine widespread uncertainty about future market conditions does not provide a reason for investment to be directed, designed or funded by the UK government.

Some reports and papers have also examined the case for supporting new generation technologies, such as CCS or renewables, on the grounds that R&D and learning by doing creates external benefits that initial developers of new technologies (such as CCS or certain renewables) cannot capture. R&D spillover, i.e. innovations that cannot be patented, is an external benefit that may generate an inefficiently low level of investment in R&D.\(^{15}\) The UK government is already moving towards sponsorship of CCS projects for this reason. However, the sponsorship is intended to provide information about all parts of the chain involved in capturing, transporting and storing CO\(_2\). This report considers the case for government support in the provision of the CO\(_2\) pipelines alone. Since pipeline construction is a relatively mature technology, arguments about potential R&D spillovers lie outside the scope of this report.

### 2.4. Economies of Scale

As described above, several reports and papers argue that market-led investments will not exploit economies of scale efficiently. Such arguments rely on the following claims:

1. CO\(_2\) pipeline design is subject to economies of scale;
2. Market-driven systems lead to individual investors developing small projects that do not exploit economies of scale because they do not amalgamate loads or invest ahead of demand; and
3. Therefore, government should promote larger investments to increase efficiency.

In practice, these claims seem to be incorrect.

\(^{15}\) See, for example: Stern Review: The Economics of Climate Change, HM Treasury, 2007, Chapter 16.
2.4.1. Extent of economies of scale

We consider the theory and evidence on point 1, economies of scale in pipelines, in more detail in Chapter 3. In their separate report for this project, Parsons Brinckerhoff (PB) found that economies of scale in the construction of offshore pipelines were substantial in deciding between 30” and 36” pipelines, but noted that economies of scale diminish significantly for pipelines with a diameter above 36”. One reason is a lack of ships capable of handling such larger projects. Hence, it seems to be cheaper to construct a number of offshore pipelines with 36” diameter than to construct fewer lines of a larger diameter.\(^\text{16}\)

In addition, we have reviewed academic papers that highlight the trade-off between the large cost savings available from building trunk pipelines, and the extra costs of building long feeder pipes to CO\(_2\) hubs. In some cases it is more efficient to build several small pipelines directly from sources to sinks rather than one large trunk line and a number of feeder lines leading into the trunk line at some “pooling point”. Bielicki, for instance, sets out how this trade-off affects different cases:

"If all of the sources are clustered near to each other, for example, the CO\(_2\) flows can be aggregated into large diameter trunk distribution lines at small distances from the sources in order to take advantage of the returns to scale from pipeline transportation using larger diameters…"

"If the reservoirs are dispersed, it is possible that they will be located close to sources and it is thus possible that CO\(_2\) will be transported with dispersed pipelines that are not connected much and thus the potential returns to scale from transportation cannot be exploited…"

"CO\(_2\) flows can be aggregated more easily when the sources are located close to each other and when the reservoirs are located close to each other, and thus constant returns to scale for transportation set in at lower scales."\(^\text{17}\)

Thus, at any time, dispersal of sources and sinks can militate against the exploitation of economies of scale. However, Bielicki did not envisage government action to impose a clustering of CO\(_2\) sources and sinks. Economies of scale in constructing a CO\(_2\) pipeline may be offset by diseconomies of scale in other parts of the chain.

Uncertainty over the size and location of future CCS sources further weakens the case for large pipelines. Even if individual pipelines exhibit economies of scale, it may be inefficient to oversize CO\(_2\) pipelines in anticipation of demand from future users who may or may not materialise. PB’s analysis shows that there is indeed significant uncertainty regarding the timing, scale and location of future CCS projects, because of uncertainty about the long-term benefits and future costs of CCS and about the level of those benefits and costs relative to those of alternative low carbon generation technologies.

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\(^{16}\) PB’s report suggests that the majority of the CO\(_2\) transport network is likely to be located offshore: Options for Developing CCS Infrastructure: Task 1, Parsons Brinckerhoff Ltd, March 2009, page 26.

As a result, any investment in spare pipeline capacity faces a high probability that demand for the spare capacity will not materialise, or not for a long period of time. Private investors in CO\textsubscript{2} pipelines would take account of this risk of assets being stranded or unutilised for long periods. Reluctance to commit money to risky investments before it is needed is not always a sign of inefficiency. It is often a result of efficient risk management.

### 2.4.2. Ability of markets to capture economies of scale

Many writers rely on the second claim, that private companies will only invest to meet their own needs and, in doing so, will fail to exploit economies of scale. For example, in discussing a potential network of CO\textsubscript{2} pipelines in the US, Parfomak and Folger (2007) state the following:\textsuperscript{18}

“It is debatable, however, whether piecemeal growth of a CO\textsubscript{2} pipeline network in this way, presumably by individual facility operators seeking to minimize their own costs, would ultimately yield an economically efficient and publicly accessible CO\textsubscript{2} pipeline network for CCS.”

The implication, that investment must be centrally coordinated, is unwarranted. However, there are cases where network investment must be coordinated (or has been inefficient due to lack of coordination), for example in the presence of “network externalities”. The term “network externalities” is explained by Liebowitz and Margolis (1994):

“According to the received definition then, goods exhibit a network externality wherever the consumer enjoys benefits or suffers costs from changes in the size of an associated network, that is, changes in quantities demanded [by others].”\textsuperscript{19}

“Network externalities” have nothing to do with environmental externalities, but arise from interactions between users of a network. They can be positive or negative. More users owning telephones increases the usefulness of each person’s own telephone (i.e. a positive externality) while increased use of the road network by drivers in general results in congestion and additional delays for each individual (i.e. a negative externality).

The nature of “network externalities” differs between networks of different types, as do the implications for efficient decentralised investment. Much of the fear about decentralised investment is derived from analysis of electricity networks, where “network externalities” make it difficult or impossible for individual investors to capture the benefits of their own investments. A similar type of “network externality” arises when gas networks adopt the “entry-exit” definition of capacity, which divorces the capacity offered to users from the capacity created by individual investments. However, operators of gas pipelines do not have to adopt an “entry-exit” system, because pipeline capacity is a well-defined and measurable concept.

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Therefore, if the definition of capacity offered to users does not create unnecessary network externalities, the mere presence of economies of scale may not prevent efficient, market-led investment.

There are many cases of private investors combining their resources to benefit from lower average costs through economies of scale by forming joint ventures and other “coalitions” (to use the economic term). For example, in the power generation business, economies of scale are not large enough to prevent competitive markets emerging, but investors do club together to invest in power stations of a minimum economic size, in return for a share of the output. Similar arrangements are found in both the UK’s offshore gas pipeline system and the arrangements for building long-distance (interstate) gas pipelines in Germany and in the US. The UK offshore and the US interstate pipeline systems both use a point-to-point definition of capacity. The German pipeline system was built largely using such a definition.

The regulatory regimes in the North Sea and the US interstate gas pipeline sector do not rely entirely on voluntary decisions to promote efficient pipeline investment. Both regimes contain formal obligations on pipeline investors to run “open seasons” (through which other investors may join the project) and other rules designed to foster cooperation. In many cases, investors would choose to cooperate anyway, because of the potential reduction in investment costs, but such mechanisms help to overcome the “transactions costs” of forming joint project and restrict the use of market power to keep competing investors out of the sector.

A recent switch to entry-exit definitions of capacity in Germany has increased the need for centralised coordination because the administered capacity prices that emerge under entry-exit systems mean no single investor can capture the full benefits of a pipeline investment. As we describe in Section 4.2, previous experience in Germany and other jurisdictions shows that entry-exit regimes are not required to ensure coordination between investors. Moreover, such systems result in inefficient investment decisions, cause disputes between network owners and users and prohibit competition in the provision of pipelines.

When the UK government considers whether to fund a demonstration project using CCS, it would be well advised to run its own open season, to see whether private sector investors are prepared to pay for additional pipeline capacity. In all likelihood, it will be too early, and future demand will be too uncertain, to elicit interest from the private sector. However, such market tests would ensure that the investment is sized efficiently, taking into account all current demands for CO₂ pipeline capacity.

Thus, assuming that the UK government can strengthen incentives for investment in CO₂ pipelines by letting investors capture the benefit of CO₂ abatement, investors will also have both the incentive and the ability to exploit economies of scale, by forming joint projects whenever it is efficient to do so.

**2.4.3. Need for government intervention**

Finally, with regard to final claim, it is not necessarily true that governments will increase efficiency by promoting larger investments in CO₂ pipelines. The willingness of competing investors to exploit economies of scale may be obstructed by diseconomies of scale arising in the other parts of the CCS industry (i.e. capture, feeder, storage), by the gradual increase in CCS capacity and by uncertainty over future demand. None of these economic conditions
provides a reason for investment by government, since governments are no more able to get around them than the private sector. Efficient investment takes account of all costs and risks, whether it is being considered by private investors or by government bodies.

Furthermore, the efficiency of investment in gas pipelines depends partly on the degree of competition in the sector. Decentralised pipeline investments driven by (fully operational) market incentives is likely to be more efficient than centrally planned provision of (theoretically more efficient) larger pipelines. Preserving the beneficial impact of competition is another reason for governments to avoid promoting large projects for their own sake.

2.5. Conclusion

This chapter describes a confusion that has arisen in previous studies and academic papers over the respective roles of externalities and economies of scale in a market-led deployment of CO₂ pipelines. These problems require quite different responses by government.

2.5.1. Externalities and incentives to invest

Efficient investment by the private sector will require government action to “internalise the externality”, i.e. to ensure that investments in CO₂ abatement are rewarded for reducing CO₂ emissions into the atmosphere. The need to capture this value arises for all private sector investment, whether it is undertaken by a regulated monopoly or a market-driven system, and an estimate of this value is needed for any investment appraisal.

The provision of incentives for efficient investment must address a number of institutional constraints. The EU is in the process of approving a Directive that would place CCS installations within the EU ETS and would hence reward CO₂ abatement via CCS at the price of an EUA. However:

- Any additional value placed on CO₂ abatement by the UK government (such as the value implicit in the ROC scheme) must also be made available to investments in CCS; and
- Investors may require longer-term commitments to such values (at least, if the viability of CCS depends on benefits over a long asset life).

Government has an advantage over private sector investors if it possesses information which the private sector does not possess about the considerable uncertainties surrounding the costs and benefits of CCS (e.g. about future policy). In that case, the solution may be just to publish this information. However, if long-term policies suffer from a problem of credibility or commitment, governments may need to back them up with enforceable commitments such as long-term contracts. On the other hand, a lack of long-term commitment may also reflect genuine uncertainty over future government policy. In that case, the current government is in no better position than the private sector to assess whether investment in CCS is efficient or not, or to decide whether it should proceed or not. A decision by the private sector or government not to invest in a new and currently unproven generation technology may be a sign of efficient risk management rather than inefficiency.
2.5.2. Economies of scale and incentives to minimise costs

The potential to exploit economies of scale also provides no basis for government intervention in CCS investments, for a number of empirical and theoretical reasons.

First, diseconomies of scale in other parts of the chain (capture, feeder lines, storage) diminish or eliminate the benefits of building bigger pipelines at any one time. For example construction of CO$_2$ capacity may distort incentives over where investors should site new power stations, as building excess CO$_2$ capacity may induce power stations to locate close to the large CO$_2$ transportation facilities and not near to load centres or close to sources of fuel supply. Second, the take-up of CCS is likely to be spread over many years, which makes gradually adding capacity in small increments more efficient than building one large pipeline. Third, uncertainty over the timing, scale and location of future CCS projects reduces the efficiency of building large pipelines, owing to the risk of assets being stranded (under-used). These three economic factors mean the desirability of building ever larger pipelines is not a foregone conclusion.

PB’s own investigation of likely CO$_2$ pipeline developments suggests that the optimal network would be concentrated in three corridors, to maximise economies of scale, but that each corridor would be served by a number of 30” or 36” pipelines, each added at different times, rather than by larger pipelines designed to manage the entire forecast load.

Private investors have shown their ability to form “coalitions” (e.g. joint ventures) which amalgamate demands in order to exploit economies of scale. Such efforts will be possible for CO$_2$ pipelines, as for other pipelines, primarily because the economies of scale are limited. The incentive to form such joint ventures relies on investors’ ability to capture the benefits of their investment, i.e. the absence of “network externalities”. Such network externalities would reduce the private sector’s incentive to invest as part of the benefit of the investment would accrue to third parties. These benefits would encourage some investors to stay outside coalitions, in order to benefit from the external effects of other people’s investments. However, in practice, gas pipelines do not suffer from this problem.  

In the second volume of this report, we describe a number of regulatory regimes intended to promote investment in network capacity. Here, we will refer extensively to regulatory frameworks that overcome economies of scale in pipeline design, even though investment is decentralised and coordinated through competition. US interstate gas pipelines and the UK’s offshore regime for natural gas pipelines in the North Sea both provide interesting examples. Investment in these pipelines is driven by the demand for natural gas (i.e. not by externalities) and is open to anyone, so investment is ‘market-led’ and competitive. In the US, efficient competition depends on a regulatory and legal system that converts decentralised investment in pipelines into well-defined property rights over pipeline capacity. Experience has led

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$^{20}$ More accurately, gas pipelines do not exhibit network externalities unless the pipeline operator is forced to define capacity in a way that is divorced from the underlying reality. Pipelines provide “point-to-point” capacity, but network externalities arise in the “entry-exit” capacity systems used by most electricity and onshore gas networks in Europe. The rationale for adopting entry-exit systems is the desire to help new entrants trade the commodity without having to deal with a large incumbent who may dominate supplies at individual nodes. Such concerns do not arise if pipelines are built by competing operators from the start.
regulators to impose conditions on these property rights that permit or encourage more efficient competition. These conditions fall into three categories, with three distinct aims:

- **To encourage investors to exploit economies of scale in new pipeline projects:** a requirement to hold “open seasons” which amalgamate demand for new capacity, as we discuss in detail in Chapter 3;

- **To promote efficient integration of pipelines into a network:** obligations on pipeline owners to provide “taps” (i.e. connections to other pipelines), so that anyone has the right to expand capacity between any two locations, as we discuss in detail in Chapter 4;

- **To promote efficient use of existing capacity (as an alternative to new investment):** rules on the unbundling of shipping from pipeline ownership, on cost-based pipeline tariffs, and on the tradability of capacity rights, as we discuss in detail in Chapter 5.

The UK’s offshore gas pipeline regime possesses some of the same features, but differs in important respects. The nature and effect of these differences between the two regimes are informative, and we build upon them when describing what kind of regime promotes efficient investment. Ultimately, though, the scope of regulatory rules and obligations depends on the importance accorded to the three aims listed above.

### 2.5.3. Summary

In summary, the EU ETS has a limited duration, and the UK Government values CO\textsubscript{2} abatement by renewable generation more highly than the EU ETS, so private investors in generation with CCS will not capture the full social benefit of CO\textsubscript{2} abatement. This market failure creates a rationale for the UK Government to intervene in promoting efficient investment in CCS technologies.

Economies of scale in the provision of pipelines do not provide a rationale for government intervention as (1) empirical evidence suggests the economies of scale in the provision of offshore pipelines are limited, and (2) pipeline investors in other sectors and jurisdictions have been able to form coalitions to exploit economies of scale. The benefits of exploiting economies of scale in CO\textsubscript{2} pipelines may also be offset by diseconomies of scale in other parts of electricity industry, such as the need for longer electricity or gas transmission lines. Arguments for government intervention to capture R&D spillovers do not relate to the construction of pipelines, which is an established technology.

### 2.6. Key Lessons

Given the nature of environmental policy, calls for government intervention often do not distinguish between different types of intervention, or specify precisely what problem the intervention is intended to overcome. Consideration of relevant case studies and the underlying economics provides the following key lessons:

- **Demand for pipelines is driven by demand for the commodity being transported:**
  - Whereas consumers have a demand for water and natural gas (and other services provided by utility networks) because they benefit directly from their consumption, the benefits of CO\textsubscript{2} sequestration accrue to the environment and hence to the population at large;
Because such environmental benefits are an “externality”, government action is required to help investors in CO\textsubscript{2} sequestration to capture (“internalise”) the benefits of their investment; they will then have a demand for CO\textsubscript{2} pipeline capacity;

- The environmental benefits of CO\textsubscript{2} abatement by CO\textsubscript{2} emitting installations have already been converted into financial benefits through the EU ETS and the market price for CO\textsubscript{2} emissions allowances; CCS can be brought within the same scheme;

- The UK government has set out tighter and longer term targets for CO\textsubscript{2} abatement than those contained in the EU ETS, which implies a higher shadow value for CO\textsubscript{2} abatement than emerges from the EU ETS; further action may be necessary to award additional benefits to CCS projects (see the ROC scheme applied to renewable generators);

§ If the UK government publishes all current policy commitments on CO\textsubscript{2} abatement:

- private investors will be as well placed as any government body to decide whether to invest in CO\textsubscript{2} pipelines; although:-

- The UK government may have to back up long-term policy commitments with explicit contracts, to make good the lack of any formal basis for forward markets in EUAs, ROCs, etc.

§ There are some economies of scale in gas pipeline construction, but it is not always efficient to build bigger pipelines:

- Economies of scale in pipelines are offset by diseconomies of scale in other parts of the CCS chain, especially if CO\textsubscript{2} sources and reservoirs are relatively widely dispersed;

- Building ahead of a demand that is rising slowly is not always more efficient than building to meet demand when it occurs;

- Uncertainty over the future costs and benefits of CCS – including genuine uncertainty over future government policy in this area – diminishes the efficiency advantage of creating spare capacity in advance of need;\textsuperscript{21}

§ Given a supportive regulatory regime, investors can club together to exploit economies of scale efficiently, even in a market-led system of competing projects;

- Investors have an incentive to form joint ventures and similar “coalitions” to amalgamate their demands for pipeline capacity;

- To prevent incumbent pipeline owners from exploiting any first mover advantage, regulatory rules may be required to promote efficient cooperation in project design (open seasons), in network integration (“taps”) and in use of existing capacity ( unbundling, tariffs, tradeability).

\textsuperscript{21} Although the government has announced requirements for new coal-fired power stations to fit CCS on part of their capacity, uncertainty still remains regarding any future subsidy (such as that offered to renewables) that CCS investors may receive in the future, pending the findings from the proposed demonstration projects. Also, the short duration of the EU ETS creates uncertainty for investors in respect of future government (or EU) policy.
The UK government may wish to bear in mind these lessons when commissioning CCS demonstration projects, to ensure that they contribute as far as possible to the future development of an efficient network.

In the following chapters, we describe in more detail the economics of CO₂ pipeline investments, and spell out in greater detail what kind of regulatory framework is likely to promote efficient development of a CO₂ pipeline network in the UK.
3. The Economics of CO₂ Pipeline Construction

In this section, we use a simple model to illustrate the decision faced by a pipeline developer regarding how much new capacity to provide through a CO₂ pipeline project. We assume that any problems with externalities have been addressed already. We then examine the conditions under which it is efficient to “oversize” a pipeline to meet the needs of future users by exploiting economies of scale. Non-technical readers may wish to jump to section 3.4, where we set out our conclusions.

3.1. Economies of Scale: A Simple Theoretical Model

Consider the example of an investor who is commissioning a CCS power station in the Thames Estuary, and wishes to transport captured CO₂ to the Leman field in the southern North Sea. Suppose there is no existing (or no spare) CO₂ pipeline capacity on that route, and so the developer must invest in a new pipeline. The investor’s generation project requires \( k \) units (tCO₂/day) of CO₂ transport capacity on the Thames-Leman route.

The investor is developing its plant and pipeline in period 1. Suppose he knows that:

- demand for CO₂ pipeline capacity along the Thames-Leman route may rise by a further \( k \) units in period 2 with probability \( p \), but will not grow at all in period 2 with probability \((1-p)\);
- the fixed cost of laying a new pipeline (irrespective of how much capacity that pipeline provides) is \( F \); and
- the variable cost of adding an extra inch of diameter to the pipeline is \( v \) per inch; but
- capacity is proportional to the square of the diameter, \( x \).

The presence of the fixed cost \((F)\) and the quadratic relationship between diameter (radius) and capacity means that the cost function exhibits economies of scale. The investor has the option of oversizing the pipeline compared to current needs by \( k \) units, in order to provide capacity for the potential future CCS developer in the area.

3.1.1. Defining efficient investment

The economically efficient investment decision in period 1 may be defined as building the capacity that minimises the expected costs of providing capacity across the route and over the two periods in question (in net present value terms). Using the results we derive in Section A.1 of Appendix A, we have found that providing an oversized pipeline (with capacity of \( 2k \)) minimises expected total cost as at period 1 if the following condition is met:

\[
\text{The cost of providing an oversized line in period 1 must be less than the cost of providing } k \text{ units of capacity in period 1, plus the expected discounted cost}
\]

22 The capacity of a pipeline is roughly proportional to the square (or higher power) of its radius. Hence, if the initial developer has the same need for pipeline capacity as the second comer (in tonnes of CO₂ per day, for example), the second comer’s incremental requirement for pipeline diameter (denoted \( x_2 \)) will be less than the initial developer’s requirement, and so \( x_1 \) would be greater than \( x_2 \).
of providing a further k units of capacity in period 2 if the second comer requires it.

This statement can be alternatively expressed as the following condition:

\[(\sqrt{2 - 1} \cdot v \cdot x < p \cdot (F + v \cdot x) / (1 + r) \]  

(1)

This condition means that, providing an oversized pipeline is economically efficient if (but only if) the incremental cost of oversizing a pipeline now (the expression on the left hand side) is less than the probability weighted cost of providing a new pipeline later (expression on the right hand side). This inequality can be rearranged to show that oversizing the initial pipeline minimises costs if:

- F, the fixed costs of investment (i.e. economies of scale) are high; and
- r, the discount rate is low\(^{23}\); and/or
- p, the probability of demand growing in period 2 is high.

This analysis illustrates that, where there are economies of scale in pipeline investments (i.e. if F is significant), oversizing pipelines can be – but need not be – an efficient investment strategy.

The analysis also means that it is less likely to be efficient to build oversized pipelines where the future demand for or location of CO\(_2\) transportation capacity is uncertain (p is low). Hence, if the developer of a CCS plant at a particular location does not know where later CCS developments will take place, or whether they will take place at all, it is efficient not build additional capacity above today’s needs.

The contrast between PB’s high and low CCS adoption scenarios highlights uncertainty over the timing and location of CCS developments.\(^{24}\) It would be efficient for any investor, private or public, to take account of these uncertainties when deciding how much CO\(_2\) pipeline capacity to provide along a particular route.

The equation above also shows that when demand for CO\(_2\) pipeline capacity is not expected to increase for several years, and so the compounded discount rate between periods (r) is high, providing an oversized pipeline would also be inefficient for either private investors or the government.

### 3.1.2. The costs of constructing CO\(_2\) pipelines

The analysis above considers the efficiency of oversizing CO\(_2\) pipelines to exploit economies of scale by accounting for the needs of future users. We found that providing capacity ahead

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\(^{23}\) Note that r is the cumulative discount rate between the first period and the second period, in which demand might turn up with probability p. It can in principle take any value and is determined by the following formula: \(r = (1 + a)^{-y}\), where a is the annualised discount rate (or the opportunity cost of capital) and y is the number of years after the initial investment when demand for access to the CO\(_2\) pipeline may materialise.

\(^{24}\) Options for Developing CCS Infrastructure: Task 1, Parsons Brinckerhoff Ltd, March 2009, Tables 3.7 and 3.8.
of need (providing \(2k\) units of capacity in period 1) is more likely to be efficient if \(F\) is high, i.e. where economies of scale are large.

We used information supplied by PB to examine the extent of economies of scale in the provision of CO\(_2\) pipelines, by estimating values of \(F\) and \(v\) implied by the costs of 30” and 36” pipelines for specific routes. The estimates shown in Table 3.1 imply that \(F\) constitutes around 80% of total costs for these routes, so that there are significant economies of scale in the construction of CO\(_2\) pipelines with diameters up to 36” (or at least in the range 30”-36”).

### Table 3.1

<table>
<thead>
<tr>
<th>Route</th>
<th>Diameter (inches)</th>
<th>Length (km)</th>
<th>Cost (£m)</th>
<th>Average Cost (£/km)</th>
<th>Estimated Fixed Costs Per Pipeline (£, F)</th>
<th>Estimated Variable Costs Per Unit of Diameter (£, v)</th>
<th>(F) (% of total costs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrow to Morecombe South</td>
<td>36</td>
<td>31</td>
<td>43.92</td>
<td>1,416,790</td>
<td>34,657,700</td>
<td>257,300</td>
<td>78.91%</td>
</tr>
<tr>
<td>Barrow to Morecombe South</td>
<td>30</td>
<td>31</td>
<td>42.38</td>
<td>1,366,990</td>
<td>34,657,700</td>
<td>257,300</td>
<td>81.78%</td>
</tr>
<tr>
<td>Barrow to Morecombe North</td>
<td>36</td>
<td>14</td>
<td>22.58</td>
<td>1,612,643</td>
<td>18,393,800</td>
<td>116,200</td>
<td>81.47%</td>
</tr>
<tr>
<td>Barrow to Morecombe North</td>
<td>30</td>
<td>14</td>
<td>21.88</td>
<td>1,562,843</td>
<td>18,393,800</td>
<td>116,200</td>
<td>84.07%</td>
</tr>
</tbody>
</table>

Source: NERA Analysis of data in PB report, Table 4.4.
Note: The data selected for this analysis uses PB’s examples of pipelines with different diameters but the same length.

PB assumes in its cost analysis that 36” is the maximum diameter pipeline. PB notes that, while larger pipeline sizes are available, laying larger pipelines offshore would “severely restrict the number of vessels capable of laying such a pipeline, and potentially cause logistical problems.” It may be the case that without these logistical difficulties “larger pipeline diameter would result in a decrease in [average] costs”, as PB states. PB also noted that the development of CCS would be spread out between (at least) the three main hubs and over the whole period of the study. The existence of these factors creates diseconomies of scale in the construction of larger pipelines, which means it may be more economic to construct a number of smaller pipelines along any given route.\(^25\)

#### 3.1.3. Calibrating the theoretical model

We have used the estimates of \(F\) and \(v\) in Table 3.1 to examine the efficiency of providing capacity ahead of need, compared to specifying a pipeline to match the needs of existing users. Figure 3.1 shows the costs of these two options for different levels of probability (\(p\)) using the cost model set out above, parameterised using the data in Table 3.1. The (i) (dark) solid black line and (ii) the three (lighter) pink lines in the figure are respectively calculated as:

\[
\begin{align*}
(i) \text{ Cost of building one large pipeline } &= F + \sqrt{2 \cdot v \cdot x} \\
(ii) \text{ Expected cost of building two small pipelines } &= F + v \cdot x + p \left[ F + v \cdot x \right] / (1+r)
\end{align*}
\]

The chart shows the expected cost of building two small pipelines for three different levels of \(r\), reflecting different assumptions about the number of years between period 1 and 2, and

\(^{25}\) Options for Developing CCS Infrastructure: Task 1, Parsons Brinckerhoff Ltd, March 2009, page 29.
hence different total discount rates between “period 1” and “period 2”. (The discount rate per year is 12% in every case. The cases cover delays of 5, 10 and 20 years.) The figure shows that, if demand is expected to grow within five years of the original investment, it is efficient to invest ahead of need at all levels of $p$ above 0.1, i.e. where there is at least a 10% chance of demand growing. If the expected delay increases to 10 years, the probability of additional demand must be at least 20%, whereas an expected delay of 20 years raises the necessary probability to almost 50%. If the probabilities are lower than these levels, investing ahead of demand is inefficient.

The high and low scenarios for CCS deployment shown in PB’s report show that the periods of delay between expected expansions along a particular route span many years.\textsuperscript{26} For instance, in PB’s high scenario the time between the first and second pipelines being constructed along the Barrow to Morecombe South route is 21 years. According to our analysis, it would not be efficient to oversize pipelines (even up to 36”) where there are such long periods between CCS plants coming online – unless there is a very high probability that they will do so. The necessary degree of certainty is not likely to prevail, in relation to possible investments 20 years in the future. The benefits of building pipelines larger than 36” diameter would be even smaller, if economics of scale diminish above that point, as PB implies.

\textbf{Figure 3.1}

\textit{The Efficiency of Oversizing CO$_2$ Pipelines (up to 36’’)}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.1.png}
\caption{The Efficiency of Oversizing CO$_2$ Pipelines (up to 36’’)}
\end{figure}

\textit{Source: NERA Analysis. Assumptions: (1) annual discount rate = 12%; (2) F and v are calculated for a 36” pipeline in Table 3.1; and (3) k = $\sqrt{36} / 2$.}

\textsuperscript{26} Options for Developing CCS Infrastructure: Task 1, Parsons Brinckerhoff Ltd, March 2009, Tables 3.7 and 3.8.
3.2. Incentives to Exploit Economies of Scale Efficiently

The analysis above demonstrates when it will be cost-minimising to invest ahead of need. However, private investors will care about the costs and revenue implications of a decision to provide capacity that is not yet required by users. In Appendix A we derive the following condition that shows how much revenue (denoted $R$) the initial developer must expect to receive in period 2 from second comers (if they materialise), in order to promote efficient investment:

$$ R = (F + v \cdot x) $$

This expression means that an investor will efficiently exploit economies of scale, if he can expect to recover the full new entrant cost of providing spare pipeline capacity, if and when it turns out to be needed in period 2. That is, the investor must capture the full benefit of exploiting economies of scale. Allowing the investor to capture the full benefit of economies of scale means that the second-comer will not benefit from the lower average cost. However, such a pricing rule would ensure the most efficient pattern of pipeline development.

An investor in a regulated pipeline must normally set its prices equal to its costs and will be unable to capture the full value of the economies of scale from investing ahead of demand. Decisions to build excess capacity would have to be driven by regulatory approval processes. However, a market-driven system with regulated pipeline tariffs and long-term contracts (like the US gas pipeline sector) can capture any benefits of investing ahead efficiently. In that system, the holders of pipeline capacity contracts (rather than the owners of the pipeline) pay the costs of the pipeline and can expect to receive the market price for selling any spare capacity that they order to be built. The role of long-term contracts is therefore crucial for the efficiency of market-driven systems.

3.2.1. Prices in a competitive market

In a competitive market with many buyers and sellers, prices settle around the marginal cost of the most expensive supplier required to meet demand. If capacity is limited, then in periods when capacity is short, the price may spike above the short-run marginal cost of adding capacity. Instead, prices reflect the marginal cost of curtailing demand. However, sustained capacity shortages that cause average prices to rise above the long-run marginal cost of new entry would attract new entrants to the market. Price spikes are therefore not sustainable (as long as there are no technical or logistical barriers that prohibit the construction of new capacity).

In the example outlined above, the initial developer can only choose between providing $k$ and $2k$ units of capacity in period 1. If demand for $2k$ units of capacity materialises by period 2, it will create a capacity shortage. In a competitive market, holders of pipeline capacity would then be able to sell capacity for any price up to the cost of new entry. As we have shown above, this result encourages the developer to exploit economies of scale efficiently.

In this example, the “second comper” would be indifferent between accessing the existing pipeline (at a cost of $R$) and building a new pipeline with capacity $x$ (at a cost of $F + v \cdot x$). In practice, this condition could never be met with equality. The best the initial developer can hope for is that the second comer would be willing to pay fractionally less than the new
entrant cost \((F + v' x - \varepsilon, \text{ where } \varepsilon \text{ is an arbitrarily small number})\). However, the loss of efficiency from this compromise would be small and is unlikely to explain any perception that pipeline investors do not invest ahead of demand. More likely, the tendency of investors to avoid speculative investment in spare capacity is driven by the delay before demand will materialise \((r)\) and the risk that it will not \((1-p)\).

### 3.2.2. Negotiated access to pipeline capacity

Any market for CCS transport capacity might involve only a small number of participants (at least initially). Therefore once a pipeline is built, there may not be a liquid market for trading capacity. Instead, the owner will have to negotiate capacity charges with the second comer who wishes to access the pipeline. The outcome of this negotiation will depend on the “outside options” of the parties.

- The second-comer’s outside options are (1) to build a new pipeline from scratch at a cost of \(F + v' x\), (2) to build its CCS plant elsewhere and use someone else’s pipeline, (3) to use another method of CO\(_2\) transportation such as tanker ships, or (4) not to develop a CCS plant at all.

- Given that its capacity costs are sunk, the pipeline owner’s outside options are either (1) to recover no revenue for the use of \(k\) units of capacity, or (2) to sell the capacity to someone else.

The more expensive the outside options of the second comer, the more likely that the negotiations will result in charges that are close to the new entrant cost of a CO\(_2\) pipeline \((F + v' x - \varepsilon)\) and vice versa.

### 3.2.3. Resolution of access disputes

Some regulatory frameworks allow for arbitration by a regulatory authority in cases of disputes over the terms of access to existing pipelines. The Secretary of State can intervene in disputes regarding offshore oil and gas networks in the UK if requested by a prospective investor in a new pipeline (see Appendix D section D.2 and Volume 2.). In such circumstances the Secretary of State would set access charges equal to the incremental cost of capacity.\(^{27}\) Such a rule can theoretically create difficulties for pipeline investors in some circumstances (see below), but our analysis suggests it would certainly be inefficient to extend such a rule to cover disputes over access to existing pipelines. If an investor builds capacity ahead of need, a regulated tariff based on the incremental cost of capacity would allow the pipeline operator to recover only the following amount:

\[
R = (\sqrt{2} - 1) v' x
\]

This amount is below the level required for efficient investment (condition 2).

An alternative system would be to use an average cost pricing rule in case of disputes. However, depending on the parameters in our model \((F, v' \text{ and } r)\) this rule may also produce tariffs that are below the new entrant cost, which would also incentivise too little investment.

\(^{27}\) Petroleum Act 1998, section 15, clause (7).
compared to the efficient level. An alternative approach is to facilitate competitive trading of capacity, rather than imposing a price for such trades, and the US authorities have adopted this approach for interstate gas pipelines. (See Appendix D section D.4 and Volume 2.)

3.2.4. Regulation of investment decisions

As we describe in more detail in Appendix B, an alternative to allowing the competitive provision of pipelines would be to appoint a regulated monopolist to construct CO\(_2\) pipelines on a centrally planned basis. This would require an economic regulator to approve the revenues needed to recover the cost of capital investments, either ex ante or ex post. In this context, the monopolist’s incentives to exploit economies of scale depend on the structure and parameters of regulatory incentives. The efficiency of the outcome is then highly sensitive to the administrative procedures of and decisions by the regulator.

Experience from the regulation of UK gas and electricity networks shows that regulated companies have been reluctant to invest in return for low regulated rates of return when the demand for capacity is uncertain. Regulated companies are exposed to this demand risk whenever regulators have the ability and incentive to “disallow” capital expenditure ex post, especially if they are more likely to do when assets are “stranded”. To overcome this problem, regulators would have to engage in the regulated company’s process of identifying and designing the investment. The regulator could then ensure that the company’s process took economies of scale into account, where appropriate, and the company could be (more) certain that the regulator would allow cost recovery, regardless of the actual development of demand.

3.3. Asymmetric Information

Our discussion of economies of scale shows that investing in spare pipeline capacity ahead of need is efficient if there is a high probability that demand for CO\(_2\) transport capacity will grow in the future. However, this analysis assumed that investors were fully informed about the probability of demand for CO\(_2\) transport capacity growing along a given route. In reality, different investors have different information about future growth in CCS and its timing.

Suppose there is a probability \(p\) (as above) that demand for CO\(_2\) transport capacity will increase at some stage in the future (called period 2 in the above). Investors may receive different signals about this probability, i.e. they may observe or estimate the probability \(p\) with an error. In this case, individual investors may choose to provide more or less capacity, depending on their perceptions of \(p\). If no-one knows what the true probability is, however, no more efficient outcome is possible.
3.3.1. The case for centrally planning CO\(_2\) pipeline investments

To overcome uncertainty about future demand growth, the government might decide to take over central planning of the network and to dictate how much CO\(_2\) transport capacity can be built, where it can be built and when. However, this policy will only improve efficiency, if either (1) the government is best informed about the true value of \(p\), or (2) the government knows who is best informed about the true value of \(p\) and appoints them to plan the network. These conditions hold only if the government or some other party has better information about the value of CO\(_2\) transport capacity than is publicly available.

This better information may relate to one of the following factors that affect the value of CO\(_2\) transport capacity along a particular route:

1. Changes in the costs of CCS plant and equipment compared to other CO\(_2\) abatement technologies;
2. The availability and location of CO\(_2\) storage sites;
3. The evolution of international commodity prices;
4. Developments in the electricity and gas markets, such as changes in the structure of transmission charges; and
5. The value of government/EU subsidies offered to CCS and to other CO\(_2\) abatement technologies.

In practice, there is little or no reason to think that a government is better informed about the evolution of the cost of different technologies than any private investor. Likewise, the availability of storage sites depends on the speed at which oil and gas fields deplete, and the suitability of those fields for storage. That information is best known by the fields’ owners, despite several attempts to survey the potential for CCS.

The UK Government also has no better information than traders about the likely evolution of international commodity prices, which affect the competitiveness of CCS compared to other low carbon technologies like nuclear or renewables. Developments in the gas and electricity market are usually public information.

The only area where the UK Government is likely to have better information is point 5, the future value of government policy support for CCS. As we explained in section 2.3, the UK Government may be able to make such information public, or by offering a long-term financial commitment or merely by publishing all known policy commitments. However, where there is genuine uncertainty over the level of future support, because the government itself has not reached a decision, there is no information advantage to be gained by public sector investment.

There is therefore very little information that would tilt the advantage in favour of public investment over private investment.
3.4. Conclusion

In this section we have described the conditions under which it is efficient to invest in CO\textsubscript{2} pipeline capacity ahead of immediate requirements, to accommodate the expected needs of future CCS generators. There are economies of scale in the construction of offshore CO\textsubscript{2} pipelines of diameter up to 36”; PB has noted diseconomies of scale in the construction of pipelines with a diameter above that level. We found that it would be efficient to exploit economies of scale by building pipelines ahead of demand, if demand growth was likely within a few years.

We also found that in theory that a competitive market would ensure efficient exploitation of economies of scale, provided that the owners of pipeline capacity (i.e. holders of capacity contracts) could sell capacity at the new entrant price. (Our analysis assumes that new entrants could build only what was needed to alleviate a constraint – e.g. a loop – and did not have to substitute for capacity along the entire route.) Some regulation of the terms on which pipelines sell their capacity may be needed to ensure such efficient outcomes.

On the other hand, imposing defined pricing rules on spare capacity appears to be unlikely to enhance efficiency. Since any price based on the costs of providing existing pipeline capacity is unlikely to match the cost of a new entrant, investors anticipating such rules are unlikely to choose the efficient size of project. Similarly, investments made by regulated monopolies may be distorted in other ways by the risks inherent in regulatory approval of investment.

The inability of private investors to observe accurately the future value of CO\textsubscript{2} transport capacity may cause them to hold back from investing in pipeline capacity. If the UK Government has a better idea about that value, it may have to provide a long-term financial commitment to back up its statements. However, if that future value is not yet certain, because future policy remains undecided, there is no reason to think that government is significantly better informed about the value of future investment than any private investor. In this case, central planning of CO\textsubscript{2} network investments and government direction of investment by the private sector are unlikely to improve the efficiency of CO\textsubscript{2} pipeline investments compared to more “market driven” systems.
4. Promoting Efficient Investment

In Chapters 2 and 3 we discuss the economics of externalities and incentives to construct CO₂ pipelines. We found that the presence of externalities creates a role for government to promote economically efficient levels of investment in CCS and CO₂ pipelines by assigning property rights to create markets for certain benefits. We also found that such interventions can permit efficient exploitation of economies of scale. For instance, our review of international precedents shows that investors in gas and oil pipelines can club together to exploit economies of scale efficiently, even in a market-led system of competing projects. Given a demand for investment, investors have an incentive to minimise costs, by forming joint ventures and similar “coalitions” to amalgamate their demands.

The regulatory framework for offshore oil and gas pipelines in the UK provides an important example where pipeline developers collaborate to construct pipelines that meet the needs of multiple users. It therefore provides a useful starting point for considering a regulatory regime for CO₂ pipelines in the UK. However, certain features of the offshore (‘upstream’) oil and gas regime might discourage investment in CO₂ pipelines and would need to be amended in any new regulatory regime for CCS.

In this chapter, we will summarise briefly potential problems with the regulatory regime for offshore oil and gas pipelines, and describe how the system can be improved for use in regulating a CO₂ pipeline network. In doing so we draw on lessons from various other regulatory frameworks for gas pipelines, where such problems have also had to be addressed. Specifically, this chapter covers the definition of capacity (i.e. point-to-point vs. entry-exit), rules to ensure coordination between prospective pipeline investors to ensure they efficiently exploit economies of scale, and the use of planning regulations to ensure efficient investment.

4.1. Potential Problems with Adopting the Offshore Oil and Gas Regime

The UK’s offshore oil and gas transportation infrastructure is constructed in conjunction with the development of oil and gas fields. Construction is decentralised, but is subject to certain regulatory requirements.

At two stages in the process, the Secretary of State has the power to require existing pipeline operators to offer access to third parties. When field developers submit plans to develop infrastructure, the government has powers to compel developers to accommodate the expected demands of future customers, and the law obliges developers to let others join the project at incremental cost.²⁸ Also, the Secretary of State can be asked to impose terms for access to existing pipelines.²⁹ The Secretary of State has never made such a determination, but from recent guidelines issued by DECC it appears that the pipeline owners would be obliged, at least in some circumstances, to accommodate later entrants at incremental cost.³⁰

³⁰ https://www.og.berr.gov.uk/upstream/infrastructure/TPA_Guide.pdf. Section 12.1(2) says that charges for using existing pipeline capacity should “take into account any realistic impact of prospective new business on their system”. We are not able to say whether this phrase means the impact on (incremental) costs of the pipeline, or the impact on the business of existing pipeline users, including any loss of value due to their giving up valuable capacity.
These requirements appear to have been designed to promote efficient construction and use of the pipelines. However, at least from a theoretical perspective, the UK offshore regime raises concerns about the efficiency of investment.

The requirement to accommodate other users at incremental cost creates a potential source of inefficiency in the offshore oil and gas regime. Due to economies of scale, the incremental cost of adding capacity is lower than the average costs of the original capacity incurred by the pipeline developer. Hence, the obligation to let third parties pay the incremental cost of capacity provides an incentive to be a “late comer” in developing oil and gas pipelines, and to avoid being the first mover in some cases. This incentive leads to the theoretical concern that some offshore investments may be held back unnecessarily. The problem is particularly acute where the fixed costs of a project (in our example, $F$) represent a particularly large share of total costs, and the benefits per unit of capacity are particularly small (as in the case of marginal fields). A negotiated settlement with an equal sharing of $F$ may permit each user to develop its field. However, if a subset of users chooses to enter the project at incremental cost $(v)$ by applying to the Secretary of State, the original proposers will have to bear all of $F$. On that basis, the original proposers may find the project is economically unviable and hence withdraw it (or not propose it in the first place).

It is not possible to prove, one way or another, whether the UK regime has deterred investment in practice because deterred investment by its nature is not observable. Neither can we draw any inference from the fact that the Secretary of State has never used powers of determination or oversizing, since the threat of intervention would be sufficient to discourage project developers. Nonetheless, the particular characteristics of the offshore regime suggest at least the potential for inefficient underinvestment in a network in some conditions.

Furthermore, any access rights granted by the Secretary of State are not tradable, and so do not provide the recipient with the full value of the capacity. Fortunately, participants in the offshore industry (working in conjunction with the UK Government) have developed an alternative code for negotiating access on existing pipelines which allows the negotiating parties to agree that the capacity will be tradeable. The emergence of such a code indicates there are gaps in the formal regime, such that investors see unexploited potential for increasing efficiency if they collaborate on additional or alternative rules.

4.2. Point-to-Point Capacity

The regulatory regime for offshore oil and gas infrastructure does not require operators to offer capacity by any particular method, for example entry-exit capacity or point-to-point capacity. However, we understand that most operators have defined access to pipelines on a point-to-point basis. In regulating the US interstate gas pipelines, FERC has also adopted a point-to-point method of defining capacity as part of the standard terms that any pipeline must offer.

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31 Petroleum Act 1998, section 17(9).
4.2.1. Entry-exit vs point-to-point capacity

Figure 4.1 below compares an entry-exit system with point-to-point pipeline capacity. Under an entry-exit system, entry capacity gives the holder a right to flow gas at a certain rate between an entry point and a “virtual” (i.e. imaginary) trading hub such as the National Balancing Point (NBP) in the UK, and exit capacity gives the holder the right to flow gas from the virtual trading hub to a particular exit point. Hence, in an entry-exit system, a shipper wishing to flow gas from entry point 1 to exit point 1 would need to acquire entry and exit capacity at both these points. Charges for entry-exit capacity in the UK tend to reflect the system operator’s estimate of the marginal cost of accommodating additional injections at each point (based on an assumption about the pattern of flows), plus a mark-up intended to ensure recovery of total allowed revenues (although some charges are now set by auctions).

In contrast, to flow gas along the same route under a point-to-point system, shippers would book capacity on the pipelines between points A and B, points B and C, and from point C to the customer’s premises. In the US (at least), contract prices in a point-to-point system are derived from the accounting costs attributable to each stretch of pipeline; short-term trades take place at unregulated market prices.

In an entry-exit system, the system operator must decide where to add capacity in response to requests to inject or withdraw gas at particular points. In the US gas pipeline system, the system operator is not responsible for making such decisions. Instead, the users themselves commission investment in pipeline capacity, in return for a long-term contract for capacity, between specified points. The charge for this capacity would reflect the actual incremental cost of adding that piece of capacity. This transparency of tariffs allows a shipper wishing to move gas from point A to C to make a trade-off between:

- Purchasing capacity on existing pipelines between points A and C (if available);
The ability of any shipper to choose between all these options on the basis of the costs that each option entails leads to the creation of a truly competitive market in the construction of gas transportation capacity. It is also essential for promoting efficient investment on pipeline networks, as experience of the British gas transmission network illustrates.

4.2.2. Entry-exit on the British gas transmission network

Capacity on the British gas transmission network is offered to users as either entry capacity (from an entry point to the NBP) or exit capacity (from the NBP to an exit point). This method of defining capacity is unrelated to the underlying physical characteristics of the network, but instead reflects judgements about the level and allocation of capacity. These judgements have created pressure for the system to evolve and have resulted in several disputes over the mechanisms used to define the amount of available capacity, to allocate capacity between users and to charge for capacity.

Figure 4.1 exposes at least two problems with the entry-exit system: (1) where to draw the boundary between entry capacity and exit capacity within the part of the network linking B with C; and (2) how to allocate pipeline capacity from B to C between the two entry points (and/or the two exit points), if it is constrained. Both decisions require essentially arbitrary decisions. More complex networks require decisions that are more complex, but just as arbitrary.

Regulators have adopted the entry-exit system in Europe in order to increase retail market competition, by facilitating wholesale trades in gas. All gas entering the network passes through one virtual trading point and can be traded at a common price. New entrant retailers can meet their needs by buying gas from any new entrant supplier with gas at any place in the network and they do not have to deal with the incumbent (ex-)monopoly. However, in practice, many such gas trades are fictitious. In a complex network, a gas retailer may buy gas that cannot actually be delivered to its customers; the system operator must then arrange a gas swap behind the scenes, in which the retailer gives up its gas to another retailer, in return for some gas that can be delivered to its customers. In many European countries (including Britain when the entry-exit system was introduced), the system operator is part of the ex-monopoly gas company. Entry-exit systems therefore impose an obligation on the ex-monopoly to facilitate retail competition (at a cost of distorting wholesale competition). However, CO₂ networks are not (yet) under any monopoly provider, so this aspect of entry-exit systems is not needed.

On the other hand, entry-exit systems have explicit disadvantages for the efficiency of investment in a pipeline network. The mis-match between entry-exit capacity and the physical network prevents the development of competition in the provision of pipelines. If
there is a constraint within the network (say between B and C in Figure 4.1), users of the network cannot identify its precise location from the definition of entry and exit capacity. They cannot commission additional pipelines to be built in order to circumvent the constraint. Even if they can identify the physical location of the constraint, the entry-exit tariff system does not indicate what costs they would avoid by building a new pipeline around it, making objective appraisal of the project very difficult. The incumbent network operator therefore has a major advantage in identifying and appraising potential pipeline investments and the entry-exit system tends to entrench the monopoly position of any existing network owner. It relies on that network owner to plan virtually all major network investments, subject to detailed regulatory oversight. However, CO$_2$ networks are not yet a monopoly and it is possible to retain the benefits of competition by adopting a different framework.

### 4.2.3. Entry-exit on the German gas network

In recent years, the German regulatory authorities have obliged the owners of gas pipelines in Germany to switch away from selling their capacity through long-term point-to-point contracts, and to adopt instead entry-exit tariff systems covering one or more pipelines. The reason for adopting this policy was the same as in the UK: point-to-point contracts were seen as obstructive because (a) regulators felt that competition was limited when the incumbent, vertically integrated operator held all or most of the capacity in any one area and (b) the contracts offered to independent traders did not permit flexible use of the capacity. Entry-exit systems were regarded as a solution to these problems, because it allowed new entrants to transport and to trade gas without having to involve the incumbent as a trading partner. However, it came at the cost of (effectively) abandoning competition in pipeline construction and centralising investment decisions.

### 4.2.4. Lessons for a CO$_2$ network

Adopting a point-to-point approach has many advantages for the decentralisation of investment, since it enables charges to be linked to costs. It helps to prevent the kinds of disputes over capacity definition and allocation that have arisen on the British gas transmission network. Most existing offshore oil and gas pipeline operators define capacity on a point-to-point basis, although it is not compulsory under the existing rules. It may be desirable to enshrine the requirement for this type of capacity contract within the regulatory framework for CO$_2$ pipelines.

Regulatory concerns about the flexibility of long-term contracts arise whenever there is some economic gain to be had from reallocating capacity over the life of a pipeline. Entry-exit provides one possible solution to these concerns, but undermines competition in pipeline construction. There are other ways to resolve these concerns and we discuss the solutions in later chapters.

### 4.3. Open Seasons

As described in Chapters 2 and 3, private investors in pipelines have incentives to exploit economies of scale to lower their average costs. To do this, investors can form coalitions to pool their needs for pipeline capacity. Both the UK offshore oil and gas regime and the regime for US interstate pipelines ensure that investors take such actions, by requiring pipeline developers to “market test” the demand for new capacity.
The offshore oil and gas regime involves the unilateral development of infrastructure by North Sea producers. The regime then allows third parties to request additional capacity on other developers’ pipeline projects at incremental cost. This scheme favours “late comers” and acts (at least theoretically) as a disincentive to project development. The procedures for obtaining regulatory approval for US interstate gas pipelines also impose an obligation to hold open seasons, but work differently and do not create the same incentives to be a “late comer”. It may therefore be useful to adopt different rules, in the light of this experience, to improve incentives to construct CO₂ pipelines.

4.3.1. FERC procedures for approving pipeline investments

Under the 1938 Natural Gas Act, pipeline developers have to obtain a “certificate of public convenience and necessity” from the Federal Energy Regulatory Commission (FERC) that allows them to construct pipelines, as well as to comply with several environmental laws.

In the past, pipeline developers would compete to build interstate pipelines in exchange for regulated tariffs. This system was highly bureaucratic, but is now much more straightforward. The simplification occurred through the creation of a market for tradable capacity rights on pipelines.

Under this system, shippers that fund the cost of increasing pipeline capacity receive a long-term capacity contract giving them an inalienable and tradable property right to access that capacity. Shippers therefore bear the demand risk associated with pipeline developments, and so will only fund investments when they are convinced that the capacity they create is required. Pipeline developers can meet the “public convenience and necessity” standard simply by demonstrating that the users of new capacity are prepared to pay its incremental costs. (Existing users do not subsidise expansion projects because, since 2000, FERC has adopted “incremental pricing” as the basis for capacity expansion projects.) FERC essentially “rubber stamps” new capacity projects that clear the necessary environmental hurdles, where the pipeline developer has sold capacity contracts in advance of construction.

In some cases, FERC may approve new capacity even when users have not signed up to pay for all the capacity provided through the investment, although pipeline developers still need to obtain finance for any capacity that is not sold upfront. In practice, pipeline operators are rarely willing to accept the risk that anyone will buy spare capacity provided by a pipeline in the future in a competitive capacity market. Most projects are ultimately sized according to the current demands of shippers. However, the shippers may be planning ahead for their future capacity requirements, when they commission new pipeline capacity. As we explain in Chapter 3, the unwillingness of pipeline developers to take on demand risk is not necessarily a sign of inefficiency, if there is little chance of extra capacity (above what shippers have planned for) being required on the route in question, or if demand is not expected to rise for a number of years.

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4.3.2. Requirements to hold open seasons

The regulatory process for approving new pipeline investments in the US is now relatively straightforward because pipeline developers have to follow some well-defined procedures. The process for developing a new interstate gas pipeline (or an expansion of an existing pipeline) regulated by FERC breaks down into four steps, as shown in Figure 4.2 below:

- Determining demand/market interest;
- Publicly announcing the project;
- Obtaining regulatory approval; and
- Construction and testing.

**Figure 4.2**
FERC’s Pipeline Development and Expansion Process

The first step in this procedure contains a requirement for prospective pipeline developers to hold open seasons, in order to gauge the level of demand for capacity along the proposed route. In an open season, the developer makes it possible for anyone to apply to join the project. Open seasons act as a regulatory assurance that private investors will coordinate to provide an efficient level of capacity through new investment, and that no pipeline developer is unduly excluding any other player.

In the second step of a FERC-mandated open season procedure, shippers enter into nonbinding agreements to purchase capacity rights provided by the proposed investment. If shippers show enough interest during the open season, the project proceeds to the next stage of examining options for creating additional capacity. These options may include building a
new pipeline, converting an oil or product pipeline into a natural gas pipeline, building a “loop” to flow gas around a constraint, or installing extra compressors.

Then, in the third step, developers obtain financial commitments from shippers and file the proposals with FERC to publicise the project and to gain regulatory approval.\textsuperscript{33} Even at this stage, others may offer to join the project.

Finally, once FERC has approved the project and its proposed method of charging, the developer goes ahead with the project and awards long-term\textsuperscript{34} contracts for capacity to each participating shipper.

The allocation of costs and capacity between shippers who express an interest is unregulated. The pipeline developer generally allocates capacity contracts between shippers, so as to maximize the Net Present Value (NPV) of the pipeline project. However, there is no explicit regulatory requirement for them to do so. Economic incentives have led developers typically to rank bids by the NPV they provide to the company. They assess the NPV using discounted cash flow analysis of shippers’ bids to assess the overall value of the bid, taking into account its term, distance of transport, date of commencement of service, and the projected load factor. Any customer who bids more than incremental cost will add to the project’s NPV. Altogether, the total NPV of the project must be positive. If there is any shortage of capacity which cannot be addressed by increasing the size of the project, developers allocate capacity first to high value customers, such as customers requesting a lot of capacity for a long period of time.

The use of open season procedures for new pipeline capacity projects means that shippers have a chance to express demands for capacity at the same time. This typically means that each shipper that purchases capacity in a new project ends up paying the average cost of providing it, rather than the incremental cost. Occasionally, negotiations between shippers can result in some paying a tariff that lies above or below average cost, but in practice such arrangements are rare. When all shippers pay the same average cost-based tariff for the capacity they purchase (or some other negotiated allocation of costs), there is no disadvantage to “first movers” in pipeline projects. This removes the incentive to delay developments that may arise from the rules governing the UK offshore pipeline system.

\subsection*{4.3.3. Application to CO\textsubscript{2} pipelines}

Under the existing regulatory regime for offshore oil and gas pipelines, the Secretary of State can require project developers to provide extra capacity to accommodate the (actual or anticipated) needs of additional users.\textsuperscript{35} Such an obligation may have been intended to force the exploitation of economies of scale. However, investors can (we believe) exploit economies of scale where it is efficient to do so, by collaborating voluntarily. Requiring them to invest in additional capacity would discourage investment in cases where the

\textsuperscript{33} Energy Information Administration Website, visited on 25 February 2009. URL: http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/develop.html

\textsuperscript{34} Many contracts offer capacity rights for a fixed period, e.g. 25 or 30 years, with an option at the end of that period to renew the contract for the same period again, at the agreed tariff.

\textsuperscript{35} That power seems to us, at least, to be implicit in the power of the Secretary of State to define the capacity of a new pipeline under the Petroleum Act 1998, section 15 (3).
developer would not choose to add capacity voluntarily. Because of economies of scale in CO₂ pipelines (up to 36” in diameter), project developers will have strong incentives to market their projects as widely as possible to minimise their average costs. If developers have an obligation to run an open season, they will not be able to exclude any willing investors. This requirement to provide extra capacity therefore seems to be unnecessary.

The open season process for UK offshore pipelines also allows shippers to request capacity at incremental cost. This provision also seems to be unnecessary (it has never been invoked, so far as we are aware) but it has the potential, in some circumstances, to discourage project development. In practice, this problem is solved in the UK by all shippers agreeing to act collaboratively to prevent free-riding (which may be one purpose of the joint government-industry code). However, there seems to be no reason to introduce such a rule for CO₂ pipelines, as long as investors are competing to provide capacity at least cost.

The US regulatory system imposes no such obligation on the allocation of costs within a project. Instead, it only states that new projects may not be cross-subsidised by users of existing capacity. The participants in any project are therefore free to arrange any allocation of costs, which in practice usually means that they share costs in proportion to the capacity they are commissioning.\textsuperscript{36}

The Secretary of State’s power to set the charges levied by project developers would be replaced by the right of those bidding for capacity to complain (possibly to the Secretary of State, but perhaps to a court) if the developers did not carry out the open season in a transparent and non-discriminatory manner. In practice, developers would wish to accommodate any participant who met all the prequalification criteria (creditworthiness, etc) and who was prepared to pay at least enough to cover the incremental costs of the requested capacity. (See section 4.3.2.)

To test the demand for additional capacity, the government might consider holding open seasons for the CO₂ transport capacity provided as part of the CCS demonstration project(s) it decides to sponsor. This would ensure that prospective future developers of CCS plant have an opportunity to request additional transport capacity to exploit economies of scale.

4.4. Planning Regulations

Any CO₂ pipeline sector will require planning procedures for onshore pipelines (which are not part of the UK’s offshore pipeline framework).

In the UK, developers of large energy infrastructure, such as power transmission lines or wind turbines have often experienced delays in obtaining planning permission. In response, the government introduced a new planning system for nationally significant infrastructure (in the energy and other sectors) through the Planning Act 2008.

The Act established an Infrastructure Planning Commission (IPC) as the new authority granting development consent for nationally significant infrastructure projects, and provided

\textsuperscript{36} In principle, the project developer may want to offer a discount to a “low value” user who is willing to pay less than average cost but more than incremental cost. Such discounts would allow a more efficient exploitation of economies of scale. However, in practice, most users are so similar that such differences in willingness to pay do not often arise.
for the government to produce National Policy Statements (NPSs) to be used as the policy framework for the Commission’s decisions. These new institutions will allow planning procedures to account for the national case for developing infrastructure, as well as any costs to the communities situated near proposed developments. The planning white paper envisaged that a NPS on energy would cover “projects necessary to the operational effectiveness, reliability and resilience of the electricity transmission and distribution network.”

The government may need to publish a NPS covering CCS to promote the efficient development of onshore CO₂ pipelines, if the projects are not to be delayed. Without facilitating planning procedures, developers may favour offshore pipelines, even though they are more expensive to construct.

4.5. Summary and Conclusion

In this chapter, we have described some key improvements to the existing offshore oil and gas regulatory framework that could be applied to the regulation of CO₂ pipeline construction. The aim of the resulting framework would be to permit or even encourage efficient competition for the right to build new pipelines.

Although most existing offshore oil and gas pipeline operators define capacity on a point-to-point basis, it is not compulsory under the regulatory rules. It may be desirable to enshrine this requirement within the regulatory framework for CO₂ pipelines. In the first instance, such rules would reduce the potential for disputes over capacity allocation and charges. They would also permit a rule that tied pipeline charges to the costs of the expansion (incremental cost pricing of the project as a whole), which will encourage efficient investment. However, the purpose of standardising contract terms in this way will become clearer, when we discuss below the provisions for encouraging more efficient use and trading of capacity.

The requirement that new developers hold open seasons would avoid any potential for non-competitive foreclosure of users from investment projects and so would promote efficient project sizing. However, it would not be advantageous to dictate cost allocation rules, particularly one suggesting that late comers should be able to pay only incremental costs of additional capacity within a project.

Finally, to promote efficient choices between building onshore and offshore pipelines, the government may need to incorporate CO₂ pipelines into its existing policies on planning used for other kinds of energy sector infrastructure.

37 Communities and Local Government website, visited on 19 March 2009: http://www.communities.gov.uk/planningandbuilding/planning/planningpolicyimplementation/reformplanningsystem/planningbill/

5. **Promoting Efficiently Integrated Networks**

The previous chapter explored the possibility of private investors coming together to fund efficiently sized pipelines for transporting \( \text{CO}_2 \) from A to B. Some studies of possible future CCS systems suggest that only such point-to-point pipelines will be required. However, some of the calls for government intervention and/or monopoly provision are driven by a concern for efficient integration of pipeline investments into a “network”.

The need for a network is not immediately apparent in the gas sector, since gas flows from specified sources to specified destinations. (In the electricity and telecommunications sectors, there is no such link between sources and destinations, so a network is required to provide suitable flexibility for load flows to shift.) However, gas pipelines do frequently encounter conditions in which it is efficient to link one pipeline to another, particularly when it is necessary to reinforce capacity over a particular section of pipeline. When these conditions arise, it is important that anyone should be able to build the pipeline reinforcement, regardless of who owns the existing pipeline, in order to maintain the potential for competition in pipeline construction. Such a rule enables efficient integration between pipelines.

In the case of US interstate gas pipelines, this objective is supported by a FERC-mandated obligation on any pipeline to provide a connection (a “tap”) to any other pipeline.

5.1. **Obligation to Provide Taps on US Interstate Gas Pipelines**

Several years of FERC Orders and legal precedents in the US have established a precedent that interstate pipeline operators are obliged to provide connections to other pipelines, known as “taps”, on request. The obligation on pipeline companies is a crucial element in the regulatory framework for US interstate gas pipelines as it prevents vertical foreclosure by operators seeking to prevent new entrants from competing in the provision of pipelines.\(^{39}\)

5.1.1. **Economic effects of obligation to provide taps**

The requirement on incumbents to provide taps means that any investor can alleviate transmission constraints by investing in pipeline capacity *anywhere within the network*. For instance, suppose a pipeline connects points A, B, C and D. Users of the pipeline may note that their usage is constrained by the amount of capacity available between B and C. (See Figure 5.1 below.) Alternatively, the market for capacity (see Section 6.3) may indicate a high price for capacity from B to C, but low prices for the other sections (A to B and C to D). Any investor can respond to these signals by building a parallel pipeline (a “loop”) from B to C, and can expect to be able to tap into the existing pipeline at these points. By this method, the market coordinates competing investors so that they invest in capacity where it is needed. Individual investments contribute to the creation of a truly integrated network.

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\(^{39}\) The obligation to provide taps is slightly different to the EU Third Party Access rules. EU TPA regulations are designed to prevent incumbent monopolists from vertically foreclosing up- and downstream gas and electricity markets, whereas the obligation to provide taps prevents incumbent pipeline operators from exercising vertical foreclosure in the provision of pipelines as well.
This obligation to provide taps does not require the incumbent operator to transport the gas of the connecting pipeline company. To transport gas along an existing pipeline, a shipper must hold transport capacity on that pipeline. This system is therefore unlike the Third Party Access requirements set out in the EU gas directive, which require network operators to accept a connection and to transport the gas of third party shippers (see our case study on British onshore gas networks). Such rules pose a risk to investors in gas market infrastructure in the EU, as it weakens their right to use the capacity enhancements that they sponsor. The obligation to provide taps does not undermine investment incentives in the same way, as the presence of taps does not affect incumbent shippers’ ability to access the pipeline capacity they own.

Note that the desire to prevent incumbents from withholding spare capacity does not make it necessary to oblige incumbent pipeline operators to offer transport capacity to users that request taps. Firstly, all pipeline developers have incentives to share their pipelines if economies of scale mean that they can obtain a lower average cost by doing so. Secondly, in the case of a new pipeline, withholding spare capacity is unlikely, since it is unprofitable. A pipeline operator would have to build more capacity than it wanted, without any expectation of recouping the incremental investment cost. Finally, rules that require the separation of pipeline ownership/operation from the shipping of CO\textsubscript{2} and rules on the transparency of information (see Sections 6.1 and 6.3) would remove the incentive for, and ability of, operators to restrict access to pipeline capacity.

FERC does not impose any special obligations on parties requesting taps, e.g. to demonstrate market demand for the tap (as long as the proposed investment meets the normal criteria for approval of a pipeline). However, FERC does prohibit incumbent pipeline companies from changing significantly the proposed location of taps requested by third parties. This rule prevents incumbents from using disputes over the location of taps to stall requests for interconnection.

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40 Interestingly, a similar third party access obligation applies to oil pipelines in the United States. The result has been the formation of large, multi-company joint ventures intended to prevent free-riding, much like the outcome in the UK’s offshore pipelines.

5.1.2. Application to CO$_2$ pipelines

The offshore oil and gas network in the UK is made up of pipelines running from disparate production fields to onshore terminals. Hence, there are relatively few points of interconnection. However, in the case of CO$_2$ pipelines, the requirement to provide taps would be important if there is an advantage in bringing disparate sources of CO$_2$ to major reservoirs via a small number of major corridors. PB’s analysis of likely future developments seemed to suggest just such a pattern of investment. Although the forecast of investment envisaged mostly investment in pipelines over the whole length of the route, actual investors might find many ways to build upon the previous investment of others, if taps were permitted.

Thus, if the CO$_2$ network emerges with the same physical structure as the existing offshore pipeline network, the benefits of regulating interconnection via taps may be limited. However, uncertainty over the eventual shape of a CO$_2$ network makes it prudent to include such a provision within the regulatory framework.

5.2. Conclusion

The obligation to provide taps prevents any potential loss of efficiency due to incumbent pipeline operators having an advantage over new entrants in the pipeline construction market. The rule allows anyone to construct new pipeline capacity between any two points, including points within existing pipelines. It therefore ensures that the users of capacity can select the pipeline developer who can provide new capacity at the lowest cost, by enabling pipeline developers to compete with each other for the right to construct pipelines. Without this rule, incumbents may be able to foreclose the market for new pipelines.
6. Promoting Efficient Use of Capacity

In the previous chapters, we described certain amendments to the existing offshore oil and gas regulatory regime that would improve the efficiency of investment in new CO₂ pipelines. In this chapter, we present certain improvements that would improve the efficiency with which existing pipelines are used and capacity is allocated between shippers. As before, we will draw on the experiences of the case studies we present in Volume 2 of this report.

6.1. Unbundling

Existing oil and gas infrastructure under the North Sea is mainly operated by integrated carriers who extract oil and gas and deliver it to the beach head. Some pipelines are owned by joint venture companies involving a number of producers. In either case, pipeline operators are obliged to offer capacity to third parties on a negotiated basis. Hence, unlike the regulatory frameworks for EU gas and electricity network companies, and interstate pipelines in the US, the UK offshore regime contains no requirement to unbundle the shipping of gas/oil from pipeline ownership.

The integration of network operators with associated supply businesses has been seen as a form of vertical foreclosure which acts as barrier to efficient investment in networks and to the development of competition in the upstream and downstream gas and electricity markets. The desire to encourage or impose unbundling has been much discussed in Europe recently:

"The current level of unbundling of network and supply interests has negative repercussions on market functioning and on incentives to invest in networks. This constitutes a major obstacle to new entry and also threatens security of supply."42

In the US, FERC Order 436 (1985) gave interstate pipeline companies incentives to adopt open access arrangements voluntarily, with the aim of mitigating the effects of vertical integration implicit in long-term gas supply contracts. However, initially, open access arrangements were limited. FERC Order 636 (1992) therefore imposed obligatory unbundling of pipelines from up- and downstream activities. Order 636 required that all users have access to the same standards of service and a common tariff structure.43 It worked by requiring that any pipeline owner transfer title of its gas to its customer “as far upstream as possible”. In general, this obligation means that pipeline owners had to sell gas upstream of their own pipelines, thus removing any chance of favouring the transit of their own gas across their pipelines.44

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44 FERC Order 636, page 55.
6.1.1. The rationale for unbundling

In the case of UK CO\textsubscript{2} pipelines, a requirement that the operation and/or ownership of pipelines are unbundled from pipelines will have few benefits if the efficient selection of CCS plants in the UK turns out to use small and disparate storage sites. In this case, there would be little potential for multiple CCS generators to use the same pipelines, and so limited potential for vertical foreclosure.

Vertical integration does not necessarily promote the withholding of spare capacity – no-one has an incentive to build spare capacity in order to withhold it, as it would be cheaper not to build the capacity in the first place. (See section 5 for a discussion of foreclosure in the pipeline construction market. Such foreclosure is possible for unbundled as well as bundled pipelines.)

The rationale for imposing unbundling derives from concern over efficient use of existing capacity. Efficient use of a pipeline requires users to transfer capacity between shippers, for instance at the time when early CCS generators close and others seek to make use of their CO\textsubscript{2} pipelines. However, such transfers may not take place efficiently, if the user of a pipeline is integrated with the owner of the pipeline.

6.1.2. Reputational effects

Imposing the unbundling of pipeline ownership from the shipping of CO\textsubscript{2} may offer “reputational” benefits, which affect competition in the use of the pipeline. Unbundling prevents pipelines from indicating to customers (e.g. generators with CCS) that they will receive a better quality of service if they deliver their CO\textsubscript{2} to the company that owns the pipeline, than if they transport it themselves over the pipeline or deliver it to another shipper using the same pipeline. Similar concerns may arise if pipeline owners can own CO\textsubscript{2} storage facilities: separation of ownership between pipeline and storage prevents users getting the impression that service to the pipeline’s own storage will be more reliable than service to competitors’ storage.

Examples of this problem have emerged over the years in British gas and electricity retail markets, where one justification for consumers’ unwillingness to switch is their perception that they risk receiving a lower security of supply. These perceptions are largely misguided, as distribution network companies can only provide the same security of supply to all end-users, independent of their chosen supplier. However, there is evidence that this perception persists and it may give incumbents a basis for charging higher prices than necessary. Ofgem has commissioned research from both FDS international and Ipsos MORI into consumers’ perceptions of the switching process, including their views of new entrant energy suppliers. These studies uncovered widespread consumer mistrust of new entrant energy suppliers, including a perception that new entrants may provide lower service quality:

“Among vulnerable customers loyalty to an existing provider was sometimes based on good service or experience of the incumbent, but sometimes based on
This research also discovered that scepticism about new suppliers is not restricted to vulnerable consumers, but is also prevalent among non-vulnerable consumers.\textsuperscript{46} When asked to provide their reasons for not switching, Ipsos MORI found that 5\% of consumers who had not switched stated that they “would not trust another energy supplier”.\textsuperscript{47}

These findings apply to residential customers. Industrial-sized users of a CO\textsubscript{2} pipeline may be better informed about the risks. However, FERC’s action in forcing unbundling was driven by the remaining evidence that integrated shipper-owners could command higher prices for equivalent service, because of their ability to suggest that security of supply would be lower for other suppliers using their network. A similar risk may apply to CO\textsubscript{2} pipelines suggesting that separation between pipeline ownership and pipeline usage would be desirable. There is in principle no reason why the users of CO\textsubscript{2} pipelines (power companies, in many cases) should also build or operate the CO\textsubscript{2} gas pipelines.

### 6.1.3. Creating a market price for capacity

Another potential benefit of unbundling ownership of CO\textsubscript{2} pipelines from use of the pipeline and ownership of storage is the development of market prices. Trading in the commodity (CO\textsubscript{2} gas) and in pipeline capacity (transport rights) may develop in the absence of such unbundling. However, trading in such conditions will be illiquid and it may be difficult for traders to set prices in such a market.

The English and Welsh water sector, for example, has tried to set up trades in bulk water supplies, but predictable difficulties have arisen. The sector is dominated by regional vertically integrated companies. Recent attempts by the regulator, Ofwat, to introduce competition for upstream water supplies have been largely fruitless. No customer has changed supplier since competition in the provision of water services was introduced in December 2005. Ofwat has suggested that the cost principles used to charge for network access present an obstacle to such competition, but it is not clear that adjusting the rules to promote trades will enhance efficiency. Given the cost structure of the industry, the problem for regulators lies in the absence of any recognisable market price for bulk water supplies.

The current rules direct companies to set the prices for network access equal to the retail charge minus their avoidable costs (the so-called Cost Principle). This discount for avoided costs seems to have been too low to cover the additional costs of building and using competing water supplies. As a result, competition has not taken off. However, if the discount offered by water companies has been an accurate reflection of avoided costs, this outcome is economically efficient. New entry would only be efficient if the total cost of competing water supplies was lower than the avoided cost of the displaced water supply.

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\textsuperscript{45} Ofgem (140/08), \textit{Energy Supply Probe}, 6\textsuperscript{th} October 2008, Appendix 3, par 1.14, page 160

\textsuperscript{46} Ofgem (140/08), \textit{Energy Supply Probe}, 6\textsuperscript{th} October 2008, Appendix 3, par 1.16, page 161

\textsuperscript{47} Ipsos MORI, March 2008, \textit{Switching Rates For Vulnerable Consumers – Summary Report}, Q16 p 11
According to Ofwat, the current access conditions act as a barrier to entry. Ofwat has proposed that the Cost Principle is removed from statute and replaced with a set of general criteria on setting access charges to be determined by Ofwat.⁴⁸ Ofwat has also proposed other changes to the Water Supply Licence (WSL) arrangements, including unbundling of the current combined supply licence (which enables a retailer to develop a resource and convey the water through the network) into separate retail and upstream licences.⁴⁹ This would allow retail and upstream licensees to contract and trade with each other. Ofwat has also recommended that the retail function is functionally and legally separated from the wholesale business.⁵⁰ The Competition Appeals Tribunal (CAT) concluded in a recent case involving Albion Water that the Cost Principle precludes competition and is open to question.⁵¹

Such disputes regarding terms of access to other parties’ networks would not emerge in the case of CO₂ pipelines, if unbundling were imposed early in the network’s development. If there were substantial scope for users to change their patterns of usage and so to trade pipeline capacity, unbundling would promote the emergence of a CO₂ pipeline capacity market, and hence a market price for access to networks. However, the likelihood of this outcome, and hence the importance of unbundling, depends on the extent to which users will want to change their pattern of usage during the lifetime of the CO₂ pipelines.

6.2. Tariff Structures

Under the UK offshore oil and gas regime, there is no requirement to adopt a particular structure of capacity charges. However, the regulatory regime for US interstate pipelines does impose requirements on pipeline operators to offer access to third parties using particular tariff structures and methodologies.

FERC Order 636, which imposed unbundling of US interstate gas pipelines, also required a redesign of the pipeline companies’ transportation tariff rates. The Order required pipeline companies to recover the majority of fixed costs associated with transportation service only through the “capacity reservation fee” charged to firm customers. Thus, firm customers (i.e. those possessing a contract for firm pipeline capacity) pay a monthly reservation fee to reserve capacity, in US$ per day per unit of reserved capacity. Those customers can sell this capacity to other users at the market price; the price of such sales is unregulated. All users must then pay a variable usage charge (e.g. a share of the actual fuel cost of running compressors) for each unit of gas they send through the pipeline.⁵²

This new rate design, known as “straight fixed-variable” (SFV), was intended to eliminate price distortions that existed under the previously used “modified fixed-variable” (MFV) rate design. The MFV rate design allowed pipeline operators to recover certain fixed costs, such as return on equity and related taxes, through variable usage charges. This shift was intended

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⁴⁸ Ofwat (December 2007) op. cit. p.4.
⁴⁹ Ofwat (May 2008) op. cit. p.55
⁵⁰ Ofwat (May 2008) op. cit. p.57
to promote a more efficient utilisation of pipeline capacity because, under SFV, variable usage charges reflect the variable costs of using capacity.\textsuperscript{53}

This structure of charging for the use of capacity would ensure the efficient use of CO\(_2\) transport capacity and an efficient allocation of network capacity between users. If variable usage charges do not reflect the variable cost of using CO\(_2\) pipelines, differences between charges and costs will distort the incentives facing users and hence the way in which power plants are despatched, leading to lower efficiency in the use of CO\(_2\) pipelines, but also in the power generation sector.

Under the regulatory framework for US gas pipelines, the accounts of the companies are public information. The tariffs of pipeline operators are derived directly from the costs of the company as they appear in these accounts. These rules are an important aspect of any regulatory framework in which pipeline operators’ allowed tariffs are set or capped by a regulator. Cost-based tariffs also provide a transparent basis for capacity trading, since the rental value of capacity which determines its market price is unambiguously captured by the holder of the capacity, not by the owner of the pipeline.

Regulation of tariffs requires proper accounts from the start. Failures to set down in advance any regulatory accounting standards for gas and electricity network companies in the UK led to regulatory disputes that were only resolved incrementally through various decisions and appeals during the 1990s. These disputes related to matters that should have been relatively simple accounting questions, such as the initial value of the Regulatory Asset Base (RAB), how to revalue the RAB for inflation and how to calculate depreciation, and what types of expenditure were classed as investment. Resolving them ex post required major arguments over the division of value between owners and users of the networks.

If the UK Government is contemplating even the possibility of regulating the terms on which the owners of CO\(_2\) pipelines sell their capacity, it would be advisable to set down accounting standards in advance. These standards would be useful for supporting future regulatory decisions (e.g. on unbundling or cost allocation), even if they are not used immediately, e.g. because the pipelines are vertically integrated, or because tariffs are negotiated.

\subsection*{6.3. Capacity Trading}

\subsubsection*{6.3.1. Arrangements in the UK offshore regime}

To some extent, the offshore oil and gas regulatory regime in the UK allows for the transfer of pipeline capacity between users. However, capacity is not transferable between users in cases where access terms have been set by the Secretary of State. Holders of capacity may be able to circumvent the non-tradability of determinations, by seeking a new determination or by transporting hydrocarbons on behalf of third parties. However, the process of seeking a new determination takes too long and would be too unpredictable to allow short-term trades to take place, or to provide a transparent basis for users to evaluate contract capacity and pipeline investments.

In practice, third parties reach agreement on access with the owners of infrastructure through negotiated settlements, rather than through determinations by the Secretary of State. Operators have not widely published the precise content of these contracts. However, we understand that many modern access contracts allow capacity rights to be reassigned as production on mature fields wanes or when the ownership of fields and extraction infrastructure is reassigned.\(^54\)

An efficient regulatory framework for CO\(_2\) pipelines would offer users more flexibility in their ability to trade capacity, by setting down standard rules on how pipeline capacity is to be defined in contracts and transferred between users. The greater the degree of standardisation, the easier it will be for users to trade capacity on different pipelines and the more efficient the system will become. The regulatory regime for US interstate pipelines provides an example of how this might work in practice.

### 6.3.2. Secondary capacity markets for US interstate pipeline capacity

Although FERC regulates rates for long-term pipeline capacity contracts, holders of capacity may buy and sell pipeline capacity at prices determined in competitive markets. Any rights to pipeline capacity that users receive under capacity contracts are tradable on secondary markets, which is important for ensuring that capacity continues to be used efficiently. This requirement is imposed on pipeline operators under FERC regulations:

> “An interstate pipeline that offers transportation service on a firm basis […] must include in its tariff a mechanism for firm shippers to release firm capacity to the pipeline for resale by the pipeline on a firm basis under this section….Firm shippers must be permitted to release their capacity, in whole or in part, on a permanent or short-term basis, without restriction on the terms or conditions of the release.”\(^55\)

Hence, the original users who paid for pipeline capacity to be built can sell their rights to others if their needs change, or if someone is willing to pay more for capacity than it is worth to the current holder. In off-peak times, the price of spare capacity in this secondary market is very low, which provides a basis for users to enter the market even if their usage has a low value (or low priority).

FERC rules require pipeline operators to provide information about the release of capacity onto competitive markets:

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\(^{54}\) Source: private conversation with officials at DECC, 12/03/09.

“The pipeline must provide notice of offers to release or to purchase capacity, the terms and conditions of such offers, and the name of any replacement shipper… on an Internet web site, for a reasonable period.”

Sales in the competitive market may transfer “firm” capacity, meaning that all rights transfer to the new user for some longer or shorter period. However, many sales are “interruptible”, meaning that the original holder has the option to take back the capacity when it needs it. In practice, this condition means that users who buy interruptible capacity retain it at all but peak times.

For the purpose of transparency, pipeline companies also have to post the rate charged under each contract, the duration of the contract, the receipt and delivery points, the contract quantity, and any special terms or conditions. They must also publish details of which shippers hold capacity and how much capacity shippers are using. Pipeline operators must make this information available for download from their websites for 90 days and retain this information (to be made available on request) for four years.

Incidentally, pipeline operators also have the right to sell any capacity on their pipelines which users have not indicated they wish to use. Users can provide such an indication right up to a day or so before the gas flows, so pipelines can only offer very short term capacity. However, the threat that the pipelines might sell unused capacity provides a competitive spur for the holders of pipeline capacity to sell it themselves, if there are any alternative users.

**6.3.3. Lessons for UK CO\(_2\) pipelines**

If the early developments of CO\(_2\) pipelines take place by vertically integrated developers of CO\(_2\) plants, storage sites and pipelines, then there may be relatively little scope for secondary capacity trading. However, imposing obligations on pipeline operators to facilitate capacity trading will permit transfers of capacity between users in cases where the locations of sources and sinks change over time. It will also enable users to share pipelines more efficiently where they have non-coincidental peak requirements for transport capacity. In this respect, efficient trading prompts efficient use of existing capacity as a substitute for building new pipeline capacity, and so contributes to efficient construction of new pipelines (in the sense that it reduces or avoids unnecessary construction).

Moreover, a capacity market creates a price (or opportunity cost) for capacity which is very low in periods when there is spare capacity on the pipeline, and high at times when demand for pipeline capacity peaks. The low price periods will allow low value users to enter the market, if they can restrict their usage to such times. The high price periods will send efficient market signals to CCS generators and storage operators about the value of new and existing capacity, promoting both the efficient use and provision of CO\(_2\) transport capacity.

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6.4. Summary and Conclusion

In this chapter, we have described a number of adaptations to the existing regulatory regime for offshore oil and gas pipelines that would improve the efficiency with which pipeline capacity is used. The measures we have described in this chapter include:

- Unbundling of pipeline ownership from storage and capture;
- Tariff structures that include variable usage charges based on marginal cost; and
- Requirements that pipeline companies facilitate secondary trading of capacity.

These improvements may not significantly improve efficiency of pipeline usage in the near-term, if CO₂ pipelines are vertically integrated with the early CCS plants (as may be the case with any demonstration plants that the UK government will sponsor). However, in the longer run, it may prove necessary for the sake of efficiency to unbundle pipeline ownership and to create a capacity market, in order to facilitate capacity transfers between users. Such transfers would be efficient if enough CCS plants are located near to the start of a pipeline whose capacity they can share.

The measures described in this chapter have the aim of promoting efficiency in the use of existing pipelines by different parties. However, it should be borne in mind that efficient use of existing pipeline capacity will also reduce the need to construct new pipeline capacity, thereby promoting more efficient construction.
7. Conclusions and Recommendations

7.1. The Economics of CO₂ Pipelines

7.1.1. Externalities

Externalities are essentially the costs or benefits of using resources for production or consumption, when those resources are not owned by anyone due to the lack of well-defined property rights. This gap in property rights prevents a market mechanism from emerging to ensure the efficient use and allocation of resources. As with all environmental policies, the incentives of private investors to construct CCS generators and CO₂ pipelines depend on how governments “internalise” externalities to make producers and consumers take into account the value of these resources. The most common methods involve governments creating property rights over the resources or charging directly for their use.

The EU ETS is the main policy instrument used to internalise the externalities caused by CO₂ emissions. It works by allocating property rights to emit CO₂, and so creates a market for CO₂ emissions. However, as we have described in this report, this scheme has a short duration and there are tighter emissions targets in the UK than in the EU so that the EU ETS does not fully internalise the long-run “shadow” cost of CO₂ emissions as perceived in the UK. These problems necessitate further support from government to ensure efficient investment in low carbon generation technologies. The generation of electricity from renewable energy sources receives this support through the Renewables Obligation and the payment for the associated Certificates. In the absence of other subsidies for CO₂ abatement via CCS, incentives will be distorted and investment in CCS will be inefficiently depressed.

The presence of externalities therefore creates a strong rationale for government intervention to promote efficient investment in CCS. However, this intervention can be limited to creating long-term property rights over the ability to emit CO₂. It need not require any long-term commitment to fund, to subsidise or to direct investment in CCS pipelines.

7.1.2. Economies of scale

We have reviewed a number of studies that study the potential for CCS in the UK and elsewhere. Some of these studies conclude that there is a case for government intervention to ensure that private investors efficiently exploit economies of scale. However, such conclusions are based on the assumptions that pipeline design is subject to large economies of scale, and that market-driven systems discourage investors from exploiting economies of scale because they do not amalgamate loads or invest ahead of demand. In this report, we have presented theory and evidence showing that these claims are not likely to be true.

For instance, the cost characteristics of UK offshore CO₂ pipelines exhibit diseconomies of scale in pipelines above 36” in diameter. We have also identified academic studies showing that diseconomies of scale arise if longer feeder pipes are needed to connect disparate sources to large trunk lines.

In any case, it is not necessarily efficient (in terms of minimising expected pipeline costs) for either the government or private investors to provide pipelines ahead of demand, where (1) there are limited economies of scale, (2) the probability of demand growing along a particular
route is low, and/or (3) the time between the initial investment and the expected growth in demand is long.

Finally, investors have strong incentives to exploit economies of scale by collaborating on projects to reduce their average costs of providing capacity. However, one potential role for government may arise in order to facilitate this collaboration by reducing transaction costs. One way to do this is by mandating open season procedures during the planning phase of pipeline projects (see below). However, the purpose of such open seasons is to promote competitive entry into new pipeline projects, not to overcome any inability of investors to coordinate the exploitation of economies of scale.

7.1.3. Implications for the required regulatory regime

In light of these findings there is no reason to think that government should centrally plan network developments to ensure efficient investment and efficient exploitation of economies of scale, as long as the government puts in place policies that let private investors fully internalise the external benefits of CO\textsubscript{2} abatement. Given the appropriate resolution of externalities, market-driven deployment of CO\textsubscript{2} pipelines can achieve an efficient pattern of investment. Indeed, the market-driven investments seen in the UK offshore oil and gas networks provide a useful starting point for designing a regulatory framework for CO\textsubscript{2} networks.

Focusing on onshore gas and electricity networks might suggest that the government should appoint a private company as the monopoly provider of CO\textsubscript{2} pipelines. However, the incentives of a regulated monopolist to make efficient investments, especially ahead of need for capacity, depend entirely on the structure of administered incentive schemes. These schemes can only be approved by a sector regulator and are unlikely to offer the same incentives as a well-defined market. Experience from other sectors suggests that monopoly infrastructure providers have distorted incentives to invest due to the risks inherent in regulatory proceedings. The entry-exit tariffs associated with monopoly onshore networks inevitably distort investment incentives, both to the regulated company and to users, because of the mis-match between tariffs and the physical characteristics of a network. Therefore, investments by a regulated monopoly are likely to be less efficient than those of private investors in a well-defined market framework.

There are examples of networks where the government plays a major role in centrally planning network investments, such as the UK rail industry. In this case, detailed government involvement is necessary because the government provides discretionary subsidies to investment projects and to fund the ongoing operation of the network. These subsidies represent the chosen method of offsetting the externalities inherent in road transport. However, unless the government has private information about the value of the relevant externalities and the costs of future investments in CO\textsubscript{2} abatement, it will be no be better placed than private investors to gauge the value of new investments in CO\textsubscript{2} pipeline capacity.

The current UK offshore oil and gas pipeline regime may not guarantee efficient investment in CO\textsubscript{2} pipelines. We have presented a number of possible improvements to this framework drawing on lessons from the offshore pipeline regime itself and from other regimes (see below). In particular we refer to the regulatory regime for US interstate gas pipelines as an example of a well-functioning market-driven system for providing pipeline capacity. The
government may wish to implement some or all of these options in regulating a CO\textsubscript{2} pipeline network. It may be desirable to adopt more of them as the network develops, depending upon what aims seem to offer the most potential gains: efficient investment; efficient network integration; and/or efficient use of existing capacity. We list these options below.

7.2. Promoting Efficient Investment in Pipelines

We begin with possible improvements to the existing offshore oil and gas regulatory regime that could be adopted to improve the efficiency of investment in CO\textsubscript{2} pipelines:

- **Point-to-point capacity:** Although most existing offshore oil and gas pipeline operators define capacity on a point-to-point basis, it is not compulsory under the regulatory rules. It may therefore be desirable to enshrine this requirement within the regulatory framework for CO\textsubscript{2} pipelines. This would prevent disputes regarding capacity allocation and definition, and to prevent the weak and distorted investment incentives provided under entry-exit regimes.

- **Open seasons:** The existing offshore oil and gas regime allows for coordination between investors in the planning stages of pipeline projects. It works by allowing third parties to request capacity on other developers’ projects in return for the incremental cost of capacity. Whether or not this rule is appropriate for the offshore oil and gas sectors, it may create incentives not to be an “early mover” in developing CO\textsubscript{2} pipeline infrastructure, which may delay investments. Instead, it would be better to impose a requirement that all developers of new pipelines hold open seasons. After publicising the project and negotiating with potential participants, the developers would award long-term point-to-point capacity contracts to bidders who offer to pay *at least* the incremental costs of the capacity they request. (This is the minimum condition for participation. In practice, the participants in any project would need to agree a fair allocation of total costs among themselves that met legal requirements for non-discrimination.) The obligation to hold open seasons would facilitate the formation of coalitions to exploit economies of scale in the provision of CO\textsubscript{2} pipelines. The open seasons would exist to inform the market of potential pipeline developments and to facilitate the widest possible participation among those willing to commit funds to the project.

- **Planning rules:** To promote efficient choices between building onshore and offshore pipelines, the government may need to incorporate CO\textsubscript{2} pipelines into its existing policies on planning used for other kinds of energy sector infrastructure.

7.3. Promoting Efficient Network Integration

Whilst the rules above promote efficient investment in individual pipelines, it may be necessary to adopt additional measures to promote efficient integration of a network. Such integration has two components. A network may offer some benefits over disparate pipelines for managing the risk associated with variations in patterns of usage. However, such risks are not usually significant within gas networks. A more important motivation for network integration is the desire to maintain the potential for competitive construction of new pipelines, even when new pipelines only provide additional capacity alongside part of an existing pipeline.
To permit users to select the lowest cost provider of additional pipeline capacity, existing pipelines should be subject to an obligation to connect other pipelines (but not to accept any gas unless the shipper has a contract for capacity on the existing pipeline). Hence, if network integration appears to be important for efficiency, the UK Government should consider introducing the following rule to preserve competition:

- **Obligations to provide taps:** US interstate gas pipelines are required to provide taps (i.e. connections) to competitors’ pipelines on request. The obligation to provide taps removes the ability of incumbent pipeline operators to prevent new entrants from constructing new pipeline capacity. It also ensures that capacity is developed by the party who can provide it at the lowest cost, by enabling pipeline developers to compete with each other for the right to construct pipelines; without this rule, incumbents may be able to foreclose the market for new pipelines.

This rule ensures that competing investors will invest efficiently to alleviate constraints where they arise, without having to invest in a whole new pipeline from source to sink.

### 7.4. Promoting the Efficient Use of Capacity

Finally, we list below possible improvements to the existing offshore oil and gas regulatory regime that could be adopted to improve the efficiency with which CO$_2$ pipeline capacity is used.

These improvements may not significantly improve efficiency of pipeline usage in the near-term, if CO$_2$ pipelines are likely to be vertically integrated with the early CCS plants (That may be the case with the demonstration plants that the UK government will sponsor.) However, in the longer-run, transfers between users may be required, if there are enough CCS plants are located near to each other, and have sufficiently different patterns of operation, to allow them to share pipelines. The measures described below would then promote efficiency in the use of pipelines.

- **Unbundling:** Unbundling requirements for gas and electricity networks have been imposed by energy regulators and antitrust authorities in the EU and US to prevent vertical foreclosure of up/downstream markets by vertically integrated incumbents. Unbundling improves efficiency in cases where network capacity needs to be transferred between users. It allows a market price for capacity to emerge, which would prevent disputes regarding access pricing in the future, such as those seen in the English and Welsh water industry. Also, it would prevent incumbent pipeline operators from obtaining any perceived advantage in the eyes of pipeline users over the quality of transport capacity they can offer.

- **Tariff structures:** One way of improving the efficiency with which CO$_2$ pipelines are used would be to require that pipeline operators recover only their variable usage costs and not their fixed costs (e.g. financing costs) through variable usage charges. Pipeline operators would cover their fixed costs through fixed capacity charges to ensure they retain the full benefit of their investment.

- **Secondary capacity trading:** Finally, requirements on CO$_2$ pipeline operators to provide trading platforms for capacity on their pipelines, and to publish information about tariffs, pipeline ownership, usage and capacity availability promote the efficient usage of
pipelines in cases where transfer of capacity between users is feasible. It also improves the efficiency of investment by allowing neighbouring CCS generators to share pipelines where they have non-coincidental peak requirements for pipeline capacity.

These mechanisms release existing capacity as a substitute for constructing new capacity. Therefore, whilst they contribute in the short term to efficient usage among multiple users, they also contribute in the long term to efficient investment, by avoiding over-investment in unnecessary new capacity.

7.5. Summary

Providing that the UK Government can find a way to present the value of CO$_2$ abatement to the operators of CCS facilities, a market-driven system will promote efficient construction of CO$_2$ pipelines, both offshore and onshore. The EU ETS will in future recognise CCS and will therefore give it a value in CO$_2$ abatement; it is for the UK Government to consider whether it is necessary to provide any higher, longer term or more certain reward for CO$_2$ abatement than that offered by the EU ETS. The choice of regime then depends on which of the following aims are relevant to the emerging CCS sector:

- Promoting efficient investment in new pipeline capacity;
- Promoting efficiently integrated networks;
- Promoting efficient use of existing capacity.

In principle, the UK Government can choose to implement the different rules listed above in stages, as and when each of these aims becomes important. However, it should be borne in mind that each set of rules makes some contribution to the first aim, that of promoting efficient investment. Moreover, some of the rules that might be introduced later need a foundation (such as formal accounting for costs) to be laid down from the start.

We assume that efficient investment will be an objective from the start, but recognise that efficient integration and efficient use may become important only as the CCS sector grows in size and attracts multiple users. Nevertheless, the UK Government may wish to signal these possibilities in advance, in order to help investors manage their risks efficiently.
Appendix A. A Model of Economies of Scale

In this section, we derive the results of the theoretic model we refer to in Chapter 3, using the same notation as defined in that Chapter.

A.1. Efficient Investment in CO₂ Pipelines

If the initial developer requires \( k \) units of transport capacity, then its requirement for diameter on a single pipeline in \( x \), which we assume is equal to \( \sqrt{k} \). As we assume the second comer has the same demand for capacity \( (k) \), then their combined requirement for pipeline capacity is \( 2k^2 \), and a pipeline big enough to meet both their needs would have a diameter of \( \sqrt{2} x \). The total cost of building an oversized pipeline in period 1 is therefore:

\[
F + v \cdot \sqrt{2} x
\]  
(1)

And the cost of building a smaller pipeline with diameter \( x \) is:

\[
F + v \cdot x
\]  
(2)

It is economically efficient for the initial developer to provide capacity for the second comer ahead of need if the following condition is met:

The total cost of providing \( 2k \) units of capacity in period 1 is less than the cost of providing \( k \) units of capacity in period 1, plus the expected, discounted cost of providing \( k \) units of capacity in period 2.

This condition is equivalent to the following expression:

\[
F + v \cdot \sqrt{2} x < F + v \cdot x + p \cdot (F + v \cdot x) / (1+r)
\]

\[
\Rightarrow (\sqrt{2} - 1) \cdot v \cdot x < p \cdot (F + v \cdot x) / (1+r)
\]  
(3)

This inequality can also be expressed as follows:

\[ F > [(1 + r)(\sqrt{2} - 1) + p] \cdot v \cdot x / p \]

\[ p > (1 + r)(\sqrt{2} - 1) \cdot v \cdot x / (F + v \cdot x) \]

\[ r < [(p - \sqrt{2} +1) \cdot v \cdot x + F] / (\sqrt{2} - 1) \cdot v \cdot x \]

A.2. Investment Incentives in a Competitive Market

The developer will care about maximising expected profit, and so will only provide capacity ahead of need if the expected revenue it receives if the pipeline turns out to be needed is above the expected incremental cost of oversizing the pipeline:

\[
p \cdot R / (1+r) > (\sqrt{2} - 1) \cdot v \cdot x
\]  
(4)

\[ ^{57} \text{We make the assumption that capacity is equal to the square of diameter for simplicity. In practice, natural gas pipeline capacity is proportional to the pipeline’s diameter, to the power of 2.5, as expressed in the “Panhandle” or “Weymouth” equation. The increase in the power from the square (2) to 2.5 reflects some fluid characteristics of natural gas.} \]
This condition implies the following condition on $R$ for efficient development of pipelines by the initial developer, which we obtain by equating the left hand side of condition 4 with the right hand side of condition 3:

\[
p \cdot \frac{R}{(1+r)} = p \cdot \frac{(F + v \cdot x)}{(1+r)} \\
\Rightarrow R = \frac{(F + v \cdot x)}{(1+r)}
\]  

(5)

Note that the $R$ term can be interpreted as the Net Present Value of all charges recovered for the $k$ units of capacity provided ahead of need if the demand of the second comer materialises.
Appendix B. Incentives Under Price Regulation

If the CO$_2$ pipeline developer is subject to price control regulation, its incentives to invest efficiently in transportation infrastructure to meet future demand growth depend on the structure of the company’s price control, and the procedures for revising it.

B.1. Guaranteed Cost Recovery

The simplest form of price control regulation is full cost pass-through, whereby the regulated company is allowed to recover all the investment costs it incurs in planning for and meeting demand growth. In this case, the regulated company is sheltered from any risk that demand for capacity will not materialise, and so it will have no incentive to invest efficiently and to efficiently exploit economies of scale. Such a system would therefore not promote the efficient development of a CO$_2$ transportation network.

B.2. Ex Ante Approval of Investment Budgets

One way of avoiding the inefficiencies of passing through all investment costs may be for regulator’s to approve pipeline companies’ allowed investment costs before the investments are undertaken. The company would then receive reimbursement for the costs of providing the approved investment projects (usually over the life of the asset, including a return on invested capital). In this framework, a regulator must estimate the efficient level of investment required to meet demand growth, and fix the companies’ revenue at a level that allows them to recover the costs of such investments.

This kind of framework is used in the regulation of UK utilities, whereby the relevant industry regulator sets a revenue or price cap for several years at a time. These price/revenue caps include allowances for the return on and depreciation of a forecast regulatory asset base (RAB). At the periodic review, the regulator forecasts the RAB so that it reflects its estimate of the required level of capital expenditure over the following control period. At the following periodic review, UK regulators typically pass through into the RAB the capex that companies’ actually undertook during the preceding control period, possibly subject to an ex post efficiency review (see below).

However, because revenues are typically fixed between control periods, companies generally have an incentive to spend as little as possible to meet demand growth, subject to meeting minimum standards of service. Hence, setting regulated companies’ investment budgets ex ante is unlikely to incentivise companies to efficiently provide pipeline capacity ahead of need.

B.3. Ex Post Prudence Reviews

The purpose of prudence reviews is to counteract any incentive to spend more than necessary on investments, i.e. by investing in unnecessary projects, or by allowing the costs of any project to escalate unnecessarily. A prudence review would therefore be expected to review regulated companies’ investment decisions to see whether they were reasonable or prudent – in the light of information available at the time – and to review the conduct of the project to see if the company had kept its costs in check – e.g. by putting contracts out to a competitive tender whenever possible.
Ofgem has recently begun to use prudence reviews, and has disallowed some capital expenditure undertaken by the gas transmission and distribution networks. In the case of the gas transmission disallowance, the capital expenditure was undertaken at the St Fergus entry terminal, and Ofgem ruled that National Grid had not demonstrated shippers’ demand for the capacity provided through the investment.

Such precedents suggest that if network companies provide capacity ahead of need, there is a risk that the costs of efficiently providing capacity ahead of need may be disallowed. The result is a reluctance on the part of network operators to provide capacity ahead of need in return for low regulated rates of return. This problem has created significant delays in providing electricity transmission capacity in the UK, and has prompted the regulator to consider regulatory incentive schemes to compensate companies for risky investments (see our case study on UK electricity networks, and Section B.4 below).

However, the risk of disallowances arises principally because Ofgem has never fully defined criteria for disallowing capex ex post, which creates risks for regulated companies, and increases the rate of return required to incentivise investment, relative to a system with no such ex post review. Given the importance of ex post reviews for investment incentives – and for decisions to invest ahead of need in particular – it is important to set out the standards by which capex will be judged ex post. General standards have emerged in the US, through repeated application of prudence reviews and discussion of the standards in regulatory hearings and cases. The experience of the US is therefore useful, and provides a number of prudence standards that are particularly relevant to any decision to invest ahead of demand. We describe these standards in our case study on US interstate gas pipelines.

**B.4. Incentive Schemes to Encourage Efficient Investment**

Using similar notation as in the model described in Appendix A, suppose that the revenues of the pipeline developer are regulated and that the company is subject to an incentive scheme that conditions the revenue it receives for the $k$ units of capacity in period 2 on whether or not it is used or unused.

Suppose that if the $k$ units of capacity is *used* then the pipeline operator receives revenue of $R_u$, and if it is *unused* (i.e. stranded) the pipeline operator receives revenue of $R_s$. Each of these terms is defined as the NPV of future charges for $k$ units of capacity (e.g. in tCO$_2$/day), discounted to period 2 like the $R$ term defined in the example above. Either $R_s$ or $R_u$ may be set equal to zero or to a positive amount.

The pipeline operator will find it profitable to oversize its pipeline in period 1 if the following condition is met:

$$\text{Expected Revenue} > \text{Incremental Cost of Providing } k \text{ units of capacity}$$

$$\left[p R_u + (1-p) R_s \right] / (1+r) > (\sqrt{2} - 1) v x$$

Condition 3 in Appendix A describes the condition for oversizing the pipeline being an efficient investment strategy. By equating the right hand side of condition 3 in Appendix A with the left hand side of condition 6 above leads to the following condition for when the parameters of the regulatory incentive scheme described above lead to efficient investment:
\[
[p \ R_u + (1-p) \ R_s] / (1+r) = p \ (F + v \cdot x) / (1+r)
\]
\[\Rightarrow \quad p \ R_u + (1-p) \ R_s = p \ (F + v \cdot x) \quad (7)\]

Ideally, the regulator should then set the payments for used and unused capacity at a level that satisfies this condition to achieve the socially optimal cost-minimising decision over whether to oversize pipelines at any given level of \( p \) (i.e. the probability of demand will be high enough to require the capacity). However, in practice it will be hard for a regulator to accurately estimate the levels of \( R_u \) and \( R_s \) that promote efficient investment, and inaccuracies in its attempts to do so may distort investment incentives.

For established gas or electricity networks, one way for companies to recover any payments for unused capacity may be to “socialise” them, i.e. so they are recovered from the generality of consumers. However, in the case of a new CO\(_2\) networks, it is unlikely that this would be possible. Hence, the payment for unused capacity \( (R_s) \) may have to be set to zero, or paid through a government guarantee. Setting the term \( R_s \) to zero means that condition 7 becomes:

\[
R_u = (F + v \cdot x) \quad (8)
\]

which is the same as the condition for efficient investment in a competitive market defined in Appendix A. This condition shows that any regulated tariff that only allows recovery of the costs incurred by the pipeline operator in constructing and operating the pipeline – if the capacity provided ahead of need is utilised – will be too low to promote efficient investment.

**B.5. Conclusions**

The UK experience of regulating gas and electricity networks suggests that revenue/price regulation performs poorly in promoting the efficient provision of capacity ahead of need, i.e. the efficient exploitation of economies of scale. This is mainly because of the difficulty in accurately setting the parameters of incentive schemes to promote efficient investment decisions. Moreover, the risks associated with regulatory proceedings, such as the risk of ex-post disallowances of capital expenditure following prudence reviews, further distorts investment incentives. For this reason, the decentralised market-driven provision of CO\(_2\) pipelines may perform better in promoting efficient investments.
Appendix C. Non-UK Sources of Funding for CCS

We have researched recent news articles and press releases, as well as websites of relevant institutions, to find potential sources of funds for UK CCS projects other than the UK Government. Our research points to two main initiatives at the EU level to provide financial support for CCS. The details and allocation criteria of these initiatives are currently being finalised, and we recommend that DECC develop these potential sources further:

- In the EC Spring Council meeting of March 2009, the Commission set aside a budget of €5 billion of EU funds to finance investments in energy and broadband infrastructure, of which €180 million will be allocated to carbon storage projects in the UK. This decision is now pending approval of the European Parliament.  
  
- The European Council has announced that it will allocate 300 million EU emissions allowances to subsidise CCS demonstration plants and other innovative renewable energy projects.

In addition to these initiatives, the European Commission runs a number of schemes to support energy infrastructure and innovation, for which CCS may also be eligible:

- **TEN-E:** Investors in CCS projects may apply for funds through the EC’s grants programme under the Trans-European Networks (TEN-E) scheme, which supports projects that “contribute to the sustainable development and protection of the environment.”

- **ECO-Innovation:** The EC’s Executive Agency for Competitiveness & Innovation (EACI) manages the ECO-Innovation scheme, which has a budget of €200 million to fund “innovative products, services, and technologies that can...[...]...reduce Europe’s ecological footprint.” A new call for proposals is scheduled for April 2009.

In addition to these EU schemes, additional funds may be available from the European Investment Bank (EIB). The EIB provides financing for projects that contribute to the goals set out in the most recent Environment Action Programme and the EC’s Urban Environment Strategy, which include reducing industrial pollution.

Given the relatively novel status of CCS, some potential sources may not have set out their policy on this type of project.

This list is not intended to be exhaustive.

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60 [http://ec.europa.eu/energy/eu-leaders-clinch-deal-CO2-storage-financing/article-178038](http://ec.europa.eu/energy/eu-leaders-clinch-deal-CO2-storage-financing/article-178038)  
Appendix D. Experience from Other Sectors

As part of this study, we have conducted a number of case studies that describe the regulatory and commercial arrangements operating in other network industries and to draw lessons for the development of a CCS transportation network. This chapter contains a summary of the arrangements in the following sectors:

- British onshore gas networks;
- UK offshore oil and gas networks;
- British electricity networks;
- US interstate pipelines;
- The British rail network;
- English and Welsh water companies; and
- German gas pipelines.

We summarise below the key characteristics of these transportation networks and some lessons that we can draw from each case study. The detailed case studies are presented in volume 2 of this report.

D.1. British Onshore Gas Networks

National Grid Gas (NGG) operates the main high pressure, long distance gas pipeline network throughout Britain. NGG does not act as a gas shipper on the transmission system or supply gas to end users, but has a de facto monopoly over the provision of high-pressure gas transmission pipelines in Great Britain. (Some independent pipelines transport gas from beach terminals to particular power stations, but they do not provide a service to third parties that competes with NGG’s network.)

The degree of monopoly in the industry means that NGG’s pipeline investments are subject to major regulatory debates and reviews; the regulator, Ofgem, investigates whether investments are required and whether NGG undertakes them efficiently (i.e. at an “efficient” cost), in order to ensure that costs to consumers are kept to a minimum consistent with provision of an adequate service. However, due to the risk that the regulator may disallow capital expenditure ex post, after scrutinising investments, regulated network companies, including NGG, have been unwilling to undertake “risky” investments to increase network capacity.

Capacity on the British gas transmission network is defined in terms of entry or exit capacity. Entry capacity gives the holder the right to send gas into the network and on to the virtual point of sale. Exit capacity gives the holder the right to take gas from the point of sale to a customer (or distribution network) connected to the transmission network. This market structure facilitates retail market competition by creating a gas trading hub at which all new entrants can trade gas without ever relying on the incumbent. Regulators conventionally describe this outcome as conducive to “liquidity”. However, some of these gas trades are fictitious (i.e. they transfer gas between shippers at quite different locations, which requires the system operator to arrange some kind of gas swap behind the scenes). Moreover, the entry-exit system defines network capacity in a way which is unrelated to the underlying
physical characteristics of the network. This has created several disputes in recent years regarding the mechanisms used to define the amount of available capacity, to allocate capacity between users and to charge for network capacity.

The mismatch between network tariffs and the physical characteristics of the network due to the entry-exit system also prohibits the development of competition in the provision of gas pipelines. Shippers cannot identify the exact location of transmission constraints within NGG’s network and so cannot commission alternative pipelines to circumvent these constraints. Thus, the entry-exit system tends to entrench NGG’s monopoly position, and requires the company to plan centrally virtually all major network investments, subject to detailed regulatory oversight.

**D.2. UK Offshore Oil and Gas Networks**

Oil and gas infrastructure under the North Sea is mainly owned and operated by vertically integrated carriers who extract oil and gas and use their pipelines to deliver it to the beachhead. In some cases, developers collaborate through joint ventures, either to develop a single field or by bringing together their separate projects and funding a single pipeline in return for a pre-defined share of the contractual rights over capacity on the pipeline.

Offshore transportation infrastructure is typically planned in conjunction with the development of oil and gas fields. Plans to conduct such field developments must be approved (and licensed) by the Secretary of State. When a licensee submits an infrastructure development plan to DECC, the Secretary of State can require it to add capacity to accommodate future demand growth. Third parties also have the opportunity to request the addition of capacity to planned projects to accommodate their demand, for which they would pay the developer the incremental capital costs and ongoing operation and maintenance costs associated with the increase in capacity. Once transportation infrastructure is constructed, the Secretary of State has the power to require existing pipeline operators to offer access to third parties on defined terms. In practice, rather than invoking this procedure, operators of offshore infrastructure (including terminals and pipelines) have offered capacity and new connections to third parties on a negotiated basis, under a voluntary code of conduct set up jointly by the industry and the government (under which the Secretary of State can be asked to settle disputes). Negotiated access rights can be made transferable between users, whereas access rights granted by the Secretary of State would be non-transferable.

A potential source of inefficiency arises from the obligation of pipeline developers to accommodate others at incremental cost. Due to economies of scale, the incremental cost of adding capacity to a prospective project is lower than the average costs of the original capacity envisaged by the pipeline’s developer. Hence, the obligation to let third parties pay the incremental cost of capacity provides an incentive to be a “late comer” in developing oil and gas pipelines, and to avoid being the first mover in some cases. This incentive to delay investment may result in inefficiency if expensive investments are held back unnecessarily.

Hence, the development of offshore oil and gas transport infrastructure is market-driven, to the extent that it is provided, planned and constructed by field developers to meet their own needs. For the sake of efficiency, capacity is developed jointly and negotiated access rights may be transferred between users. In case of access disputes between users, the government has powers to direct investment through the licensing regime by requiring developers to
accommodate the expected demands of future customers, and the law obliges developers to let others join the project at incremental cost. The Secretary of State can also oblige a pipeline to offer access to third parties.

The industry, in conjunction with government, has also developed alternative codes of conduct for arranging access by negotiation.

D.3. British Electricity Networks

British electricity networks are regulated natural monopolies. There are three separate transmission networks in Britain: National Grid Electricity Transmission; Scottish Power Transmission; and Scottish Hydro Electric Transmission Ltd (SHETL). These networks are owned by different companies, but National Grid operates the whole transmission system in its capacity as “GB System Operator”. There are fourteen distribution networks, owned by seven different companies.

The two Scottish transmission networks and nine of the distribution networks are owned by vertically integrated companies with interests in generation and retail supply. However, all network businesses must be legally unbundled from their other non-network businesses. This monopoly provision of electricity networks means that investments in network capacity are subject to major regulatory debates at periodic reviews of their price controls. The regulator is deeply involved in discussions over which investments are required and whether the companies have undertaken them efficiently (i.e. at an “efficient” cost).

Transmission system users, including generators, consumers and connected networks, pay entry charges and exit charges that give them the right to supply power to or buy power from the wholesale market, respectively. In principle, entry capacity runs from the point of entry to the market, and exit capacity runs from the market to the point of exit. However, since the location of the market is not specified in the market rules, the exact nature of entry and exit capacity is undefined. In any case, electricity networks suffer from “network externalities”, meaning that the capacity available to one user depends on the pattern of usage by another user. It is not therefore possible to say with certainty what investments are used to provide any particular piece of entry (or exit) capacity, or what assets any generator (or supplier) is using at any time.

The regime therefore diminishes the amount investors would be willing to pay for the provision of additional capacity, as they would retain no property right over any capacity created by their investment. At the same time, regulated transmission companies have been unwilling to undertake “risky” investments to increase network capacity for low regulated rates of return due to the threat that the regulator will disallow capital expenditure ex post. These concerns have prompted the government and Ofgem to undertake the Transmission Access Review. One of the aims of this review is to create efficient investment incentives for the transmission network companies to provide connections to the large numbers of small renewable generators in Scotland. Given the speculative nature of such investments, the companies have been unwilling to invest in capacity until the developers of the generation show some willingness to pay for it, but the costs are proving to be prohibitive.

Like the onshore gas networks, investments in British electricity transmission and distribution networks are planned and provided by regulated natural monopolists, with
oversight and intervention from Ofgem. National Grid holds auctions for entry capacity but, given the lack of any direct link between entry capacity and specific assets, these auctions do not immediately indicate any need for investment. Thus, investments are not market driven, but are provided by a number of separate de facto central planners. As we describe above, the low regulated rates of return offered on network investments have led to an under provision of certain “risky” investments in recent years.

D.4. US Interstate Pipelines

Interstate gas pipelines in the US are provided under a highly competitive, market-based (but tightly regulated) framework. The competition arises because any investor may build an interstate gas pipeline between any two points provided that they offer the pipeline’s capacity to third parties via open season subscription to long-term contracts. All interstate pipelines are price regulated, and their tariffs and access terms must be approved by the Federal Energy Regulatory Commission (FERC). This regulation of prices and access terms ensures that any investor can identify a need for and build a new pipeline efficiently.

Therefore, FERC does not play a role in planning or specifying investments in pipelines, which it leaves to the market. FERC’s approach to regulating interstate pipelines focuses entirely on ensuring that the market for pipeline capacity operates competitively and promotes efficient decentralised investment decisions. Hence, there are no provisions for central planning by either the regulator or the government.

Shippers that fund any capacity enhancements acquire an inalienable (contractual) property right to that capacity. Contract for capacity on interstate pipelines must be defined on a point-to-point basis and must be tradeable on a common basis (so that any shipper can buy and sell it easily). Capacity markets are highly transparent due to rules set down by FERC that require pipelines to publish the prices, ownership and usage of their capacity. Moreover, pipelines’ accounts are public information and tariffs are derived directly from the costs as they appear in the pipelines’ accounts.

Decisions by FERC since the 1980s have focused on promoting competition between pipelines and preventing vertical foreclosure between pipelines and gas shipping businesses. For instance, FERC has enforced unbundling of pipeline ownership from gas shipping, by obliging the (formerly integrated) pipeline companies to sell their gas upstream of their pipelines (at so-called “pooling points”). To facilitate competitive investments in alleviating constraints, FERC also requires all pipelines to provide a connection on request to any other pipeline, although there is no obligation on pipeline operators to accept the gas of shippers if they do not hold contractual capacity rights.

The US gas pipeline system therefore functions by creating well-defined – and tightly regulated – property rights which link individual investments to tradeable contracts. This system permits efficient long-term competition in the construction of new pipelines and efficient short-term competition in the trading of existing capacity.

D.5. The British Rail Network

Network Rail is the monopoly owner and operator of the British rail network, which is accessed by private freight operators, franchised passenger train operators and open access
(i.e. non-franchised) passenger operators. Network Rail does not operate passenger or freight train services. Network Rail’s access charges are regulated by the Office of Rail Regulation (ORR) through a price control that operates in a similar way to the UK privatised utilities.

However, unlike in the utilities sector, the government plays a central role in planning and specifying investments in the rail network through the franchising process and through Network Rail’s periodic reviews of access charges. The government pays a substantial subsidy to the rail industry through direct grants to Network Rail and through franchise agreements. Hence, major investments in British rail infrastructure are specified (and largely funded) by the government. While the government performs its role as central planner at a relatively high level, Network Rail also plans and specifies smaller investments under the supervision of ORR.

In addition to government-funded investment schemes, open access and freight operators can also sponsor specific investment projects. The industry regulator has put in place some measures to allow investors to capture the benefits of those investments, even though they remain the property of Network Rail, such as (1) a rebate mechanism, whereby companies accessing new capacity provided by another investor pay that investor a “rebate”, and (2) the use of long-term access contracts in certain cases. These measures are designed to promote efficient investments by network users and prevent the distortion of competition that would otherwise arise from network users “free riding” on other users’ investments. However, they remain a relatively minor part of the investment planning process.

D.6. English and Welsh Water Companies

The UK water sector consists of a large number of separate vertically integrated regional companies owned and operated by both private and public companies. These companies are responsible for centrally planning and undertaking investments on their networks. All companies are subject to price controls that the regulator, Ofwat, resets every five years, when investments can be subject to significant regulatory debate and scrutiny.

Companies make investment proposals to the regulator at periodic reviews, which Ofwat then scrutinises. Companies propose investments intended to ensure they can maintain current network services, e.g. by replacing obsolete pipe, and that they can meet expected growth in demand for network capacity. Ofwat scrutinises growth forecasts and required investments, assessing both the scope of proposed investments and the proposed unit costs. Companies can also propose network developments (e.g. interconnections between water systems) as substitutes for water resource developments (e.g. new reservoirs) when considering options to balance supply and demand for water. For example, companies in water stressed zones may consider water transfers from areas of water abundance when determining their least cost water resource plan. Water companies also purchase “wholesale” water from one another, although negotiations over the terms of such purchases have given rise to disputes, because of the lack of a clearly defined market price for water.

Despite the vertically integrated industry structure, recent changes in the regulatory framework are intended to allow large customers (at least) to switch their supplier of water. Existing rules allow eligible suppliers to access the network at an access price equal to the regulated retail charge minus the incumbent’s avoidable costs. However, no customer has yet changed supplier, possibly because the discount for avoided costs has been too low to cover
the additional costs of the alternative resources. Ofwat see the current access conditions as a barrier to entry, and has proposed changes to the rules including the unbundling of the licence into separate retail and upstream licences. However, the avoidable costs of existing water supplies may be too low (and insufficiently different between suppliers) to permit many customers to switch their supplier in a way that increases efficiency.

D.7. German Gas Pipelines

Germany has a highly fragmented gas industry, with 716 separate gas network operators. Historically, these networks have developed at three hierarchical levels: there are currently 9 supra-regional gas transport network operators, 10 regional transport network operators and 697 regional or local distribution networks.

There is no explicit law requiring co-ordination of construction among network operators and there may be competition between pipelines. However, in practice coordination of investment has been a long tradition in Germany. Most of the pipelines were built by established vertically integrated gas companies to carry their own gas. The supra-regional transport network was in many cases developed by several operators working together, and some assets are owned by joint ventures.

German law now requires all gas networks to offer their capacity through an “entry/exit” system. In particular, network access must not be attached to any transport path or transaction. As in the UK, the adoption of entry-exit will allow new entrants to trade gas among themselves without relying on the incumbent vertically integrated companies. However, the regulator is encouraging an expansion of entry-exit systems, so that they cover several pipelines within a “market area”. This expansion will further weaken the link between capacity and specific investments, thereby increasing the need for coordination of investment and entrenching the position of the existing network operators. It also creates potential for the same disputes that occur in the UK over the level and type of investments needed to provide network capacity and over the allocation of existing capacity between users.

D.8. Summary and Conclusion

The networks we have surveyed offer a variety of different approaches to providing incentives for efficient investment.

D.8.1. Central planning and government intervention

Among the cases we reviewed, the UK rail system is unique in that it is dependent on government subsidy, with the result that government takes a direct interest in the level of service and investment requirements.

Most other networks in Britain rely on the ability of a monopoly network operator to plan investment. In the water industry, the network operators are integrated with commodity supply businesses. In the (onshore) electricity and gas networks, the government has taken steps to unbundle networks from commodity trading, but so far only National Grid’s electricity and gas networks and some electricity distribution networks have no interest in energy trading.
D.8.2. Unbundling and centralisation of investment

The effort to unbundle networks has concentrated on creating a system in which independent producers, traders and suppliers can manage their business without being dependent on the incumbent supplier. This desire has led to the creation of “entry-exit” capacity regimes, which give every trader immediate access to the same (virtual) trading point. The electricity transmission system in Britain and the gas super-regional system in Germany have taken this system to a higher level, by extending it across several networks owned by different players.

The development of this entry-exit regime is often seen as a major advance for competition in energy trading. However, in practice, some of the resulting trades are fictitious (i.e. they concern the exchange of energy by traders in different locations, which can only be fulfilled by the network operator arranging gas swaps behind the scenes). Moreover, the separation of transmission capacity from any physical facilities means that users cannot see or provide signals on the value of capacity sufficient to promote efficient, decentralised investment. Instead, the creation of entry-exit systems has entrenched the central role of existing network owners in identifying and fulfilling investment needs. The coordination of investment across many pipelines operating within the same entry-exit system (“market area”) can only be solved by detailed cooperation between network owners.

D.8.3. Decentralised investment decisions by competing pipelines

Two of the systems we have reviewed were set up to promote competition between pipelines, i.e. decentralised investment decisions driven by the needs of the users. The offshore gas pipeline regime operating in the British sector of the North Sea is driven largely by users’ need for point-to-point pipeline capacity. It has been largely successful in encouraging the investment necessary to land oil and gas from fields in the sector, subject to two caveats.

First, the legal framework gives the Secretary of State responsible for energy powers to direct investors in offshore pipelines to provide additional capacity for future demand, and to accommodate other parties on payment of the incremental cost of meeting their needs, and to offer third parties access to existing capacity on specified terms. Faced with the uncertainty inherent in these powers, investors have instead developed a joint code of conduct, which sets out alternative and (presumably) preferable rules for arranging investments in new pipelines and access to existing ones. A large number of pipelines are joint ventures, which is another way to promote cooperation and to reduce risks. Investment in offshore gas pipelines is therefore collaborative, rather than competitive.

Second, the rule that any party can ask to be included in a project at incremental cost can act as a factor discouraging users from initiating projects. Economies of scale give the late comer an advantage, because its average costs per unit of capacity will be lower that the average costs paid by the initial project developers. In some cases, this may give the late comer an advantage in competition (as well as an immediate cost saving). It may also lead to some marginally profitable projects being delayed, as all investors hope to be able to join in at lower cost at a later stage.

However successful the offshore gas arrangements have been in Britain, the US interstate pipeline system is normally reckoned to have performed well in recent years. The differences between the regimes are therefore instructive. First, no government agency dictates the form
of a pipeline investment, provided that its developers give all comers a sufficient opportunity to participate, via an open season process. In this open season, no party has any right to ask for capacity at incremental cost; the participating users negotiate an equitable sharing of costs (i.e. normally proportional to the capacity they get in return).

Intrinsic to the approval of the project is an obligation to make capacity available to users via contracts with standard terms, in particular the ability to trade capacity (without reference to any regulatory authority). Similarly, FERC does not mandate access to existing networks; instead holders of capacity have an incentive to trade any unused capacity (or else the network operator will sell it and capture the revenues).

FERC has created an obligation on pipelines to accommodate interconnections (“taps”) with new pipelines. That means that any investor can invest in pipeline capacity to alleviate constraints. For instance, suppose a pipeline runs in a line between points A, B, C and D. The market for capacity may indicate a high price, i.e. a shortage, for capacity from B to C, but low prices for the other sections (A to B and C to D). Any investor can build a parallel pipeline (a “loop”) from B to C, and can expect to be able to tap into the existing pipeline at these points. By this method, the market coordinates competing investors to invest in capacity where it is needed.

The success of the US regime therefore relies on a regime that creates tightly defined and tradeable property rights, i.e. standard capacity contracts that reflect the nature and costs of the underlying investment. The price signals created by markets in this capacity then provide signals that encourage efficient investment.

D.8.4. Conclusion

The networks we have reviewed provide a wide range of experience, with different degrees of government intervention and decentralisation. The most market-driven system is the US gas pipeline network, in which regulatory policies created tightly defined contractual (property) rights that directly reflect the underlying investments. The market in pipeline capacity provides a sufficient price signal to motivate investment in new pipelines.

The offshore gas pipeline regime in the North Sea shares some elements of the US gas pipeline regime, but the potential role of the Secretary of State weakens investors’ rights over their own investments. As a result, the industry has developed its own, collaborative methods to induce investment.

The other networks we reviewed all have even weaker links between investments and capacity. As a result, investment is (and will always be) managed by a monopoly network provider. Where different networks have been placed under one capacity regime (“market area”) coordination of their investments will represent a challenge. The reliance on monopoly or coordinated provision creates a need for regulatory suspension of investments and of costs in general.
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