Effectiveness of Financial Incentives for Carbon Capture and Storage*

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Introduction

Over the last two decades, governments around the world have enacted various types of financial incentives to encourage the construction and operation of Large-Scale Integrated Projects (LSIPs) for Carbon Capture and Storage (CCS) of carbon dioxide (CO_2).[1] LSIPs are important to the development and commercial deployment of CCS because they are at full commercial scale and integrate the multiple technologies needed for CCS. They are particularly challenging because they have high capital costs, usually in excess of US$1 billion, may entail significant financial, business and technical risks and must operate commercially, not just as research and development projects.

Some of the financial incentives that apply to CCS were intended to reduce greenhouse gas emissions from a broad range of sources; others were specifically targeted at incenting the development of CCS projects. All but one of the incentives that specifically target CCS were enacted since 2005,[2] providing about a decade of experience with these incentives.

Governments put these incentives in place because CCS at its state of technical development was seen as not financially viable in commercial applications without them. CCS would add to the capital and operating costs of the commercial facilities of which they were an integral part, which would make those facilities uncompetitive compared to other facilities without CCS. The idea was to incent first-of-a-kind and other early-stage projects at commercial scale in order to enable the learning of design, construction and operational lessons. These lessons would drive down the cost to a level that would make them competitive with other low- or no-emissions technologies. Such learning is typical of what occurs with process equipment. Over time, as experience is gained, the cost of CCS would come down.[3] Indeed, such learning has already taken place as a result of CCS projects already in operation.[4] The expectation is that the cost of reducing carbon emissions would fall below the value of such emissions reductions for all such facilities on a permanent basis.[5]

An array of financial incentives has been used by governments to stimulate private investment in CCS projects in various countries throughout the world. The CSLF Incentives Registry, for example, found about 100 financial incentives used for CCS through 2010.[6]

This paper describes the types of incentives that have been implemented for CCS LSIPs, evaluates their effectiveness for CCS projects that have become operational using those incentives or since 2008[7] and then draws preliminary lessons from this experience.

1 LSIPs are projects that are active or planned, of commercial scale and that integrate, capture, store and sometimes transport CO_2 within an integrated system. The LSIP concept was first defined in Worley Parsons, "Strategic analysis of the global status of carbon capture and storage. Report 1: status of carbon capture and storage projects globally," Report to Global CCS Institute, 1 November, 2009.

2 The first financial incentive for CCS was an offshore carbon tax in Norway enacted in 1991 that led to the development of the Sleipner and Snøhvit CCS projects. This was not, however, the first carbon tax, which was actually enacted by Finland the year before, in 1990, but it was not intended to incent CCS, which was not an option at that time or for Finland. Sweden enacted a carbon tax in 1991, but industry pays only 50% of the tax and it does not apply to power generation. Demark and the Netherlands have also had carbon taxes since 1992, again not intended specifically for CCS.

3 Examples of process technologies that have experienced learning-based cost reductions include flue gas desulfurization, selective catalytic reduction, gas turbine combined cycles, oxygen production, hydrogen production, LNG processing and hydrogen production. See Edward S. Rubin, Sonia Yeh, Matt Antes, Michael Berkenpas and John Davidson, "Use of experience curves to estimate the future cost of power plants with CO_2 capture," International Journal of Greenhouse Gas Control, 1(2007) 188-197, 28 February 2007. Some specific ways CCS costs could be reduced are outlined in UK Carbon Capture and Storage Cost Reduction Task Force, "The Potential for Reducing The Costs of CCS in the UK, Final Report," May 2013.

4 For example, SaskPower projects that the second plant to be built with the capture technology at its Boundary Dam project would cost 30% less than the first. See www.saskpowerccs.com/newsandmedia/latest-news/the-coal-paradox. In addition, much of the design for LSIPs is based on prior learning and scaling up from smaller-scale project.

5 Incentives discussed in this paper differ in scale and scope from government R&D expenditures or cost sharing on small pilot projects in that they are intended to support projects that are commercial in both purpose and size.

6 Jeffrey Price, "CSLF Registry Update," Presentation to the CSLF Policy Group, October 7, 2010.

7 2008 is the earliest any CCS incentive except the Norway carbon tax could have incented a CCS project to operate.

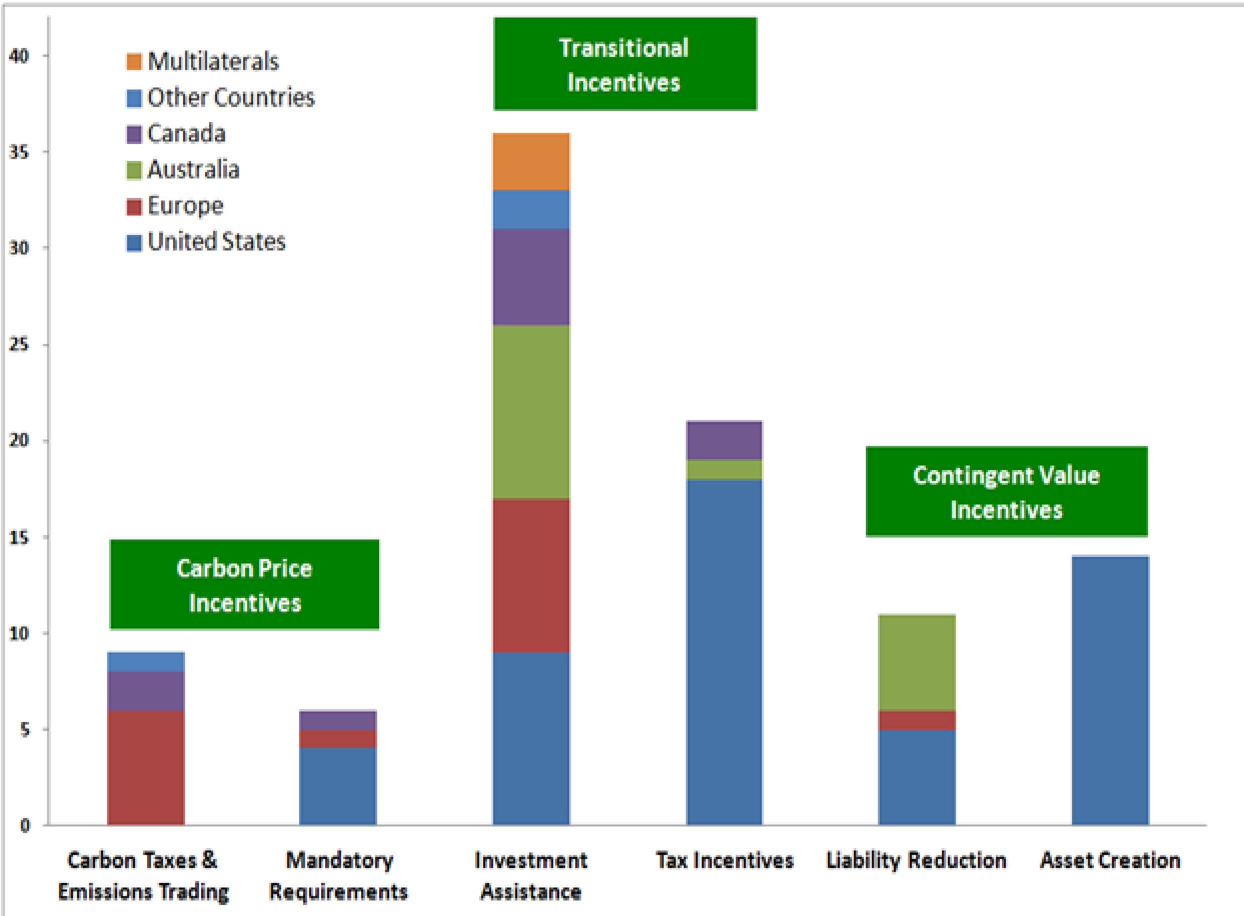
Types of Financial Incentives

Financial incentives for CCS and their implementation vary with the financial needs of the intended CCS application and the financial and economic practices of the jurisdiction in which the CCS project is to be undertaken. Some incentives are targeted at specific applications (e.g., power generation) while others have broader applicability. Three broad categories of incentives have been implemented by governments:

1. Carbon price incentives (carbon taxes, emissions trading, and mandatory requirements);
2. Transitional incentives (investment assistance and tax incentives); and
3. Contingent value incentives (liability reduction and asset creation).

Various types of incentives are used within each category. In some jurisdictions, multiple incentives are used and more incentives have been proposed over the years. Virtually all but the Nordic and Netherlands carbon taxes (discussed below) have been enacted since 2005. Figure 1 provides an overview of the types of incentives that have been in place for CCS.

Figure 1. Number of CCS Incentives by Type and Region



Source: Based on Jeffrey Price, "CSLF Registry Update," Presentation to CSLF Policy Group, Oct. 7, 2010

<u>**Carbon price incentives**</u> are intended to provide a permanent value for the CO_2 emissions reductions achieved through CCS so that developers of commercial projects can count on receiving that value from their investments. Essentially, these incentives put an explicit or implicit price on the CO_2 emissions. The price of CO_2 varies from US\$168/tCO_2 (Sweden)

to US$1/$tCO_2$ (Mexico) in 2014, but not all prices apply to a sector with CCS potential.[8] Three types of carbon price incentives that give a market value to emissions reductions have been used:

- Carbon taxes have been implemented in several countries and two Canadian provinces. These including Australia (now repealed); British Columbia; Chile; Costa Rica; Finland; France; Iceland; Ireland; Mexico; Netherlands; New Zealand (now repealed); Norway; Quebec; Sweden and Switzerland.[9] A carbon tax can be an effective financial incentive for CCS if: (1) the tax applies to an industrial or power process from which CO_2 can be captured; (2) the costs of CO_2 capture, transport and storage total less than the amount of tax that would be otherwise paid; (3) the project with CCS is still financially viable even after the expenditures on CCS; and (4) the tax is expected to continue through a financially-significant portion of the life of the project. Carbon taxes in Norway on offshore oil and gas production have met these criteria and been effective incenting CCS. In all the other jurisdictions, carbon taxes do not cover the sectors in which CCS would be used, the carbon tax has been far below the cost of CCS, or has not been permanent enough to stimulate investment.

  In Norway, the carbon tax enacted in 1991 applies to various sectors of the economy at different tax rates. The initiation of CO_2 emission taxes for petroleum-related activities on the continental shelf was a driver for the state-owned Statoil to engage in CCS. Statoil credits the carbon tax for stimulating investments in CCS at the Sleipner and Snøhvit projects. Norway increased the tax rate for offshore oil and gas production 210 NOK to 410 NOK per ton of CO_2 in 2013, nearly a doubling of the tax rate.

- Emissions trading schemes. Several jurisdictions have emissions trading schemes for CO_2 including the European Union; Alberta, Canada; China (pilots in selected provinces)[10]; California/Quebec; Japan; and the Regional Greenhouse Gas Initiative in the Northeast United States. To be an effective incentive for CCS under these schemes: (1) the price of allowances under such a scheme has to be high enough to cover the gap between the project costs and potential revenues, and (2) CCS must be an acceptable means of emissions reduction. Other than in Alberta, emissions trading has not proven to be an adequate incentive, for the most part because allowance prices have been too low.

  In addition, emissions trading for developing and transitional economies has been covered by the Clean Development Mechanism (CDM) and Joint Implementation (JI) respectively.[11] Although projects have been proposed under CDM, none have gone forward for several reasons. The treatment of CCS under CDM has long been controversial and was only approved in 2011; the CDM project application process is long and ponderous; and the value of CDM allowances (which is linked financially to the value of allowances in the emissions trading schemes in industrialized economies) has been too low to justify investment in CCS.

  Most emissions trading schemes allocate allowances to the designated sectors and allow the owners of those facilities to trade allowances among themselves. Alberta's trading scheme is unique in that it is project based. Under this scheme, large industrial emitters may purchase offset credits from unregulated projects that have voluntarily reduced their emissions in Alberta using approved protocols.

- Mandatory requirements include portfolio standards, facility performance standards and mandatory emissions reductions. Portfolio requirements have been implemented in two US states, Utah and Illinois. In Utah, CCS - along with renewables - is a clean energy option that electric utilities must use starting in 2025 to generate 20 percent of their electricity, but so far only renewable facilities have been built to comply. In Illinois, the Clean Coal Portfolio Standard law requires any new "clean coal" power plant to sequester an increasing amount of its carbon dioxide emissions, but also compels Illinois electric retailers to purchase up to 5 percent of their requirements from "clean coal" facilities. Further, the law also entitles one "clean coal" facility with a final air permit to enter into 30-year purchase agreements for sale of its output. This law was upheld in court in July 2014 and will be used to assure revenues for the FutureGen 2.0 project in Meredosia, Illinois.
  Facility emissions performance standards that would require CCS have been enacted in Alberta, Canada, and in the

8 Ecofys, "State and Trends in Carbon Pricing," Report to the World Bank, 88284, Washington, DC, May 2014.
9 http://www.worldbank.org/content/dam/Worldbank/document/SDN/background-note_carbon-tax.pdf.
10 On November 25, 2014 China announced that it would implement a national carbon market starting in 2016.
11 Ecofys, *op. cit*.

US states of California and Montana. The UK also has a performance standard as a backup which requires CCS on all new coal-fired power plants. In addition, the US Environmental Protection Agency has proposed a rulemaking for new fossil power plants that would essentially require any new coal plants to use CCS for part of their emissions. No CCS facilities have been built under any of these standards, mostly because power plants that do not use CCS have been more competitive in each of those markets.

Transitional incentives are designed to close the gap between costs and the currently low value of CO_2 emissions reductions.

- Capital and operating subsidies are copayments by governments that bear some of the cost of the CCS project. These are probably the most common type of financial incentive, have been used throughout the world, and have been the most effective type of incentives. Three effective subsidy programs are those operated by the US Department of Energy, the Canadian Federal Government, and the province of Alberta, Canada.

The US Department of Energy has the most extensive capital subsidy for CCS under several different funding programs, the largest of which was part of a stimulus program for recovery from the 2008 - 2009 recession. Currently, cofunding of US$2.8 billion is in place for six active projects under development. This is added to US$8.2 billion in developer investments. One project, the Illinois Industrial CCS project, is operational. The second, the Petra Nova project, began construction in 2014.

The Canadian Federal Government provided C$240 million to SaskPower to pay for part of the capital expense of the SaskPower's Boundary Dam Integrated CCS project. An additional C$1 billion in capital costs was born by SaskPower which is a Crown Corporation electric utility owned by the province of Saskatchewan, so the entire amount of this project was government funded.

In 2008, Alberta set aside C$2 billion to support up to 75% of the costs of building four new CCS demonstration projects in Alberta that will permanently store up to 5 million tons of carbon dioxide. Revenue received by a project on the sale of CO_2, emissions credits, etc. will reduce allowable costs upon which the grant is based. Four projects were announced to receive funding under the program in 2010. Two of those projects, the Alberta Carbon Trunk Line project and the Shell Quest project, are currently under construction and expected to begin operation in 2015. Both of these projects captured CO_2 at relatively high concentration and used the CO_2 for Enhanced Oil Recovery (EOR). The other two projects to be funded by the program, Swan Hill Synfuels and Keep Hills 3/Project Pioneer, were indefinitely delayed because lower prices for their output made them uneconomic, even though both would also have used the CO_2 for EOR.[12]

Other subsidy programs have been less effective because they have ended before they could be used. These include Australia's AU$1.8 billion CCS Flagship program, the €1 billion European Energy Program for Recovery, Norway's funding of the full-scale CCS project at the Test Centre Mongstad, and the UK's first CCS Demonstration Competition.[13]

- Investment and trust funds accumulate funding based on charges to industry that can be later applied to CCS projects. These have been proposed but not yet used.
- Bonus emissions trading allowances have a value in an emissions trading scheme and have been used by the European Commission under its NER300 program, financed by 300 million allowances. These allowances can be sold for their market value, thus offsetting the cost of the project. NER300 was designed to fund both renewable and CCS projects but only funded renewable projects in its first call for projects. According to the Commission, no CCS projects were awarded grants in the first call because "most CCS projects put forward were not confirmed by the member states concerned."[14] To some extent, this was a result of the inflexibility of the NER300 program.[15] CCS projects are much larger and more complex than renewables and take much longer to develop and evaluate. NER300 also became

[12] Capture of CO_2 for EOR and other beneficial uses such as chemical production is sometimes referred to as Carbon Capture Utilization and Storage (CCUS). Revenues from such beneficial uses can improve the economics of projects.
[13] A second UK Demonstration Competition has selected two projects, White Rose and Peterhead, as preferred bidders for £1 billion. Final investment decisions for both are expected by the end of 2015.
[14] European Commission, "Questions and Answers on the outcome of the first call for proposals under the NER300 programme," Memo, Brussels, 18 December 2012.

less effective for CCS because the price of the CO_2 emission allowances turned out to be far lower than projected, meaning the cost offset was less than expected. In the second call, just one CCS project - White Rose, a retrofit of the Drax power station in the UK - was awarded funding. At its meeting in October 2013, the European Council agreed to organize a new NER400 program financed by 400 million allowances. The effectiveness of this program for CCS remains to be seen.

- Tax incentives may include various types of tax credits, exemptions or enhanced deductions such as accelerated depreciation. They are only effective, of course, in incenting actions by taxable entities. Tax incentives for CCS have been used most commonly in the United States, both at the Federal and state level. They have also been used in Canada and Australia. The most extensive programs have been the tax credit programs for CCS administered by the US Department of Energy. Under these programs, 8 entities have received $2 billion in tax credit allocations since 2009. Three of these projects, however, were cancelled for various reasons.[16]

- Loan guarantees reduce the risks and costs of debt to projects. Attempts to use loan guarantees as an incentive for CCS have been made in the United States. The US Department of Energy issued two solicitations, one for up to $6 billion in guarantees in 2008 and the other for up to $8 billion in guarantees in 2013. Currently, $8 billion in loan guarantees are available but unused for advanced fossil energy projects, including CCS. By contrast, US Department of Energy loan guarantees have been used for new nuclear plants. Other loan guarantees have been used by the Department of Energy for renewable energy projects. The likely reasons that loan guarantees have not been used for CCS projects is that substantial application fees are required to be paid for loan guarantees starting at the beginning of the application process and other fees continue over the term of the guarantee.[17] The applications fees may not be affordable to developers at the early phase in the project development process in which they would submit an application, especially since there is no assurance that the loan guarantee would be granted.[18] Further, continuing fees during the term of the loan guarantee may or may not be competitive with what is available commercially. This leaves developers with little incentive to apply.

- Contracts for Differences. Contract for Differences (CfD) are currently planned for use with large scale clean energy projects including CCS, nuclear and renewable projects in the United Kingdom. A CfD is a long-term contract that pays the generator the difference between the market price for electricity and an estimate of the long-term price needed invest in a technology (the "strike price") if the market price is below the strike price. If the market price is above the strike price, the generator pays the government the difference. CfDs have long been used for risk management in UK electricity markets. For CCS, the UK government will enter into a CfD with CCS project developers within a Feed-in-Tariff framework to ensure enough revenues from CCS plant operation to cover costs. Specific terms such as the value, strike price and time period are to be negotiated on a project-by-project basis, based on expected market conditions and CCS project costs. Two projects, Peterhead and White Rose, are conducting Front End Engineering Design (FEED) studies and may be awarded CfDs in addition to government capital funding.[19]

Contingent value incentives create economic value based on project implementation. These incentives have included:

- Liability reductions which limit risks to a developer related to long-term storage. Several methods have been proposed including transfer of long-term liability to governments, insurance and government-backed risk pools. So far, the only type used has been the transfer of risks to governments, which has been used in Australia, the European Union and the United States.

- Ownership rights which may be held for use or, under some circumstances, be sold to others. There are several types of value to CCS. Pore space ownership is primarily an option in the United States where subsurface rights are privately held and may be separated from surface ownership. This has even motivated at least one US company, C12Energy, at

[15]See http://bellona.org/news/ccs/2013-11-ner-300-scrutinized-european-parliament-hearing.
[16] Peter Folger and Molly Sherlock, "Clean Coal Loan Guarantee and Tax Incentives: Issues in Brief," Congressional Research Service, R43690, August 19, 2014. Those entities awarded tax credits include Christian County Generation, LLC (cancelled); Summit Texas Clean Energy, LLC; Mississippi Power Company; Faustina Hydrogen Production (cancelled); Lake Charles Gasification, LLC (cancelled); Hydrogen Energy California, LLC: STCE Holdings, LLC; and SCS Energy California, LLC.
[17] See http://www.energy.gov/sites/prod/files/2014/04/f14/Fossil-Solicitation-FINAL.pdf pages 18 and 19.
[18] Application fees were waived until later in the development process for renewable energy projects.
[19] Department of Energy and Climate Change, "Next steps in CCS: Policy Scoping Document," August 2014.

one time to acquire such rights speculatively. Also in the United States, eminent domain rights have been enacted in some states for CO_2 pipelines as have provisions for the leasing of state lands for geologic storage.

Effectiveness of Incentives

The continuing major challenge over the last decade has been to build first- (and soon second-) generation LSIPs. Financial incentives have now been in place for many years and CCS projects reliant on them have been and are being built during this period, some of them using those incentives. Using the database of LSIPs assembled by the Global CCS Institute, it is now possible to determine which financial incentives have been effective in stimulating LSIPs and which have not.

The Institute classifies LSIPs according to how far along they are in the development process. It categorizes plants into five stages of development. The most recent data from the Institute identifies a total of 55 LSIPs in one stage or another of development.[20] This is down slightly from a total of 62 LSIPs first identified for the Institute in 2009.[21] It also represents a changing mix of projects as some projects have been dropped for various reasons and new projects have been announced. The three stages furthest along in development[22] are:

- Operate - operate, maintain and improve costs;
- Execute - detailed design and construction after final investment decisions; and
- Define - finalize scope and execution plan.

Between 2008 and October 2014 a total of eight LSIPs representing 13.7 MTPA of CO_2 storage volume entered the Operate stage and another nine were in the Execute stage. The next projects that are likely to operate are those in the Define stage that are scheduled for operation by 2016 or 2017. There are seven of those. There are a total of 24 projects in all three categories. The characteristics of these projects are summarized in Table 1.

Table 1. Summary of LSIPs in Operation or Advanced Development Since 2008

Stage of Development	Operate	Execute	Define*	Total
Total CO_2 Volume (MTPA)	**14.6**	**13.5**	**5.8**	**33.9**
Total Projects	**8**	**9**	**7**	**24**
Projects by type				
- Natural Gas Separation	5	2	1	8
- Industrial Separation	2	5	2	9
- Power Generation	1	2	4	7
Oil & Gas Industry Involvement	8	8	5	21
- Capture	6	3	3	12
- EOR	6	5	5	16

*Source: Global CCS Institute, "Status of Carbon Capture and Storage," November 2014. * With expected date of operation by the end of 2017*

[20] Global CCS Institute, "Status of Carbon Capture and Storage," 5 November 2014.
[21] Worley Parsons, *op cit*.
[22] Two earlier stages of project development not shown in this table are "identify," which is to establish a preliminary scope and business strategy for the project, and "evaluate," which is to establish development options and an execution strategy. In the normal process of project development, many projects are abandoned at each stage when it is determined that they do not meet the criteria to advance to the next stage.

Several characteristics of these projects are readily apparent from Table 1. First, most of these projects - 16 of 24 - use the CO_2 for EOR. Second, most of the operational projects are natural gas separation, which is probably the least expensive form of separation since the CO_2 needs to be separated from the natural gas anyway in order for the natural gas to be marketable. Projects that combine these characteristics have both a very low capture cost and a value for the CO_2. The only operating projects that do not use EOR are the two projects in Norway that face a carbon tax and use natural gas separation. The involvement of the oil and gas industry is also very clear in all but three of the 24 projects, but a shift towards other industries and power generation is also apparent. Details of these projects are shown in Table 2, including information on their financing and financial incentives, where information is available. The progress since they were categorized in 2010 is also clear from Table 1.

Operate-stage projects. Eight large scale integrated CCS projects are currently in operation. Of those, four - the Century Plant, Coffeyville Gasification Plant, Lost Cabin Gas Plant and Petrobras Lula Oil filed - were commercially viable without any financial incentives. All four sell or use CO_2 for EOR. Three of these separate the CO_2 from a natural gas production stream and the fourth gasifies inexpensive petroleum coke to produce ammonia, also producing a concentrated CO_2 stream. The other four did have government incentives. Two of these - Sleipner and Snøhvit - were incentivized by the Norwegian offshore carbon tax and are the only two in operation not using the CO_2 for EOR. The two others - Air Products Steam Methane Reforming and Boundary Dam - both received extensive government co-investment.

CCS has been widely planned as a tool for the power generation industry, particularly for coal-fired generation and, indeed, is expected to be widely used for this purpose. Yet the first coal-fired power generation LSIP, the Boundary Dam Project, only started operating in 2014.

Execute-stage projects. Nine projects are in the execute stage. Seven of these have government co-investment. The other two - the Abu Dhabi CCS Project and the Uthmaniyah CO_2 EOR Demonstration Project in Saudi Arabia - are being undertaken by government-owned entities involved in the oil and gas industry. They are also part of broader initiatives to advance the local capabilities to do CO_2-driven EOR. In the case of the Uthmaniyah Project, the CO_2 comes from low-cost natural gas separation. The Abu Dhabi CCS Project is an innovative industrial application of CO_2 capture from a direct reduction process steel mill. This project is being developed in anticipation of strong growth in the anticipated need for CO_2 for EOR in Abu Dhabi.

Define-stage projects. Seven projects in the define category are scheduled for operation by the end of 2017, but none of them has yet reached the point where a definite investment commitment has been made. It is not at all clear which of these will ultimately be built and go into operation. Two of these, FutureGen and the ROAD project, are flagship projects, have been in planning for many years and represent concepts that have evolved over the years. FutureGen 2.0 (actually the third FutureGen concept) has received a US$1 billion commitment of US government funding towards its US$1.65 billion capital cost plus Illinois state incentives for liability assumption and purchases of electricity. The ROAD project is slated to receive funding from both the European Commission and the government of the Netherlands.

Still, corporate finance of a large CCS first-of-a-kind project can have a signification impact on the creditworthiness and valuation of even a large company. This has certainly been the case with the Southern Company, whose valuation has been negatively affected by the large cost overruns of its Plant Kemper project, even with substantial government co-investment.

Table 2. Financing of Current, More Advanced Large-Scale Integrated CCS Projects, Late 2014

2014 Status	2010 Status	Project Name	Owner/Alliance	Country	Volume CO_2 (mtpa)	Operation Date	Facility Details	Capture Type	Storage Type	Capex	Government Investment	Project Developer Investment	Other Incentives
Operate	Define 2015	Air Products Steam Methane Reformer EOR Project	Air Products and Chemicals, Valero Energy Corporation, Denbury Onshore LLC	USA	1.0	2013	Hydrogen Production	Industrial Separation	EOR	$431 million	$284 million	$147 million	Texas incentives including tax benefit and pipline emminent domain.
Operate	Define 2013	Boundary Dam integrated Carbon Capture and Sequestration Demo Project	Sask Power	CANADA	1.0	2014	Power Generation	Post-Combustion Capture	EOR	C$1,240 million	C$240 M	C$1,000 M	Sask Power is a crown corporation so all financing is government.
Operate	Execute 2011	Century Plant	Occidental Petroleum, Sandridge Energy	USA	8.4	2010	Natural Gas Processing	Pre-Combustion Capture (natural gas processing)	EOR	$1.1 billion estimated	0	$1.1 billion estimated	none
Operate	Define by 2020	Coffeyville Gasification Plant	Koch Nitrogen Company, Chapparal Energy	USA	1.0	2013	Fertiliser Processing	Industrial Separation	EOR	NA	NA	NA	Verified emissions reductions (VERs)
Operate	Define 2014	Lost Cabin Gas Plant	ConocoPhillips, Denbury	USA	0.9	2013	Natural Gas Processing	Pre-Combustion Capture (natural gas processing)	EOR	$400 million pipeline	0	NA	none
Operate	X	Petrobras Lula Oil Field CCS Project	Petrobras	BRAZIL	0.7	2013	Natural Gas Processing	Pre-Combustion Capture (natural gas processing)	EOR	NA	NA	NA	NA
Operate	Operate	Sleipner CO_2 Storage Project	Statoil ASA	NORWAY	0.9	1996	Natural Gas Processing	Pre-Combustion Capture (natural gas processing)	Dedicated Geological Storage	NA	0	NA	US $59 offshore tax on CO_2
Operate	Operate	Snøhvit CO_2 Storage Project	Statoil ASA, Petro AS, Total E&P Norge AS, GDF Suez E&P Norge AS, Norsk Hydro, Hess Norge	NORWAY	0.7	2008	Natural Gas Processing	Pre-Combustion Capture (natural gas processing)	Dedicated Geological Storage	NA	0	NA	US $59 offshore tax on CO_2
Execute	Execute 2012	Alberate Carbon Trunk Line ("ACTL") with Agrium CO_2 Stream	Enhance Energy	CANADA	0.3-0.6	2015	Fertiliser Production	Industrial Separation	EOR	C$1.2B including operating costs	Canada C$63M Alberta C$495M	Remaining capital and operating costs	Alberta ETS
Execute	Execute 2012	("ACTL") with North West Sturgeon Refinery CO_2 Stream		CANADA	1.3	2017	Oil Refining	Pre-combustion capture (gasification)					
Execute	Execute 2014	Gorgon CO_2 Injection Project	Chevron with Exxon and Royal Dutch Shell as partners	AUSTRALIA	3.4-4.0	2016	Natural Gas Processing	Pre-combustion capture (natural gas processing)	Dedicated Geological Storage	~A2 billion	A $60 million	~A$1.94 billion	In anticipation of a carbon tax.
Execute	Define 2012	Illinois Industrial CCS Project	Archer Daniel Midlands	USA	1.0	2015	Chemical Production	Industrial Separation	Dedicated Geological Storage	$208 million	$141.5 million	$66.5 million	None

Table 2. Financing of Current, More Advanced Large-Scale Integrated CCS Projects, Late 2014 (Continued)

2014 Status	2010 Status	Project Name	Owner/Alliance	Country	Volume CO_2 (mtpa)	Operation Date	Facility Details	Capture Type	Storage Type	Capex	Government Investment	Project Developer Investment	Other Incentives
Execute	Execute 2014	Kemper County Energy Facility (formerly Kemper County IGCC Project)	Mississippi Power (Southern Company Subsidiary); KBR	USA	3.0	2015	Power Generation	Pre-combustion capture (gasification)	EOR	$5.6 billion	$270 million	$5.3 billion	$133 million in investment tax credits
Execute	Define 2015	Quest	Shell with Chevron Canada and Marathon Oil Sands	CANADA	1.08	2015	Hydrogen Production	Industrial separation	Dedicated Geological Storage	$1,300	Canada $120M Alberta $745M	435	Alberta ETS
Execute	X	Uthmaniyah CO_2 EOR Demonstration Project	Saudi Aramco	SAUDI ARABIA	0.8	2015	Natural Gas Processing	Pre-combustion capture (natural gas processing)	EOR	NA	NA	NA	NA
Execute	Define 2013	Abu Dhabi CCS Project	Masdar, ADN OC	UNITED ARAB EMIRATES	0.8	2016	Iron and Steel Production	Industrial separation	EOR	NA	NA	NA	NA
Execute	X	Petra Nova Carbon Capture (formerly NRG Energy Prish CCS Project)	NRG Energy, JX Nippon	USA	1.4	2016	Power Generation	Post-combustion capture	EOR	£1 billion	$167 million	$850 million	Japan Bank for Intntl. Cooperation and Mizugo Bank loan $250 million.
Define	Identify by 2020	FutureGen 2.0 Projecy	FutureGen Alliance	USA	1.1	2017	Power Generation	Oxy-fuel combustion capture	Dedicated Geological Storage	$1.65 billion	$1 billion	0.65 million	Illinois clean coal portfolio requirements; state liability assumption.
Define	X	PetroChina Jilin Oil Field EOR Project (Phase 2)	PetroChina	CHINA	0.8	2016-17	Natural Gas Processing	Pre-combustion capture (natural gas processing)	EOR	NA	NA	NA	NA
Define	Define 2015	Rotterdam Opslaf en Afvang Demonstriatie Project (ROAD)	Maasvlakte CCS Project C.V. JV of EON Benelux, Electrabel, GDF Suez and Alstom	NETHERLANDS	1.1	2017	Power Generation	Post-combustion capture	Dedicated Geological Storage	€1.2 billion	Netherlands up to €150 million; EU €180 million	~€860 million	GCCSI up to €5 million
Define	X	Sinopec Qilu Petrochemical CCS Project (formally Sinopec Shengli Congying CCS Project)	China Datang Group	CHINA	0.5	2016	Chemical Production	Pre-combustion capture (gasification)	EOR	NA	NA	NA	NA
Define	X	Sinopec Shengli Power Plant CCS Project	Sinopec	CHINA	1.0	2017	Power Generation	Post-combustion capture	EOR	NA	NA	NA	Sinopec said to have applied for aid.
Define	X	Yanchang Integrated CCS Demonstration Project	Shaanxi Yanchang Petroleum Group	CHINA	0.46	2016	Chemical Production	Pre-combustion capture (gasification)	EOR	NA	NA	NA	NA
Define	X	Sargas Texas Point Comfort Project	Sargas	USA	0.8	2017	Power Generation	Post-combustion capture	EOR	NA	NA	NA	Texas state benefits may be available.

X - Not in 2010 Report NA - Not Available

Sources: Global CCS Institute, Status of Carbon Capture and Storage, November 2014; MIT CCS Project Database at http://sequestration.mit.edu/tools/projects accessed November 2014; and project websites.

Four LSIPs in China are currently in the "Define" phase and China also has projects in earlier stages of development as well as smaller research and development activities. These projects are all being developed by large State-Owned Enterprises (SOEs), mostly in the oil and gas sector. SOEs in China do not have the same shareholder responsibilities for profitability as companies in other types of economies and they must carry out various mandates from the central government, one of which could be the development of CCS technology. For this reason, it is hard to define exactly what a "financial incentive" would be in China. Nonetheless, the SOEs may also work with various involved Ministries or research institutions which may also contribute financially. For example, it has been reported that the Ministry of Science and Technology (MOST) contributed ten percent of the funding for a 100,000 ton per year CCS project at a coal liquefaction plant operated by Shenhua in the Ordos Basin of Inner Mongolia.[23]

Lessons So Far

A number of lessons can be drawn from the financial incentives used for progress made so far on CCS LSIPs.

Early projects have been "low hanging fruit." Many of the CCS projects that have entered the operation or execute stages so far are what had been termed the "low hanging fruit." That is, they are projects which may have low capture costs, are located close to the area of storage so long-distance transport of the CO_2 is not needed, and can take advantage of revenue streams from the CO_2, typically EOR. Some have been economic even without financial incentives but others have required incentives. It is all very project-specific. The challenge now is to learn from these low hanging fruits and then move beyond them. This may require greater financial incentives than many of the already-operational projects. This is starting to happen and financial incentives are playing a role.

Projects succeed only when they achieve their overarching commercial purpose beyond CCS. CCS LSIPs that are being built and have become operational have an ongoing commercial purpose beyond just capturing and storing CO_2. This purpose may be a use for CO_2, most often EOR, but it can also be the production of electricity and/or chemicals or the development of technology for future use or as a hedge against future requirements. The commercial project as a whole - not just the CCS component - must be commercially viable. Effective incentives reinforce that business purpose and make its attainment easier with CCS by contributing enough value to make the project commercially viable. This has certainly been the case in projects developed for EOR. Companies that conduct early projects are those willing to take first-mover risks, but the perceived payoff from that risk needs to be significant.

Both project and corporate finance methods have been used to finance CCS projects. Many projects have been built by large entities using corporate finance - not project finance. Project finance allocates the revenues, costs and risks of a project to a stand-alone project entity. Corporate finance depends on the financial capabilities of the firm as a whole. Regardless of the financing method, CCS projects will be evaluated on a stand-alone basis against other investment opportunities. CCS projects using corporate finance have been implemented by large entities that are not "betting the company." The CCS project is only one part of a wider company portfolio.

Effective incentives accommodate the stage-gate process of project development. CCS LSIPs are developed using a "stage-gate" approach in which investments are made in incremental stages in order to manage risks. Much is learned about the viability of the project at each stage. Between each stage, a decision is made at a "gate" about whether to proceed to the next, more expensive stage. Projects that do not meet the criteria of the gate evaluation are dropped. As projects proceed from one stage to the next they become more likely to be carried out and better defined with costs that are more certain. Most large projects, especially first-of-a-kind, do not pass through all the gates and only a minority typically enters operation.

[23] Personal communication, Xiaolang Yang, World Resources Institute China Climate and Energy Program, November 2014.

As the Global CCS Institute's annual status reports indicates, many proposed CCS projects have been dropped for various reasons, even after they have received financial incentives. Among the most common reasons are projected costs that are too high, risks that cannot be addressed, and expected government co-financing that does not materialize.

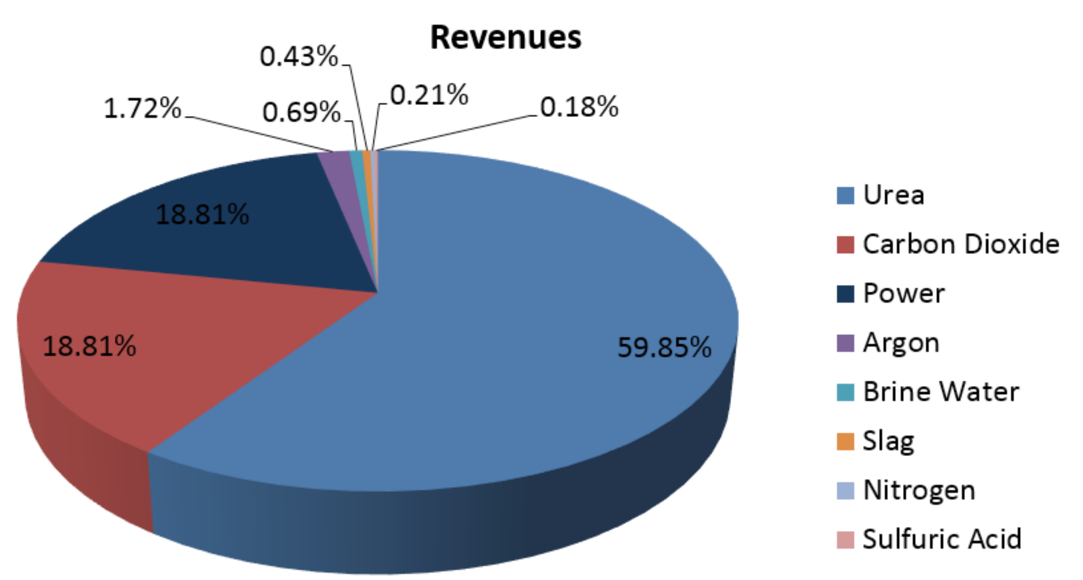
The most effective incentives are appropriate to the stage of development of the project. The cost of applying should not be beyond what is affordable to risk at each stage. Incentives larger than are needed for the current stage of a project run the risk of being stranded, that is, committed to projects that may eventually be cancelled or of blocking other projects that could have received the budgetary allocations. Examples of that are Clean Coal Tax Credit Allocations awarded by the US Department of Energy to several projects that eventually were cancelled.[24] On the other hand, more projects can be seeded at an early stage with relatively small amounts of funding with the clear understanding that only some will be chosen for larger, later-stage funding.

Effective incentives accommodate the complexity of CCS projects. CCS projects can be very complex both in technology and in business arrangements. As can be seen from Table 2, companies often work in alliances with a sharing of responsibilities, costs and risks that integrates the entire CCS value chain. Incentives need to fit within this complex framework so that they can be appropriately allocated throughout the value chain. To a significant extent this allocation is the responsibility of the company or alliance that develops the project but the needs of all entities along the value chain need to be met.

In one example of a newly on-line project, the Air Products and Chemicals Company captures CO_2 from a hydrogen production unit at an oil refinery owned by Valero Energy Corporation in Port Arthur, Texas, USA. Valero also supplies utilities. Three other parties are also involved: the Denbury Green Pipeline, which operates the CO_2 pipeline; Denbury Onshore, LLC which off-takes the CO_2 for EOR; and Valero, which hosts the hydrogen production unit at its refinery. The critical incentive was a US Department of Energy grant made to Air Products and Chemicals, which had the highest-risk part of the project, but the price of CO_2 for EOR would have been realized by Denbury Onshore, LLC and Texas incentives for CO_2 pipelines to the Denbury Green Pipeline. Each of the parties, of course, benefited from the project as a whole.

One of the most complex CCS projects to use financial incentives is the Texas Clean Energy Project, which uses polygeneration to create a slate of chemical products plus electricity and a diverse set of revenue streams (Figure 2), each of which requires its own off-take contract with a different customer. Interestingly, as can be seen from Figure 2, CO_2 (used for EOR) is the second largest revenue stream, even larger than electric power sales.

Figure 2. Expected Sources of Revenues from the Texas Clean Energy Project



Source: Douglas Middleton, US Department of Energy, "CCS in the US," Presentation to National Association of Regulatory Utility Commissioners, November 16, 2014.

This project is being developed by an alliance that includes the Summit Power Group Inc., Siemens, Fluor, Linde, R.W. Beck, Blue Source,

[24] These include the Christian County, LLC Project (US$417 million), Faustina Hydrogen Project (US$122 million) and Lake Charles Gasification project (US$128 million).

the Texas Bureau of Economic Geology and the Sinopec Engineering Group. The international nature of this alliance, especially the Chinese involvement, is particularly interesting as Chinese industry has strength in polygeneration. The planned capital structure includes:

Funding Source	Amount (Million US$)
Equity and Tax Equity:[25]	$ 845
Debt Financing:	1,300
Government Cofunding:	450
Total	$ 2,595

Source: Douglas Middleton, US Department of Energy, "CCS in the US," Presentation to National Association of Regulatory Utility Commissioners, November 16, 2014.

This project is also not alone in obtaining financing from more than one country for a very large, complex project.

In addition to the government cofunding, the project also will receive at least US$1,591 million in tax benefits:

Tax Incentives	Amount (Million US$)
Investment Tax Credits:	$ 313
Carbon Sequestration Tax Credits (5 years):	253
Accelerated Depreciation (10 years):	925
Texas State Tax Benefits:	> $ 100
Total	>$1,591

Source: Douglas Middleton, US Department of Energy, "CCS in the US," Presentation to National Association of Regulatory Utility Commissioners, November 16, 2014.

The debt financing includes both bonds and bank loans and is pending a possible US$1 billion from the Export-Import Bank of China. This project has yet to go to financial closure and is not slated for operation until 2019. It is a particularly challenging project because it is a stand-alone merchant project with multiple revenue streams. Still, it illustrates the magnitude of incentives that may be required by some projects.

Government financial incentives are only a part of the financing picture. As can be seen in this example, project developers must also assemble an appropriate mix of debt and equity financing to complete the financing of the project, which means meeting the requirements of all investors. That, too, can be challenging, even after government financial incentives are obtained.

The two examples above show the complexity of individual projects. As CCS is developed into regional clusters, individual CO_2 capture facilities and storage sites may be organized as networks. These networks, and the business and financial arrangements around them, will be even more complex.

Effective incentives for renewables and CCS may differ. This was amply demonstrated in the European Commission's NER300 program which so far has awarded bonus allowances to numerous renewables projects but only to one CCS project. Moreover, the amount of investment in all clean energy worldwide between 2004 and 2013 (US$1,988 billion)[26] has been about 100 times greater than that for CCS over the same period (US$20 billion).[27] Most of that renewables development was made in response to financial incentives, most importantly including feed-in tariffs, tax incentives co-financing and government mandates, all specifically targeted at renewable energy.

[25] "Tax equity" is a form of ownership in a project in which an investor receives a return based not only on cash flow from the project but also on income tax benefits.

Renewables projects tend to be far smaller, less complex, easier to evaluate and develop and take less time to develop compared to CCS projects. A fixed amount of funding available to both renewables and CCS would tend to go to renewables simply because renewable projects could be built faster and in smaller increments. CCS funding would need to be specifically kept separate for that purpose. Appropriate incentives and evaluation processes for awarding those incentives for each type of project need to be tailored to the characteristics of CCS projects. These may not be the same as used for renewables projects.

Oil and gas industry involvement has been critical. The oil and gas industry has been part of the vast majority of the projects (all 8 of the operational projects, 8 of 9 projects in the execute stage and 5 of the 7 projects in the define stage) that have been built or will go into operation. While most commonly this has been through EOR, the oil and gas industry operations have either been the source of the CO_2 and/or the owner/developer of the project. The oil and gas industry has several advantages related to implementing CCS. In specific, the industry has:

- Experience and expertise with the entire CCS value chain (capture, transport and storage);
- The ability to integrate the entire CCS value chain in certain situations;
- Its own high-concentration sources of CO_2;
- A use for CO_2 for EOR in some oil fields;
- The scale to finance large projects; and
- Business models and cultures applicable to CCS.

Government co-investment is important. The most important financial incentive for the non-oil and gas industry projects has been government co-investment that reduces the capital investment and risks. Of the 13 more advanced projects where the government financial incentives have been used, ten have used government co-investment. Moreover, in many cases, these have covered a substantial portion of the capital and operating expenses of early CCS projects - even where revenues are realized through EOR.

Public financing, however, is often not enough. Projects are sometimes abandoned even after the public contribution when the remaining investment cannot be financially justified by the project developer.

Other transitional incentives also help. While co-investment has been the most important transitional incentive, incentives other then government co-investment also can be important. In the United States, tax benefits of various types have been used, and these have had high value to large, profitable organizations. Still, the use of tax incentives has been very specific to the US corporate income tax system. Developers can build using transitional incentives to develop a package of financing methods, but what is viable is very project specific and some incentives such as loan guarantees have not been used. In addition, transitional incentives are, by their very nature, transitional and not permanent, and would need to be replaced at some date by carbon price incentives.

Expectations of incentive continuity are needed over the period when a project's incentives are to be used. In some important cases, incentives have not been as effective as anticipated when they were enacted. Some went into effect but were abandoned. In order to be effective, these incentives need to be consistently available over the extended period in which projects are developed and then last as long as they may be needed to keep the project operating. That is, the financial incentives must enable a return of and on capital and enable the added operating expenses to be covered. Projects have been abandoned when expected government incentives are withdrawn, as happened with the UK CCS competition, or whose value collapses as with NER300.

Incentives are needed that put a predictable, ongoing price on carbon dioxide emissions higher than the cost of CCS but not so high as to make facilities non-competitive. These have been effective in Norway and Alberta. In Norway, this was an offshore carbon tax in a situation in which the cost of capture was low, even though there was no use for the CO_2. In Alberta there are long-term incentives and a potential use for CO_2, which has provided the incentives for some projects. Currently, such carbon price incentives are available nowhere else.

[26] Luke Mills, "Global Trends in Clean Energy Investment, Global clean energy investment sustains its recovery," Bloomberg New Energy Finance, 02 October 2014.
[27] Juho Lipponen, "CCS and the global climate agenda," presentation to GCSSI Annual Conference, Abu Dhabi, 6 November 2014.

Conclusions

Financial incentives from governments are critical to the development and operation of CCS LSIPs. To be effective, those incentives must close the cost and the risk gap between projects with and without CCS in the industries in which they operate. They must enable the host project to achieve its commercial goals. Moreover, potential project developers must see government financial incentives as predictably available for use throughout the planning, construction and operating periods where they will be used for a project.

Given the multiple years it takes to complete the development of a CCS project, an incentive may need to be in place for many years before even the first project developed using it will go into operation. This will require patience and understanding by the governments that enact them. As CCS technology matures, this development time will probably shorten.

Various types of incentives have been used for CCS projects since the 1990s. For the most part, the incentives chosen reflect the financial practices and legal frameworks in each jurisdiction, which vary. Only some of these incentives have been effective in stimulating CCS projects. Most of the effective incentives so far have been government funding of part of the capital and/or operating costs of the CCS project. A number of early projects have and are being developed using these incentives.

Most of the more widely-used financial incentives have been transitional. CCS projects are large, take many years to develop in a stage-gate process, and are technically and institutionally complex. Incentives need to be calibrated to these attributes and may need to differ from incentives used, for example, for renewables. A clear and predictable changeover from transitional to permanent carbon price incentives would, in itself, be perhaps the most effective incentive, but this has not yet been achieved in most jurisdictions.

Evaluating technology options to mitigate greenhouse gas emissions

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