# CARBON DIOXIDE CAPTURE AND STORAGE DEMONSTRATION IN DEVELOPING COUNTRIES

## Analysis of Key Policy Issues and Barriers

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This report is prepared by a team of authors led by Ashok Bhargava, Director Energy Division, East Asia Department of Asian Development Bank. Independent consultants provided inputs related to the intellectual property rights (A. Damodaran), trade classification of the carbon capture and storage (C. Yoong), and costs and financial analysis of CCS projects (X.Pei and D. MacDonald).

# Key Findings and Recommendations

The crucial role of carbon capture and storage technologies (CCS) in cost-effective climate change mitigation is well established by many international studies and reports. But overcoming perceived and real risks, higher costs and financing barriers and, low public acceptance is proving difficult and time consuming resulting in slower progress on CCS. Globally, only five large-scale integrated CCS projects are in operation.

More than $26 billion public funding commitments have been announced to stimulate CCS demonstration across many developed countries. But the commercial financing needed to top up these public funding to meet the overall cost of the initial CCS demonstration projects is proving difficult. Since 2008, only one project was launched underlining the continued challenges, especially higher attrition rate during the appraisal due to perceived and real risks, low public acceptance and difficulties in securing financing.

These barriers are amplified in developing countries and complicated by additional issues related to energy security, price of electricity and limited capacity to plan and implement complex, risky large-scale demonstration projects. Moreover, CCS is seen as a direct carbon dioxide ($CO_2$) mitigation technology in developing countries that should be led by the developed countries. The current "wait and see" approach in developing countries has excluded CCS from the low-carbon energy strategies and programs being vigorously pursued in these countries.

Coal-fired power plants with CCS are particularly appealing to the large coal-based developing countries, who may continue to build significant new capacity of such power plants every year up to 2030 and beyond. But no coal-fired power plant with CCS is currently in operation constraining learning opportunities for the developing countries. Coal-fired power plants "with CCS" are financially unviable at the existing electricity tariff due to large additional capital costs (25%–65%) and excessive energy penalty (15%–30%) to capture and compress $CO_2$. In the absence of any capital subsidy or incentives, "with CCS" coal-fired power plants will require electricity tariff to be increased by as much as 80% or $CO_2$ prices to reach as high as $70/ton to become financially viable.

Regardless of proving CCS in multiple applications in developed countries, there is no substitute but to bring forward CCS demonstration in developing countries. The need for customization is high for CCS as it is plant specific, energy feedstock specific for capture and geology specific when it comes to storage. Successful demonstration in developing countries can only provide greater insight, facilitate learning by doing and most importantly prove it in local conditions. Thus, building greater confidence in its viability and improving its acceptance. There is urgent need to make the CCS demonstration phase more inclusive.

A CCS dedicated multilateral funding mechanism is urgently needed to provide capital cost subsidies and incentives for CCS demonstration in developing countries at least up to 2020. Such funding mechanism can make "with CCS" plants financially viable at a more palatable increase (20%) in electricity tariff. Without such a funding mechanism, there would be even greater delays in CCS demonstration in developing countries. On the other hand, the successful early demonstration projects can bring down the costs and provide valuable in-country lessons that may guide the developing countries to formulate appropriate policies and programs for CCS beyond 2020 accelerating its wider deployment.

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# Introduction

The importance of the Carbon Capture and Storage (CCS) technologies to fossil fuel based developing member countries (or emerging economies) cannot be overemphasized. While there are multiple challenges in launching CCS demonstration projects in developing countries, the higher capital cost combined with significantly high "energy penalty" is often cited as a key barrier by the potential CCS developers and investors in these countries. The "economic/financial gaps" for CCS, which are already well documented by the International Energy Agency, are critical bottlenecks and primary reasons for slow (or stalled) progress on CCS in developing countries.

This report analyzes these issues and barriers with particular emphasis on finding appropriate financing approaches for CCS demonstration in developing countries. The report includes discussions and summary findings on some relevant issues such as intellectual property rights and transfer of technology, and trade barriers to CCS in international trade negotiations. Detailed individual reports from related experts on these two important issues are available separately.

The report examines the CCS issues from the developing countries' perspectives. The CCS demonstration, as discussed in the report, primarily targets CCS application in coal-fired power plants in developing countries. While it is acknowledged that there are other perhaps equally important areas of application, the coal-fired power plants were prioritized due to possible positive replication effect in the next 5 to10 years. The study is supported by extensive data and information available from the People's Republic of China (PRC) and to some extent from India. But with suitable customization, the report analysis may be applicable to other developing countries.

The report analysis and recommendations are for near- to medium-term (up to 2020) time horizon. The approach has been to make practical analysis based on project costs as applicable in developing countries and suggest actionable recommendations. The report extensively utilizes ADB's energy sector project financing experiences in its region. The results and recommendations were discussed in various fora including Carbon Sequestration Leadership Forum, Clean Energy Ministerial Action Group for Carbon Capture Utilization and Storage and in some developing member countries. The report benefits from a parallel ADB financed study that is underway in PRC to develop a road map for CCS demonstration.

# CARBON CAPTURE AND STORAGE— A CRITICAL BUT SLOW MOVING TECHNOLOGY

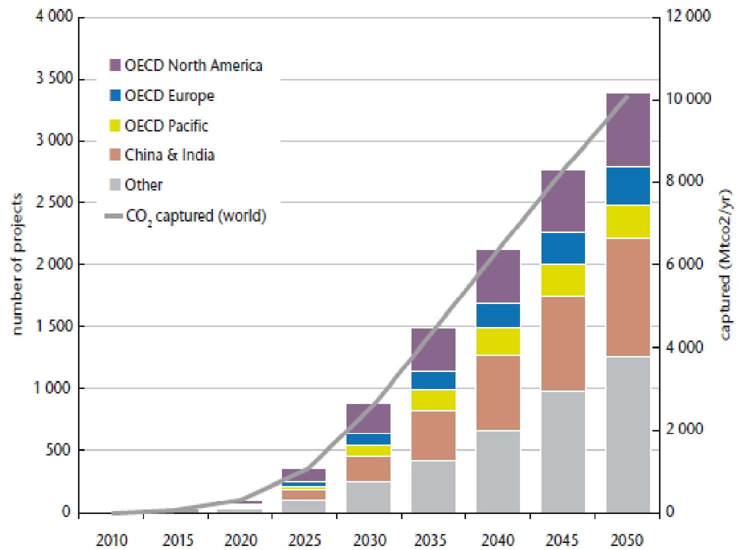
The crucial role of Carbon Capture and Storage (CCS) technologies in cost-effective management of carbon dioxide ($CO_2$) emissions globally is well documented by the Intergovernmental Panel on Climate Change and the International Energy Agency (IEA). Yet, CCS is slow to take off globally due to array of reasons. At the moment, there are only five large fully integrated operational CCS projects—Sleipner and Snohvit (Norway), In Salah (Algeria), Rangely (USA) and Weyburn-Midale (USA/Canada). This slow progress of CCS is reflective of the complex nature of CCS technologies and the unique challenges faced in its demonstration and deployment.

Notwithstanding the slow start, CCS has gathered more momentum recently. Since 2003, many international initiatives were launched with an aim to accelerate demonstration of integrated CCS projects to build confidence in the technology and its subsequent wider deployment. In 2008, the G-8 Leaders' summit announced its support to launch the construction of 20 large CCS projects by 2010 to achieve its broader deployment by 2020. In response, many large projects (between 19 and 43) were announced mainly in developed countries. Commitments of more than $26 billion public funding were also made for these projects. But so far, only one—Gorgon Project in Australia—was launched underlining the continued challenges, especially higher attrition rate during appraisal due to perceived and real risks, low public acceptance and difficulties in securing financing for CCS projects.

The fossil fuel based large developing countries recognize the relevance of CCS in reducing the carbon footprints of their rapid economic growth. But they are hesitant to fully commit to the complex and expensive CCS technologies rather relying on the energy efficiency and renewable energy to provide them the near- and medium-term (up to 2020) $CO_2$ reductions. The slow progress in the developed countries, to launch many CCS demonstration projects quickly and the ongoing challenges in getting public acceptance, is also reinforcing concerns in developing countries about the risks and safety of the CCS. Another issue complicating CCS in developing countries is their stated position that since it is a unique direct approach to mitigate $CO_2$ emissions, developed countries should move forward with it first. Hence, the developing countries have adopted a "wait and see" approach. This approach, is undermining investments and led to slow/stalled progress on CCS in developing countries. No large-scale CCS project has been announced in a developing country so far.

The IEA Technology Road Map (2009) recommends more than 100 CCS projects, half of them in the developing countries, should be in operation by 2020 for optimal $CO_2$ mitigation. But the current status does not look promising to attain this desired CCS growth trajectory, especially in the developing countries.

**Figure 1. Global Deployment of CCS 2010–2050**




| | Number of projects in 2020 | Number of projects in 2050 | Additional cost 2010-2020 (USD bn)* | Additional cost 2010-2050 (USD bn)* | Total invest. 2010-2020 (USD bn)** | Total invest. 2010-2050 (USD bn)** |
|---|---|---|---|---|---|---|
| OECD NA | 29 | 590 | 23.6 | 1 635 | 61.7 | 1 130 |
| OECD Europe | 14 | 320 | 6.8 | 590 | 15.8 | 475 |
| OECD Pacific | 7 | 280 | 5.9 | 645 | 14.1 | 530 |
| China & India | 21 | 950 | 7.6 | 1 315 | 19.0 | 1 170 |
| Non-OECD | 29 | 1 260 | 9.7 | 1 625 | 19.8 | 1 765 |
| **World** | **100** | **3 400** | **54** | **5 810** | **130** | **5 070** |

* *Includes cost of transport and storage*

** *Does not include investment in transport and storage*

b = billion, $MtCO_2/yr$ = million ton carbon dioxide per year, OECD = Organisation for Economic Co-operation and Development, USD = US dollar.
Notes: OECD NA = USA, Canada, Mexico; OECD Europe = Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom; OECD Pacific = Australia, Japan, New Zealand, South Korea; Non-OECD = the rest of the world.
Source: International Energy Agency, Technology Road Map: Carbon Capture and Storage. Paris.

It is unlikely that in the absence of a targeted initiative, especially funding support from developed countries, the developing countries could be pursuaded anytime soon to move beyond the “wait and see” approach and embark on CCS demonstration and deployment.

# KEY ISSUES AND BARRIERS FOR CCS DEMONSTRATION

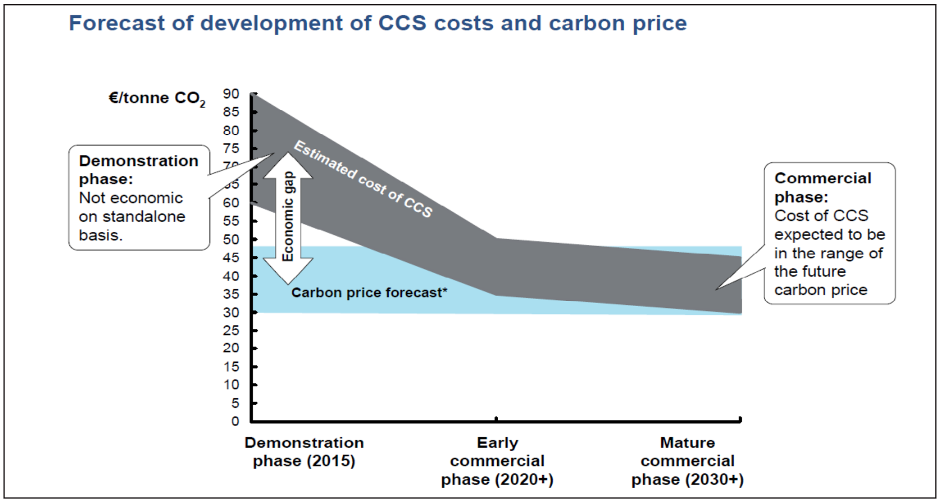
There are many reports and substantial commendable work has been done by the IEA, Carbon Sequestration Leadership Forum and more recently by the Global Carbon Capture and Storage (CCS) Institute, Australia to identify the barriers for rapid demonstration and deployment of CCS. There are also complementary studies done by the World Resource Institute and the Clinton Climate Initiative. There are mainly five sets of critical challenges/ barriers:

(1) **Strategic policy**. Due to limited familiarity with it, very few countries have either envisioned CCS in their energy portfolio or adopted supporting policies. The long-term stewardship by the government, together with a robust regulatory framework, which are essential to ensure that the CCS projects are implemented safely, have not been fully resolved nor implemented.

(2) **Technical**. The technology is immature due to limited number of CCS installations. It has been successfully proven in many applications, over a long period of time, but the challenge is proving it at large-scale in the power and industrial sectors, where it has wider applications.

(3) **Commercial**. A significant commercial/economic gap exists because the costs of fitting CCS on a power plant or industrial plant together with the high parasitic energy need to capture and store carbon dioxide ($CO_2$) cannot be covered by the current market price of $CO_2$.

**Figure 2. McKinsey Report - Carbon Capture and Storage: Assessing the Economics**



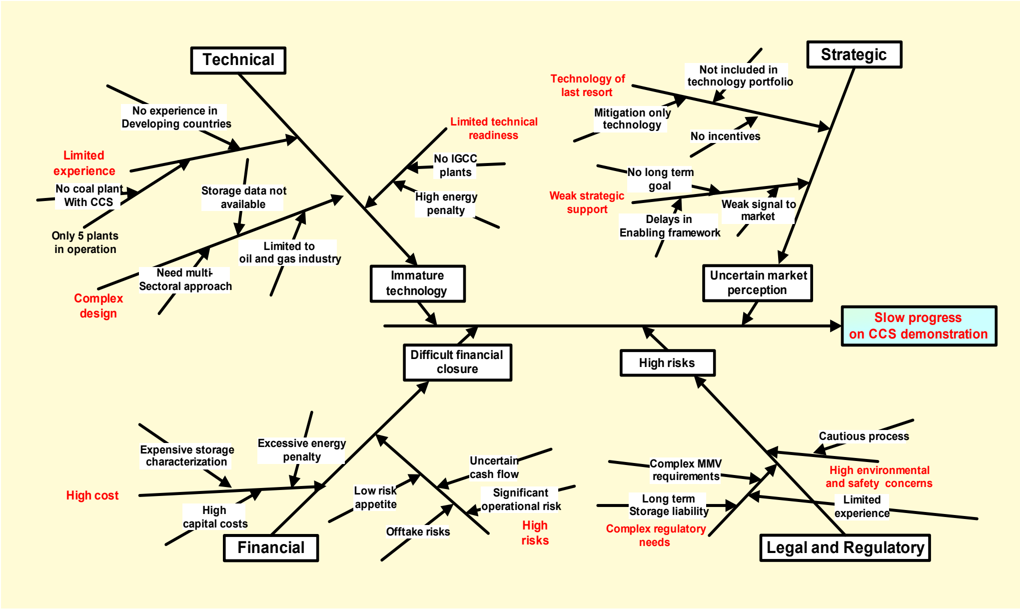

CCS = Carbon Capture and Storage, $CO_2$ = carbon dioxide.

(4) **Financial.** The high operational risks due to multi-sectoral complexities of the project, long-term storage liabilities and uncertainties on carbon prices combined with very little risk appetite in the market due to the recent financial crisis, is complicating the financing of greenfield CCS projects. Public funding combined with risk sharing (or preferably bearing) by the government is essential for early demonstration projects.

(5) **Public acceptance.** Due to lack of information, risks and safety concerns are dominating the public opinion about the CCS. It is proving a difficult issue in many countries and locations causing slower progress of CCS demonstration projects and in some cases, cancellation of projects.

The following diagram depicts these issues and their cause and effect relationships.

**Figure 2. McKinsey Report - Carbon Capture and Storage: Assessing the Economics**




While these are formidable challenges and barriers, enabling works are underway on all of them, creating a conducive environment for launching multiple CCS demonstration projects. Further refinements in policies, financing and regulatory frameworks will emerge as more insight in large-scale CCS projects is gained through the implementation of the first generation of demonstration projects.

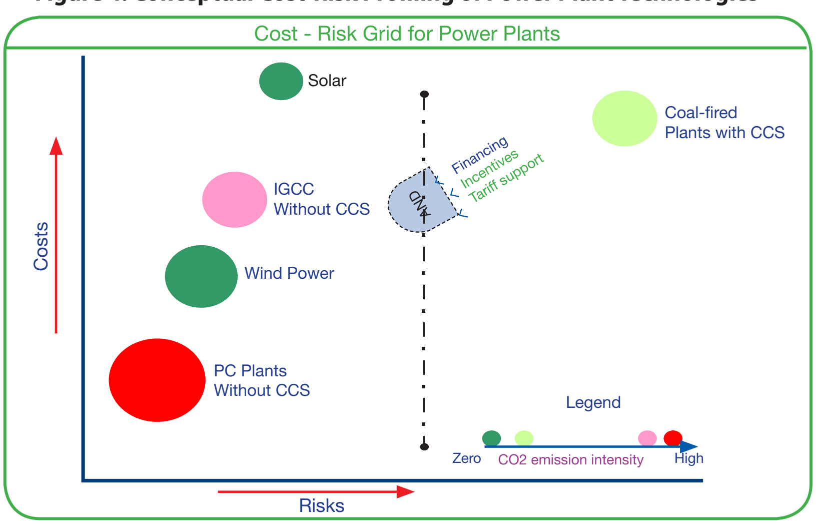
## Key Issues and Barriers for CCS Demonstration—Developing Countries' Perspectives

These same barriers are amplified in developing countries and further complicated by additional issues relating to energy security, price of electricity, limited capacity to plan and manage complex, and risky, integrated projects. Some of these are discussed below:

**CCS is not a strategic choice.** The understanding on CCS and its strategic fit within the low-carbon portfolio of technologies is weak in most developing countries. CCS is currently being viewed as a technology of last resort that is needed in future for climate change mitigation rather than a essential technology that can decarbonize the power and industry sectors to help them achieve their carbon intensity targets. This has pushed CCS almost out of the portfolio of clean and low-carbon technologies being vigorously pursued in developing countries. "With CCS" coal-fired power plants are also unfairly compared only to similar "without CCS" plants, which complicates the decision process. Since "with CCS" coal-fired plants are near-zero $CO_2$ emission plant, they should also be eligible for higher electricity tariffs and other incentives available to $CO_2$ free technologies in developing countries. But this has not been successfully advocated so far by the CCS industry and developers. In the absence of such incentives, power plants "with CCS" are financially unviable. Another crucial factor contributing to low strategic priority for CCS is the limited international experience with the technology and no experience in developing countries.

***For investors, risks are high for CCS due to no tariff incentives but higher costs.***

**Figure 4. Conceptual Cost-Risk Profiling of Power Plant Technologies**




Source: Author's estimates based on the People's Republic of China's data.

**No CCS experience with coal-fired power plants.** Energy security considerations favour construction of coal-fired power plants in developing countries, which rely on coal. Proving CCS on conventional coal-fired power plants may provide a long-term energy security solution for these countries. But at the moment, there is no operational coal-fired power plant equipped with CCS. Coal-fired power plants are large $CO_2$ emission sources—a typical 500 megawatt (MW) power plant emits about 3.6 million tons (Mt) of $CO_2$ every year providing the opportunity for large-scale $CO_2$ capture from single source. Most of the new coal-fired power plants in developing countries are already designed to operate at the efficiencies on a par with the international standards. Thus, CCS is the next logical step to reduce $CO_2$ emissions from these plants. From the financing point of view, the power sector in developing countries has some of the best operating companies with a long history of sound management and financial capacities, which are essential for large CCS projects. They also have a track record of implementing projects of the scale and complexity involved with CCS, thus considerably mitigating associated operation risks.

***Proving CCS in coal-fired power plants will provide long-term energy security in environmentally sustainable manner.***

**Limited technical readiness but significant opportunities.** Most of the new coal-based power plants being constructed in developing countries are using high efficiency supercritical (SC) and ultra-supercritical (USC) technologies, which are essential for post-combustion $CO_2$ capture. But so far, there is no integrated gasification combined cycle (IGCC) power plant in operation in any developing country. IGCC power plants can provide a low-cost high efficiency pre-combustion $CO_2$ capture platform. It is anticipated that newly all of the new IGCC power plants in developing countries will be fitted with CCS. Accelerating multiple demonstrations of IGCC power plants will facilitate transition to the CCS demonstration phase. An Asian Development Bank (ADB) financed 250 MW coal-based IGCC power plant, the first such plant, is under construction in the People's Republic of China (PRC). A pilot CCS project with a capacity of about 100,000 t/year $CO_2$ capture and storage from this power plant is being assessed by ADB for financing in 2011.

***IGCC capital costs will sharply reduce by about 30% after first 5 gigawatt of capacity installation in PRC.***

Natural Gas Combined Cycle (NGCC) power plants are environmentally attractive options to supply heat and power. Some NGCC plants, which are good candidate for post-combustion $CO_2$ capture and storage, are being planned or constructed near major urban centers in the PRC. But due to low $CO_2$ concentration in their flue gas and inherently higher cost of heat and electricity from NGCC plants, the CCS demonstration on them is particularly challenging in the near term. An interim approach by making the "CCS ready" will provide significant opportunities for future retrofit. Similarly, many large coal chemical plants such as coal to oil and coal to synthetic natural gas are being constructed in the PRC, which are early candidates for pre-combustion CCS demonstration. It is evident that new planned capacity provides significant opprtunities for both pre and post combustion capture and storage demonstration now and for retrofitting later.

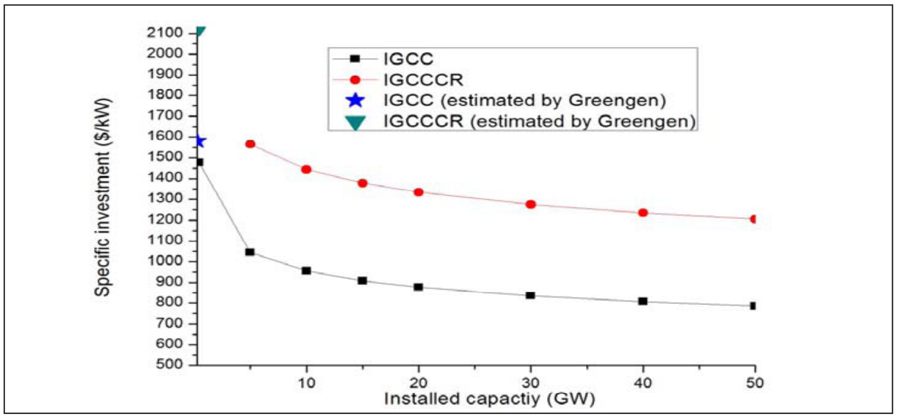
***NGCC plant are good CCS ready candidates.***

**High additional capital cost.** This report has analyzed the additional cost impact due to CCS on possible pre- and post-combustion plants as exist or planned now in PRC. The approach is to visualize the impact in real terms. For this purpose 600 MW SC unit for post-combustion and a 400 MW IGCC unit for pre-combustion were selected. The 600 MW SC unit is a nominal standard size for power plant units widely used in PRC (660 MW in India). The 400 MW IGCC is the next stage for the GreenGen program in the PRC.

***The incremental capital cost for IGCC-CCS plants is much lower than SC-CCS plants.***

The SC power plant "without CCS" ($0.7 million/MW) is less expensive compared to the demonstration stage IGCC plant ($1.4 million/MW). But the additional "with CCS" capital investments for post-combustion power plants are particularly steep compared to the pre-combustion plants. The "with CCS" estimated additional capital cost for the selected post-combustion plant that captures about 1.9 Mt of $CO_2$ is $350 million (65% higher) compared to $135 million (24%) for the selected pre-combustion plant that captures about 1.8 Mt. The lower additional cost for IGCC power plants is primarily due to the fact that the $CO_2$ is captured from a much smaller volume (about 1/100th of the SC plant flue gas) of cleaner gas that requires smaller equipment. The interesting observation is that "with CCS", the total cost differential for IGCC ($1.6 million/MW) narrows down to less than 50% from SC ($1.1 million/MW) plant but is still higher. But while the SC pulverized coal-based power generation is a mature technology with smaller potential for cost reductions, IGCC plant costs are expected to come down significantly. An ADB financed study in PRC suggests that the capital cost of IGCC power plants will decrease sharply from $1.6 million/MW to about $1.0 million/MW when the IGCC capacity reaches more than 5 gigawatts (GW) and it may come down to the SC plant level for an IGCC capacity for 50 GW and higher.

**Figure 5. IGCC Capital Cost Reduction Potential due to the Learning Factor and Localization of Equipment in the People's Republic of China**




IGCC = integrated gasification combined cycle; IGCCCR = "with CCS" IGCC.
Source: ADB. 2010. *Carbon Capture and Storage Demonstration—Strategic Analysis and Capacity Strengthening; Midterm Report.* Manila (TA 7286-PRC).

**Excessive energy penalty.** Apart from the significant additional capital costs to install CCS as discussed above, the large parasitic energy needs (or energy penalty) to capture and compress $CO_2$ from power plants is particularly problematic. This energy penalty comprises of additional coal consumption and loss of electricity output. This report analysis suggests that "with CCS", IGCC plants will consume 6% additional coal and lose 10% of the electricity output while the SC plants will consume 25% additional coal and lose 12% electricity. Combined together, the additional capital and operational investments on one hand and the resulting lower revenues do not create a positive investment climate. The current levels of energy penalty are very high and are of great concern when there are ongoing electricity shortages in some developing countries. The need to accelerate further research to bring down the energy penalty to within an acceptable level of, say, less than 10% is essential to overcome this critical barrier for broader deployment of CCS. As more demonstration projects are implemented, the technology is expected to improve and the energy penalty to come down.

***The additional capital cost combined with energy penalty make CCS a difficult choice in developing countries.***

**Limited government funding.** Developing countries are on high energy growth paths in tandem with the rapid economic development. Thus, the scale of CCS financing itself is not a major challenge. As an illustration, the investment in 2009, in the power sector alone, was about $100 billion in PRC. But the governments in developing countries have moved away from providing direct funding for the power sector. Public funding for promoting other low-carbon power generation is likewise not being provided. Technologies are incentivized through higher tariffs, preference in load dispatch, supporting transmission infrastructure, etc. Most greenfield power project financing involves 60% to 80% debt financing. Due to the high liquidity in the local banks and generally solid track record of the power companies, debt financing through local commercial financial institutions is relatively easy for financially viable power projects. But the CCS demonstration financing is complicated as it is financially unviable and involves increased technical risks and uncertainty.

It is evident from the large public funding commitments ($26 billion) announced in developed countries that the CCS demonstration in developing countries will also need similar public financing. It does not appear likely that the governments in developing countries will make comparable funding commitments or will increase the electricity tariff by as much as 80% to make them financially viable with CCS. But they may be open to consider reasonable tariff incentives for decarbonized electricity from coal-fired power plants through CCS.

**Uncertain clean development mechanism eligibility.** There has been some encouraging progress to include CCS in the clean development mechanism (CDM). But major concerns remain on how quickly and, if successfully, CCS can be included as CDM eligible technology. In the absence of other incentive mechanisms, this will continue to be a serious impediment to lowering the financial/commercial barrier. Moreover, the report analysis does not show that the CDM eligibility of the CCS alone can address the financial gap. Due to high uncertainty on the outcome of the CDM process and the prevalent "pay on delivery" approach, carbon offset revenue is always considered sensitive in assessing financial viability. Moreover, at the current carbon prices, the carbon offset revenue from CDM is too low to play a deciding role in the CCS investment decisions. At best, it can offset the energy penalty and marginally strengthen the cash flow situation. This report has examined a sensitivity case to check the financial viability of "with CCS" plants under consideration on carbon offset revenues alone and found that a carbon price of $40–$70/ton is needed to make them financially viable. When and whether $CO_2$ prices will reach that level, is uncertain.

**Complex and expensive up-front development cost.** The CCS projects extend far beyond the traditional power plant boundaries, especially for geological storage. There is very little credible geological data and information available in the public domain or with power generators to determine an optimum location for "with CCS" plant. The oil and gas industry has the technical expertise and may have access to data on potential storage sites but they operate independent of the power sector in most countries and tend to prioritize $CO_2$ capture for their own activities. The five large operating CCS plants corroborate this as most of them are in the oil and gas sector. There is a critical need to bring together power and oil industries through a joint venture to overcome this barrier.

Apart from the above, the storage characterization is expensive (tens of millions of dollars) and time consuming (2–3 years minimum) with significant uncertainties. Exploration of storage opportunities will be a complex issue for any form of power and oil company collaboration. Oil companies operate on high risk, high return model and are able to finance expensive exploration. But the CCS storage exploration results in negative return (except for the enhanced oil recovery) with front-end loaded expenses and ongoing monitoring, measurement and verification (MMV) costs and liabilities. The power generators are also unlikely to invest significant up-front costs on storage characterization. The ongoing capture only approach in some power plants in PRC corroborates this risk. Without the attractive storage site location, CCS demonstration plants are unlikely to take off.

# ANALYSIS OF FINANCIAL ISSUES AND BARRIERS IN DEVELOPING COUNTRIES

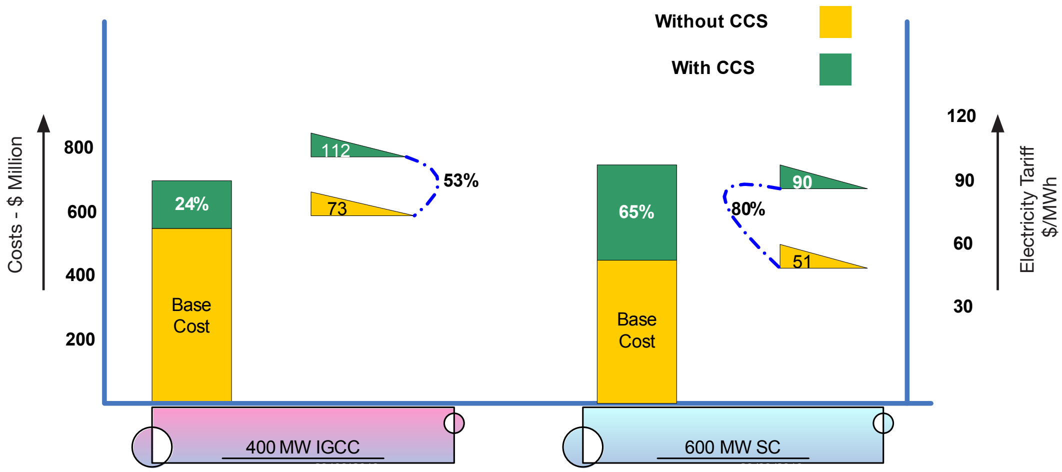
For greater understanding of the financial and commercial issues and barriers that may confront a possible CCS demonstration in developing countries, this report developed a financial analysis model of a 600 megawatt (MW) post-combustion supercritical (SC) plant and a 400 MW pre-combustion integrated gasification combined cycle (IGCC) plant in the PRC. This study does not compare the cost–benefit analysis between pre- and post-combustion plants as assumed in this report. It is expected and strongly encouraged to undertake multiple demonstrations for both pre- and post-combustion technologies. The details of financial model, key assumptions, scenario details, etc. are in Appendix 1.

The financial model is setup to undertake standard financial analysis as per the Asian Development Bank's (ADB) guidelines. It captures all costs including total capital and operational costs. "Without CCS" cost for the 600 MW SC plant is based on a latest estimate from PRC. Similarly, the 400 MW IGCC cost is based on the preliminary assessment by the Greengen company. The "with CCS" costs for both pre- and post-combustion capture are primarily based on the National Energy Technology Laboratory analysis but with suitable adjustments to reflect local costs. Due to high uncertainties, the storage characterization costs are not included in the total cost. It is considered as the sunk cost in the analysis. The costs for pipeline transport and storage are assumed to be $0.6 million per kilometer with a tariff of $7/ton of carbon dioxide ($CO_2$), respectively, based on a typical pipeline construction and unit rates stated in many reports. For the purpose of this study, storage costs were assumed to be break-even with revenues generated by the production of additional oil. Monitoring, measurement, and verification (MMV), costs are small and for this study are considered to be within the cost estimate uncertainties.

Under the base case the total financing is assumed to be 30% equity and 70% debt financing. The 70% debt financing comprises 40% domestic banks and 30% ADB standard public sector financing. The amount of CCS is about 1.8 million ton (Mt) from IGCC and 1.9 Mt from SC plants. The storage site is assumed as equidistant from both plants.

The "without CCS" electricity tariffs are assumed to be $51 per megawatt-hour (MWh) for SC and $73/MWh for IGCC plants based on the recently approved tariffs in PRC. The analysis suggests that for "with CCS" the capital cost incremental for IGCC plants is $135 million (24%) compared to $350 million (65%) for SC plants. The required tariff for "with CCS" to ensure same return on equity "with CCS" in the absence of any incentive is $90/MWh (an increase of 80%) for SC and $112/MWh (increase of 53%) for IGCC.

**Figure 6: The Impacts of Carbon Capture and Storage on Coal-fired Power Plant in People's Republic of China**




% = percent, CCS = carbon capture and storage, IGCC = integrated gasification combined cycle, MW = megawatt.

The financial analysis considers a range of sensitivity cases which are further detailed in Appendix 1. It tries to calculate the electricity tariff if (i) the additional incremental cost is full offset through capital subsidy, and (ii) the energy penalty is full offset by value received for $CO_2$, and (iii) allowing higher capital cost for IGCC plant consider same capital subsidy on both IGCC and SC with a possible carbon offset revenue at \$20/ton $CO_2$. The last scenario brings the tariff to a level where decision makers may be comfortable to consider it.

**Table 1: Sensitivity Analysis on Electricity Tariff Under Various Financing Scenarios**

| Scenarios | Tariff $/MWh IGCC | Tariff $/MWh SC | 400 MW IGCC With CCS | 600 MW SC With CCS |
|---|---|---|---|---|
| Base Case (No subsidy) | 112 | 90 | No subsidy | No subsidy |
| **"What if" assessments with targeted financing and incentives** | | | | |
| Carbon offset revenues only | 83 | 56 | \$37/ton $CO_2$ | \$70/ton $CO_2$ |
| Capital subsidy only | 99 | 73 | \$135 million | \$350 milion |
| Capital subsidy and energy penalty offset | 88 | 61 | \$135 million +\$24 million per year | \$350 million +\$50 million per year |
| Identical capital subsidy and carbon offset revenue at \$20/ton | 75 | 67 | \$226 million | \$226 million |

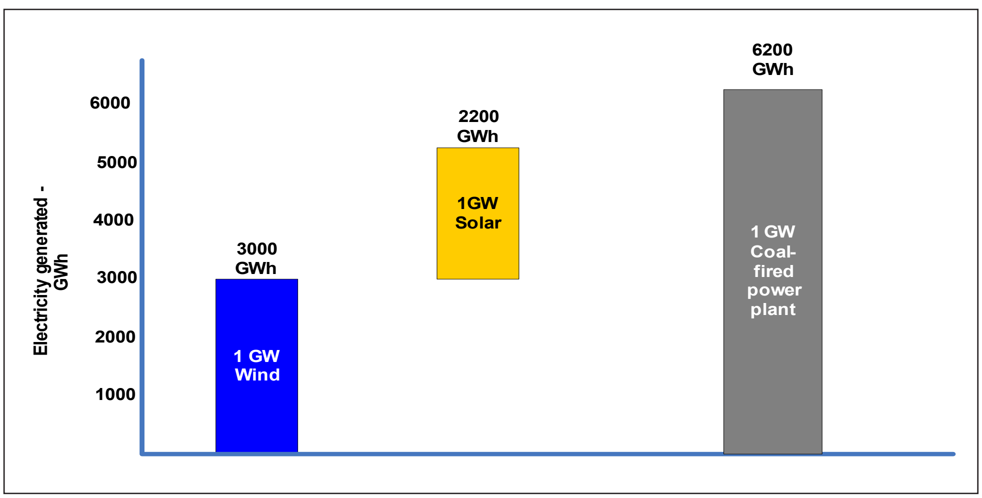
\$ = US dollar, CCS = carbon capture and storage, $CO_2$ = carbon dioxide, IGCC = integrated gasification combined cycle, MW = megawatt, MWh = megawatt-hour, SC = supercritical.

# RATIONALE FOR BRINGING FORWARD CCS DEMONSTRATION IN DEVELOPING COUNTRIES

In 2009, the developing countries have pledged deep cuts in their carbon intensity ($CO_2$ emissions per unit of the gross domestic product) primarily anchoring their efforts on energy efficiency, nuclear power (in some cases) and renewable energy. They have set out clear visions, formulated long-term plans, and announced consistent and encouraging policies attracting large investments in these areas. These are very encouraging and commendable activities that will provide significant cut in $CO_2$ emissions from the business as usual scenario and should continue to be prioritized and further intensified. But the concurrent rapid growth of fossil fuel consumption and related $CO_2$ emissions in developing countries will, in most cases, more than offset the avoided $CO_2$. The overall $CO_2$ emissions will continue to rise. On the other hand, deploying CCS even at a moderate rate will have a "doubling up" effect. As an illustration, the avoided $CO_2$ from 100 gigawatt (GW) of wind power (PRC target for 2020) is fully offset by about 45 GW of coal-fired power plant (about 60 GW was installed in the PRC in 2009).

The following chart illustrates how 1 GW of CCS, equipped coal-fired power plant addition, can more than double up the avoided $CO_2$ emissions from 1 GW each of wind and solar power plants combined.

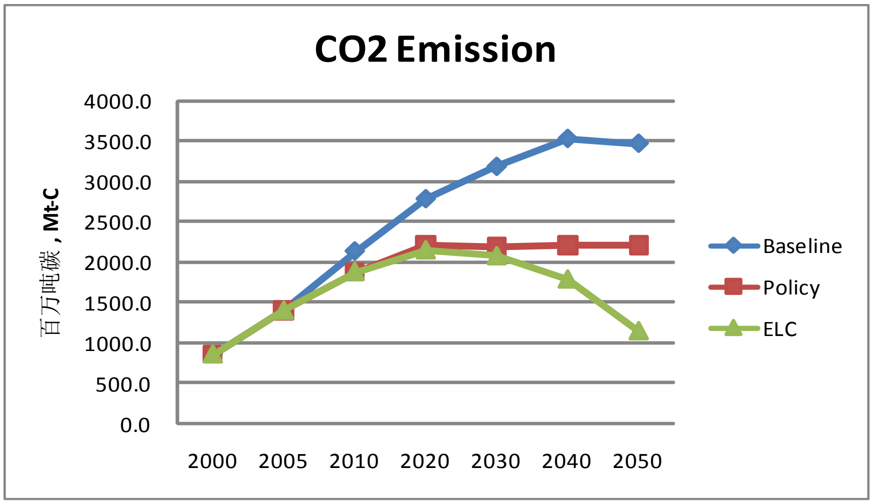
**Figure 7. Comparison of Electricity Output from Various Technologies Based on Utilization Factor**




GW = gigawatt, GWh = gigawatt-hour.
Source: Data from the People's Republic of China and Authors' experience.

In PRC, the essential role of CCS in long-term $CO_2$ emissions reduction is best explained by a study undertaken on the Integrated Policy Assessment Model of China (IPAC), developed jointly by the Japan National Institute of Environmental Studies and the Energy Research Institute of the PRC. The IPAC model simulated the $CO_2$ emissions trajectory up to 2050 under various scenarios. The study suggests that the $CO_2$ emissions will consistently rise in the PRC up to 2030 and may stabilize around that level with the ongoing low-carbon efforts, targets and policies but would not decline. Under the enhanced low-carbon scenario (ELC), which assumes (1) wider IGCC deployment from 2020, and (2) CCS on - 100% IGCC and NGCC plants, 22% ultra-supercritical, and 10% supercritical - for a total of 560 GW from 2030 onwards, the emissions will reduce significantly by about 1.4 gigatons per year. The obvious benefits of early CCS demonstration and deployment than what has been assumed in this IPAC study are compelling reasons to bring forward CCS demonstration in PRC. The report expects similar trends in other developing countries, who likewise have steep energy demand growth with continued fossil fuel dependency.

**Figure 8: Carbon Dioxide Emission Trajectory in People's Republic of China**




$CO_2$ = carbon dioxide, Mt = million ton.

Source: ADB. 2010. *Carbon Capture and Storage Demonstration—Strategic Analysis and Capacity Strengthening; Midterm Report*. Manila (TA 7286-PRC).

Regardless of proving CCS at multiple applications in developed countries, there is no substitute for bringing forward CCS demonstration in developing countries. The need for customization is high for CCS as it is plant specific, energy feedstock specific for capture and geological specific when it comes to storage. Successful demonstration at-scale in developing countries can only provide greater insight, facilitate learning by doing and most importantly prove and improve the technology and economics in local conditions, thus, building greater confidence in its viability and improving its acceptance.

# FAST TRACK CCS DEMONSTRATION IN DEVELOPING COUNTRIES—RECOMMENDED ACTIONS

The importance of the carbon capture and storage (CCS) is widely recognized in the developing countries who are actively participating in familiarization, capacity building and knowledge development activities to enhance their understanding of the technology and assessing its strategic fit with their low-carbon development approach. But the reluctance to commit to early demonstration is keeping CCS out of their planning horizons up to 2020. Due to this, no CCS specific programs have been launched or targets specified in any developing countries. In this policy, program and incentive vacuum, it is unlikely that a transition technology like CCS can make significant progress in the near- to medium-term.

The large energy and power enterprises (mostly public sector enterprises) in developing countries especially in the People's Republic of China (PRC) see the strategic importance and the long-term business imperative to move up on the CCS learning curve and are testing out elements of CCS especially the cost intensive capture technologies with small-scale pilots which (i) are generally within their business domain and do not require cross sectoral cooperation; (ii) have marginal cost implications, thereby do not affect the financial viability of the power plant(s); and (iii) can fit within the existing regulatory framework. Under this low-risk, low-cost approach, the large-scale CCS demonstration (1 million ton/year or higher) will take much longer time in PRC and may not happen in the foreseeable future in other developing countries.

To fast track the CCS demonstration in the developing countries and encourage large-scale activities, the urgent need is to provide targeted financing and incentives to remove some critical barriers. These may include (i) grant financing for the higher up-front development cost including storage characterization; (ii) capital subsidy to offset most of the additional capital cost for CCS-equipped facilities; (iii) interim incentives for carbon dioxide storage on a fixed rate ($/ton) for at least 10-year term to be scaled back as soon as clean development mechanism or its equivalent kicks in; and (iv) a set of smart incentives for encouraging larger capture; early launch of projects by 2013 and additional incentives for projects completed by 2017.

It is unlikely that the governments in developing countries will commit to a complex and potentially risky technology without testing and proving it themselves. The CCS demonstration will need to pass rigorous performance and cost tests during its demonstration phase. It is anticipated that once demonstration projects are implemented and the costs start to come down, the developing countries may begin to include CCS in their long-term energy planning and set targets and complementary policies. But the demonstration phase would need international support.

An action list to fast track CCS demonstration in developing countries is in Table 2.

## FAST TRACK CCS DEMONSTRATION IN DEVELOPING COUNTRIES—RECOMMENDED ACTIONS

| Action | Purpose | By |
|---|---|---|
| Establish CCS Demonstration Fund of billion dollar scale | Overcome near- to medium-term commercial/economic gaps (up to 2020)<br><br>Provide positive incentives for CCS demonstration<br><br>Reduce time lag for CCS demonstration between developed and developing countries | Contributions from developed countries<br><br>Multilateral development banks to actively work with the donor governments and developing countries in setting up the fund |
| Provide complementary policy support<br><br>Establish country-specific pilot regulatory framework to govern demonstration projects<br><br>Actively encourage domestic companies to engage in CCS demonstration activities<br><br>Provide suitable financial incentives—tax relief, tariff premiums for carbon-free electricity, incentives, loan guarantees, etc. for "with CCS" demonstration projects | Encourage energy and power companies in developing countries to move forward with CCS demonstration | Governments in relevant developing countries |
| Form suitable cross-sectoral partnerships to develop integrated CCS projects<br><br>Chart out a CCS demonstration path up to 2020 | Overcome project development issues and capacity gaps | Project developers and energy companies in developing countries |
| Provide knowledge sharing platforms for disseminating lessons and results from demonstration phase<br><br>Develop relevant best practices guidelines on environmental impact assessment, measurement, verification and validation of stored carbon dioxide; storage site characterization | Overcome knowledge and capacity barriers | Knowledge institutions and CCS specific initiatives— CSLF, IEA, Global CCS Institute, Australia |
| Intensify research and development to bring down the energy penalty further | Provide positive reinforcements on CCS viability | Research institutes and energy technology laboratories |

CCS = carbon capture and storage, CSLF = Carbon Sequestration Leadership Forum, IEA = International Energy Agency.

The report assumes that the proposed CCS demonstration fund will remove critical barriers and would motivate timely activities on other action items listed in Table 2.

# CCS DEMONSTRATION IN DEVELOPING COUNTRIES—ROLE OF CCS DEMONSTRATION FUND

The International Energy Agency's Carbon Capture and Storage (CCS) Technology Roadmap (2009) highlights the central role that developing countries are expected to play in CCS deployment starting as early as 2020 when about 50% of the global CCS projects are projected to be in the developing countries. Considering that tens of CCS plants with billions of public funding are expected to roll out in developed countries in the next 5 to 10 years, there is a potential risk of a CCS divide unless the demonstration phase itself is made inclusive by providing funding support to the developing countries to learn and implement projects.

The high growth trajectory for fossil fuel consumptions primarily in the developing countries suggests that their active participation in the CCS is essential for ensuring its long-term commercial success. But CCS is a low (or no priority) for developing countries due to lack of policy and financial drivers. The need for a CCS dedicated funding mechanism can not be overemphasized. This report has taken stock of all available incentive mechanisms and multilateral funds to judge their suitability to support CCS demonstration in developing countries. Based on this assessment, only a trust fund under Asian Development Bank's Clean Energy Financing Partnership Facility, setup by AUS$21.5 million contribution from the Global CCS Institute, Australia, came out as a relevant fund. But with its current contributions, it is grossly inadequate to support any large-scale demonstration project. There are many bilateral and a multilateral initiatives especially in the People's Republic of China, but they lack proper coordination and do not have the size or long-term commitments to remove the barriers confronting CCS.

A CCS Demonstration Fund (the CCS Fund) is essential to stimulate and incentivize CCS demonstration in developing countries. Without such a fund, the CCS would remain a low priority with marginal activities in developing countries delaying its uptake. It is essential that the fund be setup with a scale large enough ($5 billion) to illustrate commitments to include multiple project in many developing countries during the demonstration phase and to provide collaborative support in implementing demonstration projects. As explained earlier, the demonstration phase is a key learning phase before the developing countries will seriously consider commitments to CCS. This approach, to support demonstration projects in developing countries before their formal commitments to long-term CCS plans, will avoid the barriers or perceptions that have prevented some developing countries' participation in similar other funds setup recently.

A preliminary design and monitoring framework for the proposed CCS Fund together with key assumptions and associated risks is in the following pages. Due to the limited resources, this report has not examined in detail all relevant issues concerning the CCS Fund, but key features with explanation are included in the following pages. A follow on study can examine these issues, such as its detailed organization, governing structure and administration of activities.

## DESIGN AND MONITORING FRAMEWORK
## CCS Demonstration Fund

| Design Summary | Performance Targets/ Indicators | Data Sources/Reporting Mechanisms | Assumptions and Risks |
|---|---|---|---|
| **Impact**<br>CCS deployed from 2020 in multiple developing countries decarbonizing power and industry sector | Multiple CCS demonstration projects completed in developing countries cutting $CO_2$ emissions by at least 20 million tonnes per year from 2020<br><br>CCS demonstration projects launched/completed in at least three large developing countries<br><br>Costs of CCS projects reduced by at least 15% from 2020 compared to 2010<br><br>Regulatory framework established | Various international reports from IEA, CSLF and Global CCS Institute, Australia | **Assumptions**<br>• Governments in relevant developing countries commit to CCS and provide adequate policy support.<br>• CCS is included in the portfolio of low-carbon technologies in developing countries<br>• Sound macroeconomic conditions in the developing countries to continue.<br>• CCS technology development stays on track.<br><br>**Risks**<br>• Commercially deployable CCS is not ready in this time horizon<br>• Macroeconomic conditions deteriorate<br>• Binding commitments for $CO_2$ reductions not agreed. |
| **Outcome**<br>Launched multiple CCS demonstration projects in developing countries | At least three CCS demonstration projects appraised and construction launched by 2015 | Various CCS relevant reports —IPCC, IEA, Global CCS Institute, Australia | **Assumptions**<br>• CCS pilots pass performance tests<br>• The feasibility reports approved for the demonstration projects on time.<br>• The electricity tariff premiums are sufficient to ensure financial viability.<br>• The government agencies and energy enterprises have gained sufficient expertise and capacity.<br><br>**Risks**<br>• The storage characterization studies delayed and/or do not provide encouraging results.<br>• The CCS pilots are not launched or completed on time.<br>• The energy enterprises do not take sufficient interest. |

| | | | |
|---|---|---|---|
| **Outputs**<br>1. Pre-investment studies and activities supported to build pipeline of CCS demonstration projects | Storage characterization supported for at least three sites by 2012 | Progress report on the CCS Fund | **Assumptions**<br>• The CCS Fund is operational by 2011.<br>• Developing countries show interest to actively utilize the fund.<br>• The energy enterprises see sufficient incentives to move quickly for CCS demonstration.<br>• Trained staff stays and put in their skills and expertise to good use. |
| 2. Feasibility assessment completed for demonstration projects | Feasibility studies completed for at least five CCS demonstration projects in at least three countries | | |
| 3. Launched multiple pilots and demonstration projects | At least three pre-and/or post-combustion capture and storage pilots launched | | **Risks**<br>• The CCS Fund is not operational on time and does not receive adequate funding.<br>• The pilot regulatory frameworks are not ready in time delaying the domestic approvals in developing countries.<br>• Inadequate capacity of the project developers and/or government agencies delays the project feasibility assessment/approvals.<br>• Complementary incentives not announced for the first CCS demonstrations in developing countries. |
| 4. Capacity developed throughout the CCS chain in relevant developing countries | Extensive capacity strengthening of policy makers, project developers, regulators and stakeholders in selected developing countries | | |
| **Activities**<br>1.0 Establish a CCS Demonstration Fund by 2012 targeting CCS demonstration in developing countries up to 2020. The CCS Demonstration Fund will provide (i) grant support for $CO_2$ storage characterization for shortlisted CCS demonstration projects, (ii) up-front financing support to mitigate or offset the higher incremental costs, and (iii) offset the energy penalty by pricing the stored $CO_2$ at a reasonable rate and encourage higher percentage of $CO_2$ capture and storage | | | **Inputs**<br>Developed countries: $5 billion multilateral development banks provide project financing of $2 billion and leverage another $6 billion |

CCS = carbon capture and storage, $CO_2$ = carbon dioxide, CSLF = Carbon Sequestration Leadership Forum, IEA = International Energy Agency, IPCC = Intergovernmental Panel on Climate Change.

## Proposed CCS Demonstration Fund – Key Features and Explanations

**Why a CCS dedicated fund is needed?** For reasons explained in this report, the CCS is a low priority in the developing countries and will remain so in the near-term (at least up to 2015). On the other hand, a CCS dedicated fund, which will mitigate or eliminate the additional cost of CCS, may motivate developing countries to test the technology by undertaking pilot and demonstration project(s). This may help CCS gain momentum in developing countries and accelerate its deployment. A similar dedicated funding approach has proved successful in encouraging multiple CCS project in many developed countries.

**Who will contribute? How will it link to the Global Climate Fund?** The proposed CCS Demonstration Fund (the CCS Fund) contributions will come from developed countries (donors). The Fund is an interim measure to fill an immediate financing gaps for CCS in developing countries till the Global Climate Fund(s) being committed under the United Nations' Framework Convention on Climate change (UNFCCC) negotiations are fully operational. Thus, the CCS Fund will have a clear sunset clause. While the target is a $5 billion contribution from donors, it is anticipated that not all contributions need to come up-front. The CCS Fund may kick start with a smaller amount ($500 million), which will be essential to support project preparatory and start up activities. But later as projects get ready for investments, the full contribution shall be provided by donors.

**What CCS activities will be financed from the CCS Demonstration Fund?** A complete set of financing instruments such as grants and concessional loans, and risk mitigation instruments such as guarantees and equity etc. will be available to offset "with CCS" additional costs of proposed projects in developing countries. The CCS Fund will provide capital cost subsidies as well as tariff incentives to ensure financial viability of "with CCS" projects. The CCS Fund will also support upstream project development activities such as storage characterization through a cost reimbursement approach. The CCS Fund will primarily target development of at-scale CCS Project (capturing and storing at least 1 Mt CO2 per year from coal-based and at least 0.5 Mt CO2 / year from natural gas plants). But it may also support construction of selected pilot projects (up to 120,000 tons of CO2/year) as well as "CCS ready" projects that may enable large fully integrated CCS projects later in a developing country.

**Who will manage the CCS Demonstration Fund?** The detailed organization of the CCS Fund, its governance structure and administration of activities will be firmed up later in a subsequent study. But it is obvious that multilateral development banks (MDBs) such as Asian Development Bank, who have long and proven history of working in developing countries will play crucial role together with the donors in setting up the Fund and its management. The MDBs involvement will also leverage their own expertise, financing and additional resources.

**Who can apply from the CCS Demonstration Fund?** The developing countries that have ODA-eligibility and an active MDB country program will be eligible to request support from the CCS Fund. To ensure wider utilization of the CCS Fund across developing countries, a ceiling may be applied for maximum support to an individual developing country from the CCS Fund.

APPENDIX 1

# FINANCIAL ANALYSIS OF COAL-BASED POWER PLANTS EQUIPPED WITH CCS

## I. Introduction

A standard financial analysis in accordance with the general principles and steps described in the Asian Development Bank (ADB) guidelines of financial management is followed. An integrated gasification combined cycle (IGCC) power plant equipped with carbon capture and storage (CCS) (pre-combustion) and a SC coal-fired power plant equipped with CCS (post-combustion) were included in the analysis. Three technical schemes, (i) without CCS; (ii) 50% carbon dioxide ($CO_2$) capture and storage; (iii)100% $CO_2$ capture, and storage were analyzed for each of the IGCC and SC power plants.

The electricity tariff, which is usually regulated and plays a key role in the approval of power plants in developing countries, has been considered as the key variable. The outcome from the analysis is an expected electricity tariff under certain conditions. This expected tariff should not only cover all the project-related costs including capital cost, operation cost, financing cost and taxes, but also guarantee the investors' expected returns on investments. The approach is to check the sensitivity of the electricity tariff to various concessional financing and incentives.

## II. Assumptions for the Base Case

### 2.1 Technical Parameters of the Projects

| Item | Unit | IGCC without CCS | IGCC + 50% CCS | IGCC + 100% CCS |
|---|---|---|---|---|
| Gross capacity | MW | 400 | 400 | 400 |
| Net capacity | MW | 332.45 | 311.26 | 298.37 |
| Energy loss in power plant | % | 16.9 | 22.2 | 25.4 |
| Net electricity supply | MWh | 2,329,810 | 2,181,310 | 2,090,977 |
| Capital cost of the power plant | $ million | 557.94 | 681.45 | 689.64 |
| $CO_2$ capture | ton | n.a. | 882,614 | 1,765,227 |

$ = US dollar, % = percentage, CCS = carbon capture and storage, $CO_2$ = carbon dioxide, IGCC = integrated gasification combined cycle, MW = megawatt, MWh = megawatt-hour, n.a. = no applicable.
Source: D. MacDonald, CCS Technical Expert for ADB TA 7278-REG.

**Table A1.2 Post-Combustion Project**

| Item | Unit | SC without CCS | SC + 50% CCS | SC + 100% CCS |
|---|---|---|---|---|
| Gross capacity | MW | 600 | 600 | 600 |
| Net capacity | MW | 568.87 | 523.83 | 493.78 |
| Energy loss in power plant | % | 5.2 | 12.7 | 17.7 |
| Net electricity supply | MWh | 4,235,806 | 3,900,400 | 3,676,686 |
| Capital cost of the power plant | $ million | 427.12 | 745.99 | 879.58 |
| $CO_2$ capture | ton | n.a. | 1,913,307 | 3,826,614 |

$ = US dollar, $CO_2$ = carbon dioxide, CCS = carbon capture and storage, MW = megawatt, MWh = megawatt-hour, SC = supercritical.
Source: D. MacDonald, CCS Technical Expert for ADB TA 7278-REG.

## 2.2 Common Economic and Financial Assumptions for All Cases

(1) The plant capacity would be 50%, 70%, 90% and 100% during the first 4 years of operation.
(2) The project economic life is 20 years.
(3) The domestic inflation rate is 2%. The electricity tariff escalation rate is 2%. The fuel cost escalation rate is 3%. The international inflation rate is 1%.
(4) The plant uses a 20-year term of straight-line depreciation for the fixed assets. The sale tax rate is 1.5% and the corporate income tax rate is 25%.
(5) The carbon dioxide ($CO_2$) storage cost is estimated as $20 per ton.
(6) The debt-equity ratio is 70:30. The free rate of return on investment is considered to be 10%–12%. But due to high potential risk associated with the new technology, a 15% return on equity is assumed.
(7) The domestic debt ratio is 40% and the corresponding interest rate is 6% with a 15-year term. The international debt ratio (ADB) is 30% with a 20-year term. Its interest rate is 4%.
(8) In the base case, no subsidy or grant is included for the project. There is no income from carbon offset revenues under the clean development mechanism (CDM) and no income from enhanced oil recovery.

## III. Scenarios and Results

The current tariff for conventional coal-based power at the assumed locality is 56 per megawatt-hour. The analysis is to determine the incremental electricity tariff that is needed to ensure fixed return on equity when the plant is equipped with CCS. The results are summarized in the table below. The following describes the various scenarios simulated in the model.

(1) The base case is essentially "as is" case i.e., no capital cost subsidy and/or any tariff incentive. Similarly, no carbon offset revenue.
Following "what if" scenarios were generated when plants are equipped with CCS.
    (a) the price of $CO_2$.
    (b) the electricity tariff if the higher capital cost is fully subsidized.
    (c) the electricity tariff if the higher capital cost and energy penalty are fully subsidized.
    (d) the electricity tariff if the project can receive income from carbon offset revenue at $20 per ton and the same subsidy as determined on SC plant is applied to IGCC plant.

**Table A1.3 Scenarios and Indicators**

| Scenarios | Tariff $/MWh | | 400 MW IGCC With CCS | 600 MW SC With CCS |
|---|---|---|---|---|
| | IGCC | SC | | |
| Base Case (No subsidy) | 112 | 90 | No subsidy | No subsidy |
| **"What if" assessments to provide targeted financing and incentives** | | | | |
| Carbon revenues only | 83 | 56 | $37/ton CO2 | $70/ton CO2 |
| Capital subsidy only | 99 | 73 | $135 million | $350 milion |
| Capital subsidy and energy penalty offset | 88 | 61 | $135 million +$24 million per year | $350 million +$50 million per year |
| Identical capital subsidy and carbon offset revenue at $20/ton | 75 | 67 | $226 million | $226 million |

$ = US dollar, CCS = carbon capture and storage, IGCC = integrated gasification combined cycle, MW = megawatt, MWh = megawatt-hour, SC = supercritical.
Source: P. Xiadong, Financial Expert. ADB TA 7278-REG.

APPENDIX 2

# ASSESSMENT OF TRADE BARRIERS TO CCS IN INTERNATIONAL TRADE NEGOTIATIONS

A trade barrier can be any government policy or regulation that restricts international trade namely through the use of tariffs (such as custom duties applied on goods) and non-tariff measures which is everything else that can inhibit trade (such as import bans or quotas that restrict goods or quantities selectively).

Tariff generally give a price advantage to locally produced goods over similar goods that are imported as well as basic revenues for governments. Removing tariff and non-tariff barriers will likely bring down the cost of carbon capture and storage (CCS) and accelerate their development and deployment.

A principal trade barrier surrounding CCS technology in international trade negotiations is the absence of an accepted definition of environmental goods and services (EGS). Other barriers to trading or developing CCS technology include high tariffs and such non-tariff barriers as technology transfer, investment measures, intellectual property rules, available regulatory frameworks, and other bureaucratic or legal issues.

It is unlikely that CCS technology will benefit from the multilateral elimination or large reduction of tariffs, until there is either an agreed identification of the definition of EGS, or there is a sector specific agreement, which is inclusive of CCS technology and liberalizes trade in EGS. This is further complicated by the different technical processes that can be classified under CCS technology.

This analysis looks to critically examine the ways to reduce these barriers to CCS within the World Trade Organization (WTO) Doha Declaration and beyond, and evaluates the eligibility of CCS to benefit from reduced tariffs. It also provides a comparison of possible options and perspectives of both developing and developed countries.

## I. Trade Barriers Surrounding CCS in International Trade Negotiations

**Lack of definition and agreement on environmental goods and services.** CCS technologies and CCS services are not included in the EGS and should be rightfully considered in the EGS product coverage as it directly addresses climate change mitigation. However, as an agreement on what products are deemed to be "environmental" are yet to be worked out, for CCS to benefit from the reduction of trade barriers, it will need to be negotiated outside of the WTO EGS talks until such time that EGS is defined.

**Limitation of the Harmonized System.** A key problem in defining EGS arises from the fact that the harmonized system codes used to classify trade products do not capture the multiple uses, including environmental usage of particular products. Therefore, negotiating tariff reductions for a certain category of products would imply lowering tariffs both for environmentally friendly products and their conventional counterparts as well as for products that may or may not be put to an environmental end-use. This is a step many countries do not want to take as they are eager to protect their domestic markets through import tariffs from other competing countries.

**Defining Carbon Capture and Storage technology.** CCS refers to various technologies and technological processes aimed at reducing greenhouse gas emissions from fossil fuels. Although, there is not yet an agreement on EGS, the perception or misconception of what is considered CCS technology may also act as a trade barrier to its inclusion in a future agreement on EGS. The imprecise definition of CCS technology across harmonized system codes can raise issues for countries that are considering lowering trade barriers for CCS technology and related components. In cases where the code is not detailed enough, the scope of tariff reduction becomes much broader than necessary or the reduction is not applied to the code.

### II. High Tariffs on Environmental Goods which affect Carbon Capture and Storage

In 1996, as the agreements under the previous Uruguay Round of trade talks were first being implemented, the average import tariff applied by most Organization for Economic Cooperation and Development (OECD) countries on products included under the pollution management group was less than 3%. Tariffs applied by OECD members Korea, Mexico and Turkey were closer to 9% on average. However, for a group of emerging economies (Argentina, Brazil, Chile, India, Indonesia, Malaysia and Thailand), applied tariffs averaged almost 20%.

**Non-tariff barriers from importing countries.** Non-tariff barriers to trade in goods are more problematic to identify and measure as data is not always accessible, and non-tariff barriers or other technical barriers to trade such as technical regulations and standards vary from one importing market to another. Major barriers can, however, be identified through qualitative analysis such as surveying exporters and this information can be transformed into a price equivalent. The nature, availability, and quality of the evidence about these types of barriers to international technology transfer is therefore highly variable.

**Technical barriers to trade.** The technical barriers to trade (TBT) agreement seeks to establish a balance between the ability of countries to establish standards and the desire to eliminate barriers to trade. It would seem unlikely that TBT on CCS technologies would have a negative consequence to trade in CCS technologies when the common universal aim is to achieve optimal efficiencies and $CO_2$ reduction. If on the other hand, TBT were used on the actual production of CCS technologies, or imposed on the technical efficiencies of processes and systems, this would be regarded as a barrier to trade that could be contested through the WTO.

**Other barriers directly affecting carbon capture and storage.** High cost of CCS, gross domestic product, regulatory framework for climate change action, CCS in clean development mechanism (CDM), technology transfer, intellectual property rights and foreign direct investment and domestic regulations–local content requirement.

## III. Recommendation

(1) **Support negotiations on environmental goods and services.** Governments should support efforts to reach consensus on rules for improving market access for EGS.

(2) **Maintain the initiative on environmental goods and services.** Governments should maintain the initiative on EGS and outside of the WTO framework, if necessary, until such time multilateral negotiations are resumed.

(3) **Develop a defined carbon capture and storage list of environmental goods and services.** In light of WTO member proposals to define EGS, the Carbon Sequestration Leadership Forum (CSLF) should promote the inclusion of energy goods and services starting with an agreed goods and services classification list on CCS.

(4) **Promote a carbon capture and storage sectoral climate trade agreement in the World Trade Organization and the United Nations Framework Convention on Climate Change negotiations.** A CCS sectoral climate trade agreement may offer more promising opportunities to coordinate climate and trade policies in WTO and United Nations Framework Convention on Climate Change negotiations.

(5) **Consider other model agreements.** If progress within the Doha Development Agenda is unlikely, then a more limited or 'plurilateral' type of agreement on EGS, which is less than the full WTO membership should be considered.

(6) **Promote the inclusion of carbon capture and storage in regional trade agreements.** Support Asia-Pacific Economic Cooperation (APEC) and OECD work on reducing barriers to EGS to serve as the interim commitments in advance of an agreement at the WTO.

(7) **Support carbon capture and storage in the clean development mechanism.** Governments should support the inclusion of CCS as an eligible activity under the CDM of the Kyoto Protocol.

(8) **Streamline investment rules and intellectual property rights to aid technology transfer.** Create a legal environment with strict and enforced environments standards as well as financial incentives such as favorable tax treatment for the use of EGS technologies to trigger increased technology transfer.

(9) **Establish a Multi-institution global task force on government policy barriers to carbon capture and storage.** Establish a multi-institution global task force to conduct further analytical work to identify and assess the government policy barriers, as many of the policy barriers are embedded in countries' international trade and investment regimes.

(10) **Increase cooperation between World Trade Organization and other organizations, to leverage efforts at information sharing on carbon capture and storage.** Sharing information and increasing awareness of CCS as a legitimate climate change mitigation set of technologies is crucial to including CCS as an EGS. Continue cooperation between WTO and other organizations such as the CSLF, International Energy Agency, APEC and Global CCS Institute, Australia to leverage efforts at information sharing on CCS.

APPENDIX 3

# INTELLECTUAL PROPERTY RIGHTS AND TRANSFER OF TECHNOLOGY ISSUES

## I. Background

Intellectual Property Rights (IPRs) are proprietary rights that provide an inventor with the exclusive privilege to work on or transfer his rights on his inventions. Except for trade secrets, patents and other related IPRs are obtained only for a specific duration of time. The real issue with IPRs is that their non-protection, arising from inadequate intellectual property laws and/or poor enforcement of intellectual property laws in recipient countries, leads to spill-overs of the invented process or product to potential competitors.

The IPRs rights can entail problems from a competitiveness angle, as it contributes to oligopolistic trends over products and know-how, resulting in unfair dominant positions that eschew fair competition. Therefore, IPRs can have significant interface with Competition and Anti-Trust legislations. The other restraint on IPRs arises from their possible use to enforce monopolization of products that are critical to public welfare and public health.

The critical issue is to balance incentives for IPR holders, while at the same time ensuring that the technology is accessed by the needy communities. Government-to-Government agreements can help to build the trust. In some cases, there is a greater role for multilateral institutions and financing facilities that can purchase or license these technologies and transfer it to needy users. Such a facility could be in consonance with the aims and objectives of the United Nation Framework Convention on Climate Change.

## II. Status of Patent Filed on Carbon Capture and Storage

A variety of patents applications have been obtained in the area of Carbon Capture and Storage (CCS) technologies. The major focus is on the $CO_2$ capture segment, which accounts for up to 80% of the costs of a CCS system. This study analyzed the large number of patents filed on various pre- and post-combustion technologies during the 2000-2008 as shown in Table A3.1.

**Table A 3.1: CCS Related Patent Applications (2000-2008*)**

| | Carbon Storage | Membrane Technology | Amine Adsorption | Oxyfuel Combustion | IGCC | Total |
|---|---|---|---|---|---|---|
| AUSTRALIA Australian Patent officePatentlens.com | 15(24)** | 1 (57) | 0 | 1 (1) | 2 (2) | 19 (84) |
| EPTO | 9 (1126) | 3 (718+259) | 4 (411) | 3 (115) | 3 (49) | 22 (2678) |
| JAPAN | 9 (10) | 0 | 1(6) | 4 (4) | 1 (1) | 15 (21) |
| USPTO | 1 (1) | 10 (840) | 7 (144) | 1 (1) | 2 (3) | 21 (989) |
| Total | 10 (177) | 8 (700) | 13 (192) | 23 (101) | 29 (232) | 83 (1402) |

**Results reflected in the above table have been derived from patent searches in the Australian Patent office, EPTO, Japan Patent office (JAPAN), US Patent Office (USPTO), and patenlens.com for Australia. These searches include patent applications that have been filed, granted patents, and lapsed. The results derived form patentlens.com for Australia includes only granted patents.*

***Figures in parentheses denote total patents filed in the respective technology areas while those directly relevant to CCS are indicated outside the parentheses.*

The data shows that the maximum number of patents applying to CCS was in the area of membrane technology, followed by carbon storage, pre-combustion CCS (IGCC), oxyfuel combustion, and amine absorption. In the majority of these cases, the assignees are companies, rather than individual vendors. In case of the membrane technologies, the situation is likely to be a thicket of patents, which may enhance the probability of intellectual property infringement litigation. All the same time, the thicket can create conditions for smoother transfer of technologies by lowering the supply price of technologies, or can create conditions for lower license fees and royalties.

### III. Gaps and Potential for Joint Research

Notwithstanding the phenomenal increase in the number of patent applications in various patent and trade offices on CCS technologies, there are many imbalances. As said earlier, the thrust of the present systems of research is on capture technologies, and those mainly from the viewpoint of increasing technical efficiencies. Transport and storage have not attracted research and patent applications as much as one would have desired. Even these inventions are not conclusive as evident from the continuing streams of patents applications related to CCS technologies.

Even in capture technologies, there is a need for major attention on economic efficiencies that reduce capital and operational costs and are focused on customization to local conditions. The authors believe that the following areas call for systematic Joint Research:

- Developing cost-effective processes and methods of various pre- and post-combustion technologies in the actual operational situations of various power plants in developing countries,
- Developing cost-effective and safe $CO_2$ transport systems, that have faster mobility and low chances of accidental or fugitive leakages, and
- Developing carbon storage systems for various types of aquifers at lower costs and low risks of leakages and collateral ecosystem damages.

The thrust of Joint Research ought to be in the areas mentioned above. The Joint Research Programs that seek to focus on the above areas should focus on technical and risk assessments and study of operational functioning of the technologies through demonstration plants. The need is for a financing mechanism that supports these activities in an optimal manner.

### IV. Possible Business Models for Intellectual Property Rights Issues

It is reckoned that investments in Research and Development (R&D) on clean energy technologies are of the order of $16.3 billion. Of this, private funding of clean energy technologies is estimated to be $10.5 billion. This is only a fraction of funds devoted to conventional energy sources and just 2% of overall energy R&D. A good business model should be able to leverage more financial resources that can raise the scale of resources spend on clean energy technologies. More significantly, it is important to raise the level of public funding in CCS technologies on account of the fact that private investors are not willing to crowd in due to the unproven nature of the technology.

The typology of technology transfer varies. The early phase of technology transfer involves transfer of know-how and prototypes developed initially and tested out through pilot demonstration exercises. In "later phase technology transfer", the technology transferred can be one which has crossed pilot and post-pilot phase (or pre-commercial demonstration that needs fine tuning and customization at the end user level, before commercial running).

There are three business models that promote transfer of technologies. The main findings emerging from the foregoing assessments are as follows:

**1. Purchase of Technologies**

Purchase models are not considered viable option on account of high supply price of technologies offered for transfer/sale coupled with lots of uncertainties. Purchase models can succeed only for mature technologies, where the technology assessments provide clear indication of the likely promise of the technologies.

**2. Licensing in of Technologies**

Licensing models are also not outright attractive due to the prevailing low-carbon prices. The economics may improve once the carbon prices go beyond a threshold point (\$60–\$80/ton of $CO_2$). Under such scenario, some financing systems has to absorb the negative cash flow during the demonstration phase.

**3. Joint Ventures that PromoteTransfer and Commercialization of Technologies**

Joint Ventures will not succeed unless they relate to technologies which are on the threshold of commercial success, which is not the case with the CCS technologies at the moment.

## V. Public-Private Partnership in CCS Technologies

Allan Amey (2008) defines public-private partnerships (PPPs) in the context of Carbon Capture and Storage (CCS) technologies as a cooperative venture between the public and private sectors to actively manage and accelerate the development of the capture, transportation, EOR, and direct storage components of a CCS system while maximizing economic and environmental efficiencies through effective policy development and delineation of risk and investment commitments by key stakeholders.' The players in a CCS PPP structure involve private companies and governments, professional institutions with domain expertise (like Carbon Sequestration Leadership Forum, International Energy Agency), Universities and academic institutions, R&D centers, financial institutions, civil society representatives, regulators and professional assessors of technology and environment impacts. These players should steer, guide and take up responsibilities for sharing costs, risks and benefits. The PPPs typically function through Special Purpose Vehicles.

In general, PPPs allow sharing of costs and investment risks. In the European Union, PPPs are considered to be crucial factor in the commercialization of CCS. The role of PPPs in leveraging finance from multiple channels, hold great attraction for CCS projects. But considering the low risk appetite in the market combined with high risk profile of early stage CCS demonstration projects, it is imperative that the public sector participation has to bear the risks to allow private investments to flow in these projects. In case of India, the ultra mega supercritical coal-fired power plants (UMPP) is a proven business model for PPP. In these large infrastructure projects, the development risks are borne by the government and the private sector participate on build-own-operate mode. These UMPPs, especially in coastal areas are natural candidates for CCS demonstration. It is expected that PPP can be a project investment model especially if the power plant is owned by the private sector.

Cover pictures are of Tianjin Integrated Gasification Power Plant in People's Republic of China and Sleipner Carbon Capture and Storage site in Norway.

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