ADB

Technical Assistance Consultant's Report

Project Number: 46052
March 2015

People's Republic of China: Roadmap for Carbon Capture and Storage Demonstration and Deployment
(Financed by the Carbon Capture and Storage Fund)

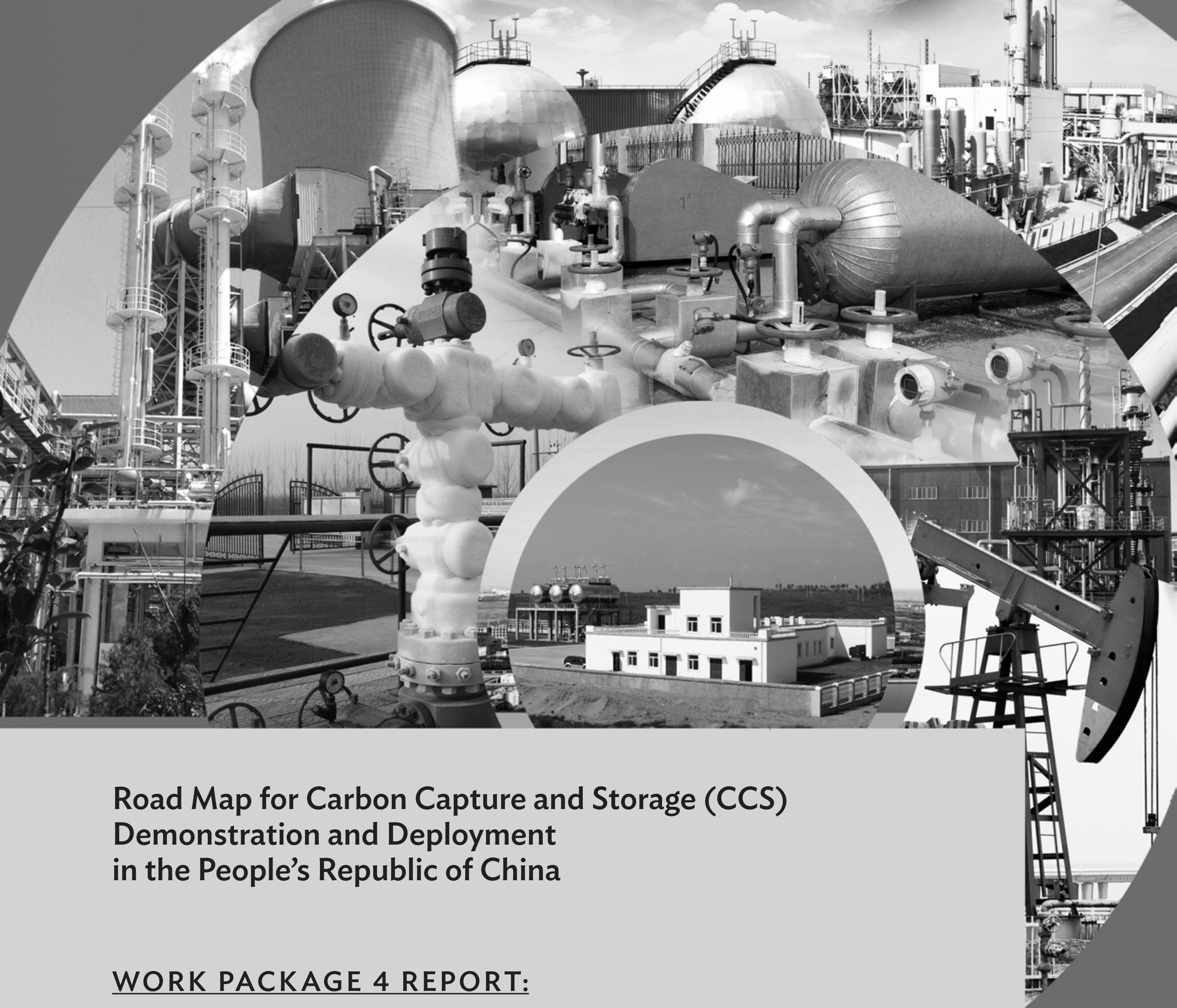
Component A–Work Package 4 Report: CCS Regulatory Framework for China

Prepared by

James Baird, Clinton Climate Initiative
Wang Can, Tsinghua University
Sarah Forbes, World Resources Institute
Baiyu Wang, Chinese Academy of Social Sciences

For Department of Climate Change, National Development and Reform Commission (Executing Agency)
National Center for Climate Change Strategy and International Cooperation (Implementing Agency)

Asian Development Bank



Road Map for Carbon Capture and Storage (CCS) Demonstration and Deployment in the People's Republic of China

WORK PACKAGE 4 REPORT:

CCS Regulatory Framework for China

James Baird, Clinton Climate Initiative
Wang Can, Tsinghua University
Sarah Forbes, World Resources Institute
Baiyu Wang, Chinese Academy of Social Sciences

March 2015

CCS Regulatory Framework for China

James Baird
Wang Can
Sarah Forbes
Baiyu Wang

December 2014

GLOBAL CCS INSTITUTE

Department of Energy & Climate Change

Table of Contents

ABBREVIATIONS

ADB	–	Asian Development Bank
APCP	–	Asian posted contract price
ARENA	–	Australian Renewable Energy Agency
CAGS	–	China Australia Geological Storage Project
CCR	–	command and control regulations
CCS	–	carbon capture and storage
CDB	–	China Development Bank
CDM	–	Clean Development Mechanism
CIT	–	corporate income tax
CO_2	–	carbon dioxide
COACH	–	Cooperation Action within CCS China-EU program
CSLF	–	Carbon Sequestration Leadership Forum
CSR	–	corporate social responsibility
DECC	–	United Kingdom Department of Energy & Climate Change
DNV	–	Det Norske Veritas
DSCR	–	Service cover ratio
ECBM	–	Enhanced coal-bed methane
EEPR	–	European Energy Program for Recovery
EIA	–	environmental impact assessment
EIDM	–	Law of Environmental Information Disclosure Methods
EOR	–	Enhanced oil recovery
ETS	–	emission trading scheme
FEED	–	front-end engineering design
GHG	–	greenhouse gas
Gt	–	Gigatonne
$GtCO_2$	–	gigatonnes of carbon dioxide
GW	–	Gigawatt
IGCC	–	integrated gasification combined cycle
IPCC	–	Intergovernmental Panel on Climate Change
IPR	–	intellectual property rights
IRR	–	internal rate or return
ISO	–	International Organization for Standardization
km	–	kilometre
ktpa	–	thousands of tonnes per annum
LCOE	–	levelized cost of electricity
M&P	–	modalities and procedures
MBI	–	market-based instruments
MMV	–	monitoring, measurement and verification
MOST	–	Ministry of Science and Technology
MOST	–	PRC Ministry of Science and Technology
MOVECBM	–	Monitoring and verification of CO_2 storage and ECBM in Poland Project

Mt	–	million tonnes
mtpa	–	millions of tonnes per annum
NDRC	–	National Development and reform Commission
NEA	–	National Energy Agency
NEPA	–	United States Environmental Protection Act
NER	–	New Entrants Reserve
NETL	–	United States National Energy Technology Laboratory
NPV	–	net present value
NZEC	–	China-EU Near Zero Emission Coal project
OECD	–	Organization for Economic Co-operation and Development
OOIP	–	original oil in place
OSPAR	–	Convention for the Protection of the Marine Environment of the North-East Atlantic
PC	–	pulverized coal power plant
PRC	–	People's Republic of China
RD&D	–	research, development and demonstration
SOE	–	state-owned enterprise
STRACO2	–	Support to Regulatory Activities for Carbon Capture and Storage Project
UK	–	United Kingdom
UNFCCC	–	United Nations Framework Convention on Climate Change
US EPA	–	United States Environmental Protection Agency
USA	–	United States of America
VA	–	voluntary approach
VAT	–	value-added tax
WRI	–	World Resources Institute

Overview

Carbon capture and storage (CCS) projects face significant barriers to deployment, not the least of which are regulatory and financial obstacles. Additionally, high capital costs as well as revenue risk consideration can inhibit a CCS project's ability to attract investment. Within the broader context of CCS deployment in the PRC, there is an abundance incentivizing policies and support measures that could be adopted and utilized to assist in overcoming these impediments to development.

This work package proposes a regulatory framework to help overcome the major obstacles to CCS deployment in the PRC. Chapter 1 examines the regulatory and policy framework currently established internationally, noting the different command-and control, market-based and voluntary approaches. Following this review, Chapter 2 outlines the current regulatory gaps within the PRC and explains the need for additional CCS regulation in the PRC. Based on the gaps identified, Chapter 3 explores a series of regulatory support policies and mechanisms that the PRC could implement to help facilitate CCS development. This involves the construction of technical and management standards for all elements across the CCS value chain (capture, transport and storage) and suggestions for ensuring efficient public engagement through effective education, requiring meaningful disclosure from project proponents and providing public engagement platforms that allow community concerns to be heard and responded to.

The issue of a lack of commerciality and financeability for CCS projects is addressed in Chapter 5. The chapter notes that some CCS applications, such as those in the coal chemicals sector involving the sale of waste CO_2 for enhanced oil recovery (EOR), can theoretically be deployed today with little or no direct financial aid, most coal-based power sector technologies face financial constraints due to the incremental costs from CO_2 separation and the energy penalty associated with the capture and compression processes. Government support is therefore necessary to ensure the viability of early mover CCS projects.

Chapter 5 presents both qualitative and quantitative analyses of series of potential complementary support measures policies, providing examples of international and domestic precedents where appropriate. The chapter notes that that the use of multiple financial policy levers can be used in conjunction to effectively bridge the commerciality gap for early mover projects. Finally, Chapter 6 identifies the major commercial counterparty risks within the CCS value chain and proposes a model for risk sharing that involves the government partially underwriting by government of revenue and certain counterparty risks.

1 Domestic and International Policy Review

National governments worldwide have begun to take action to encourage the development and adoption of carbon dioxide capture and storage (CCS) technology. Actions spanning investment in research, development and demonstration (RD&D) to establishing requirements for adopting CCS at future facilities.

At present, there is no common international standard or agreed best practice specific to assessing the environmental impacts of a CCS or CCUS project. Environmental Impact Assessments (EIAs) have been developed on a project-by-project basis according to regional, national and state-level regulatory requirements and project-specific characteristics. Impact assessments undertaken for large-scale integrated CCS projects within highly regulated environments such as the Kemper County IGCC project (United States), Gorgon (Australia) and Quest (Canada) projects provide examples of good practice, as do various official guidance documents provided by OECD countries including the United States and European Union Member States (e.g. the UK Environmental Agency).

CCS has been discussed in detail via the development of the modalities and procedures for CCS in the Clean Development Mechanism (CDM). In the CDM-context, governments raised a series of common concerns about CCS. These concerns are outlined as "issues" in the left column of Table 1 below, along with recommendations for regulatory frameworks and standards to take to address these concerns.

Table 1: Environmental health and safety actions recommended for any national government considering CCS[1]

Issue	Recommendation for National Governments
Long-term permanence	Establish an environmental regulatory framework that promotes storage security and includes: • Criteria for site selection based on geologic characteristics of the site • Operational and long-term monitoring • Risk assessment • Long-term stewardship

[1] http://www.wri.org/publication/carbon-dioxide-capture-and-storage-and-unfccc

Measuring, monitoring and verification (MMV) of CCS efforts[2]	Establish an environmental regulatory framework for CCS which: • Covers the area of injected CO_2 and any displaced fluids • Requires operators to monitor and report data key information • Establishes criteria for determining when monitoring can end
Environmental impacts	Ensure environmental regulatory frameworks provide for: • a compositional analysis of the CO_2 stream which is then used in the site-specific risk assessment • Conduct a comprehensive EIS analysis for any CCS effort which includes a risk analysis and public participation
Project activity boundaries	• Ensure an environmental regulatory framework for CCS that requires a monitoring area and project footprint be established based on site specific data, simulations, and risk assessment. • Establish national methodologies for MMV of CCS projects
International law	Follow the rules and best practices of the London Protocol and OSPAR where applicable
Liability	• Develop and agree to clear rules and procedures for managing liability in a CCS project • Develop and agree to criteria for proving that the CCS project does not endanger human health or the environment, and use these as the basis for transfer of liability and stewardship responsibilities
Safety	• Apply laws that protect worker safety to CCS projects • Ensure a regulatory framework that prioritizes human and ecosystem safety
Insurance coverage and compensation for	• Require operators to have insurance during operational project phases • Develop a national trust fund or other

[2] The ability to measure, report, and verify (MRV) CO_2 emission reduction activities is a key requirement of any greenhouse gas mitigation approach, including CCS. Individual CCS projects require a similar, site-specific process oftentimes referred to as measuring, monitoring and verification (MMV).

damages caused due to seepage or leakage	mechanism for long term-stewardship

A number of countries have developed a variety of enabling conditions for CCS deployment, including environmental regulatory frameworks, economic incentives and requirements for implementing CCS on existing and new facilities. For environmental assessments as well public engagement and consultation, governments typically rely on existing environmental impact laws. Table 2 summarizes the country-specific policy actions that have been taken to enable CCS.

Table 2: Summary of international CCS policy actions[3]

Country or region	Technical standards or environmental regulatory framework[4]	Environmental impact assessment	Economic incentives or requirements	Cross-regional cooperation mechanisms
Australia	Offshore Petroleum and Greenhouse Gas Storage Regulations 2011 Onshore regulated at the state level	Environment Protection and Biodiversity Conservation Act 1999[5]	• AUD1.68 billion in government funds for CCS Flagships Program	Established and leads the Global CCS Institute. Co-leads the Clean Energy Ministerial CCUS Action Group
Canada	Canadian Standards Association (CSA) published standards for CCS under, Z741-12. State level regulations have been adopted	Canadian Environmental Assessment Act (CEA Act).	• Emissions performance standard requiring new and old coal plants to be as efficient as natural gas[6]. Plants that use 30% CCS can	Chairs the ISO technical committee developing CCS standards

[3] Sources include IEA's Legal and regulatory review (2nd and 3rd Edition) http://www.iea.org/topics/ccs/ccslegalandregulatoryissues/ccslegalregulatoryreview/ and Environmental NGO Perspectives on CCS http://www.globalccsinstitute.com/publications/environmental-non-government-organisation-engo-perspectives-carbon-capture-and-storage

[4] http://www.iea.org/publications/freepublications/publication/CCS_Review_3rdedition_FINAL.pdf

[5] http://www.comlaw.gov.au/Details/C2013C00539

[6] http://gazette.gc.ca/rp-pr/p1/2011/2011-08-27/html/reg1-eng.html

	in Saskatchewan (using the Oil and Gas Conservation Act (the Act) and The Pipelines Act, 1998, administered by the Ministry of Energy and Resources.		receive a deferral • Public funding for demonstrations totaling $3 billion[7].	
European Union	Directive 2009/31/EC on the geological storage of carbon dioxide. Countries that have transposed the Directive into national law include: • Czech Republic • Finland (only allows R&D or exporting CO_2 for storage) • France • Germany • Ireland (prohibits except for small projects) • Italy • The Netherlands • Poland • Romania • Spain. Law 40/2010 • United Kingdom	EU EIA Directive	• CCS funding was planned under the ETS New Entrants Reserve and (NER 300) 79 projects applied. The value of NER 300 was estimated at 4-5 B Euros. • EU Energy Programme for Recovery (EEPR) set aside 1 billion Euros for CCS in Poland, Germany, the Netherlands, Spain, Italy and the UK.	COACH project, ZEP
Japan		Article 18.12 of the Marine Pollution Prevention Law		
Korea	Marine			

[7] Government of Canada and the governments of Alberta, Saskatchewan, and British Columbia, http://www.nrcan.gc.ca/energy/science/1421 (September 11, 2012)

	environment management law was amended to allow for capture and ocean disposal[8]			
Norway	CCS-specific regulations are still pending, At some future date draft regulations will be simultaneously released by the Minisries of Environment and Petroleum and Energy		• CCS requirement for natural gas developments (including future power plants). • CO_2 tax is applied to offshore developments.	
South Africa	Regulatory gaps have been analyzed and regulatory development is underway			
United Kingdom	• EU Directive has been transposed • Energy Act of 2011 allows for reuse of exisiting pipelines and infrastructure for CCS		Energy market reform of July 2011 established: 1. Emissions performance standard (new coal only with CCS) 2. Carbon price floor 3. Feed-in tarrif	• NZEC project • FEED studies from UK CCS demonstrations are publicly available • Co-leads the Clean Energy Ministerial CCUS Action Group
United States	"Class VI" regulations for Geologic storage were developed by the US EPA under the Underground injection control program and finalized in 2010[9]. No	Federally-funded projects are subject to EAs under the National Environmental Protection Act (NEPA). Some states have	• Federal funding for demonstrations ($5B) • Loan-guarantee program (new $8B[10] program announced in 2014)	Established and leads the Carbon Sequestration Leadership Forum (CSLF).

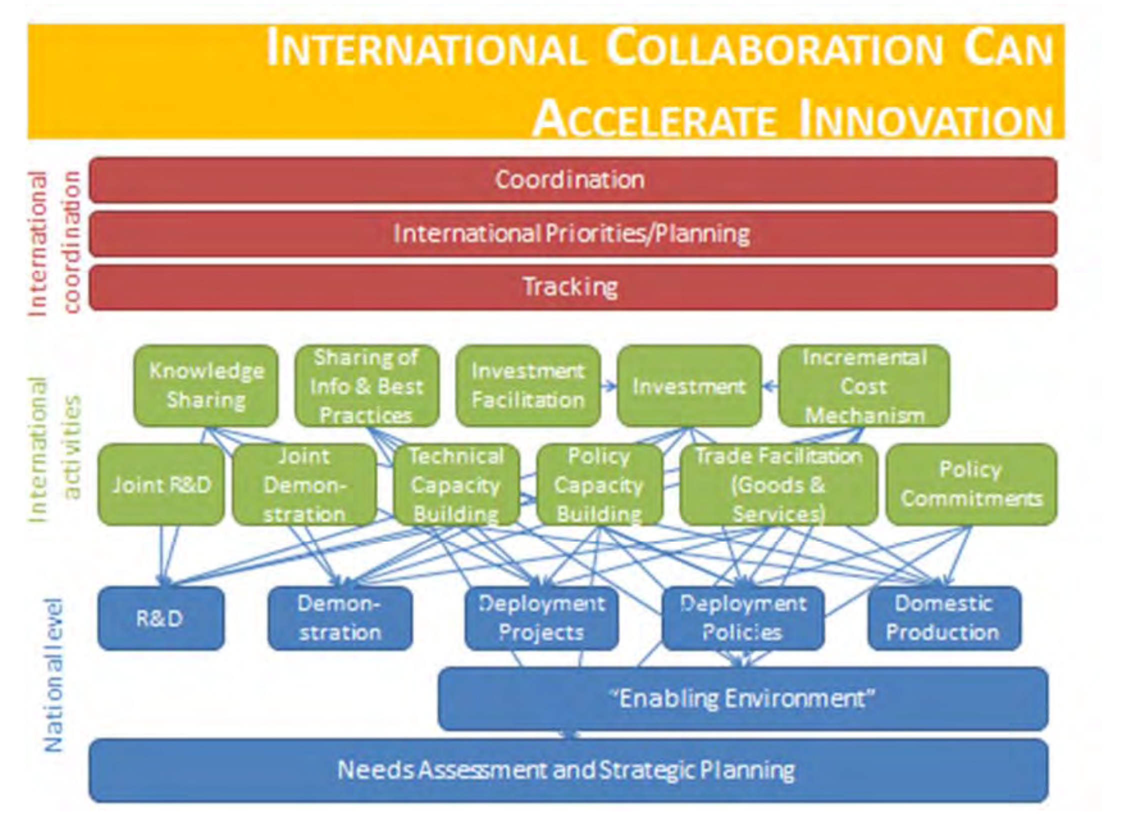
[8] http://www.iea.org/publications/freepublications/publication/ccs_legal.pdf

[9] http://www.gpo.gov/fdsys/pkg/FR-2010-12-10/pdf/2010-29954.pdf

	projects have yet been permitted under the rule.	mandatory EAs for energy projects.	• Tax credits for CO_2 storage ($10/ton for EOR and $20/ton for storage) • Proposed performance standards for new plants	

Global experience to date has shown that funding for projects and environmental regulatory frameworks alone are necessary, yet insufficient to enable demonstration of CCS at industrial scale. Figure 1. Summarizes the interconnectedness of international collaboration in expediting the process of innovation.

Figure 1: International collaboration can accelerate technology innovation



10 https://lpo.energy.gov/category/in-the-news/

1.1 Current PRC CCS Regulatory and Policy Framework

As elsewhere, the PRC is in the early stages of adoption of CCS technology. To date, the PRC has undertaken a number of initiatives to promote the development of CCS. In April 2013 the government released a policy circular document describing methods to explore and establish financial incentive mechanisms to support CCS through the pilot and demonstration phase through the use of current tax support policies, provision of access to financial sources, credit, tariff and land use support, establishment of a CCS financial security system with government guidance, multiple sector engagement.

The regulatory framework for CCS technology in the PRC includes three kinds of regulations: Command-and-Control Regulations (CCRs), Market-Based Instruments (MBIs) and Voluntary Approaches (VAs). The details of existing regulations for CCS in the PRC are shown below:

1.2 Command-and-Control Regulations (CCRs)

The PRC has listed CCS as one of the key technology groups to tackle climate change and has shown its will to promote CCS's development through regulatory documents and plans, including:

- *Scientific & Technological Actions on Climate Change (2007),*
- *National Climate Change Program,*
- *National 12th Five-year Scientific and Technological Plan,*
- *Outline of National 12th five-year economic and social development plan,*
- *Outline of National Midterm & Long-term Science and Technology Development (2006-2020),*
- *The NPC standing committee's resolution on climate change (2009),*
- *Annual report of the PRC's policies and actions on climate change (2008-2012).*

In 2013, the PRC launched the *National 12th Five-year Specialized Scientific and Technological Development Plan for Carbon Capture, Utilization and Storage (CCUS)*, a national plan for domestic CCS/CCUS development providing a comprehensive

picture of the development of CCS technologies and demonstration projects. The plan has identified the main CCUS theoretical research fields, the needed major technical breakthroughs for different CCS technologies, and the major CCS demonstration project types, setting targets for each. The plan also promotes the construction of a national technical standard system for CCS and proposes

- a specialized national coordination group of CCS
- increased the financial support for CCS theoretical research and technical development,
- strengthened international cooperation in CCS,
- establishment of an industrial alliance of CCS technological innovation, and
- additional focus on CCS in tertiary education institutions.

Many other laws the PRC issued as Command-and-Control Regulation (CCRs) can also be applicable for regulating various components of the CCS process in CCS projects. Some of the primary examples are:

- The *Marine Environmental Protection Law of the People's Republic of China* states that any entity must get legal permission for dropping waste in the sea through an application and approval system. The undersea storage of the CO_2 in the CCS projects would likely be subject to this law.
- The *Law of the People's Republic of China on Environmental Impact Assessment* requires CCS projects to perform a complete environmental impact assessment before project construction.
- The *Law of the People's Republic of China on Promotion of Cleaner Production* states that all economic entities should try to promote cleaner production by applying cleaner raw materials, utilizing more efficient technologies and equipment, promoting the recycling of the wastes, and adopting other useful methods to reduce the final emission of pollutants; CCS is among the technologies encouraged by this law to promote cleaner production.
- The Measures for the management of environmental monitoring can help to regulate the monitoring of CO_2 stored underground and prevent against the leakage of the CO_2 from the storage site.

Additional regulations of this kind are listed in Appendix A. Though the Command-and-Control Regulations summarized above can help regulate the CCS

development, the operability and feasibility of these regulations still needs to be strengthened.

1.3 Market-Based Instruments (MBIs)

Both domestic and international fiscal mechanisms have been made available to support CCS development in the PRC. The PRC has funded many CCS research, development and demonstration (RD&D) projects through national science-technology plans including the National Basic Research Program (973 Program), the National High-Technology Program (863 Program) and the National Science and Technology Support Plan. During the 11th five-year plan (2006-2010), over 1 billion CNY was invested in 20 CCS R&D and demonstration projects through the national plans mentioned above, and in 2011 over 2 billion CNY was invested in 10 CCS-related projects. Important CCS R&D and demonstration projects in the PRC to date are listed in [Appendix A]. Additionally, the *National 12th Five-year Specialized Scientific and Technological Development Plan for Carbon Capture, Utilization and Storage (CCUS)* signaled the intent to increase the fiscal support for CCUS research, from basic science research to demonstration projects.

At the same time, many CCS research and demonstration projects have been supported by the PRC's international cooperative programs, including the PRC-EU CCS collaborative research projects COACH, STRACO2, MOVECBM, PRC-UK project NZEC, PRC-Australia project CAGS, PRC-US Clean Energy Research Center for coal, etc.

Finally, the CDM mechanism recognizes CCS geological storage projects and a GHG Emission Trading System (GHG ETS) has been piloted in many cities in the PRC, including Shanghai and Guangzhou. While it is recognized that current carbon prices are insufficient to incentivize development of CCS projects, participation of future CCS projects as part of the CDM program or GHG ETS pilots in the PRC could provide additional sources of fiscal support for CCS projects in the PRC.

1.4 Voluntary Approaches (VAs)

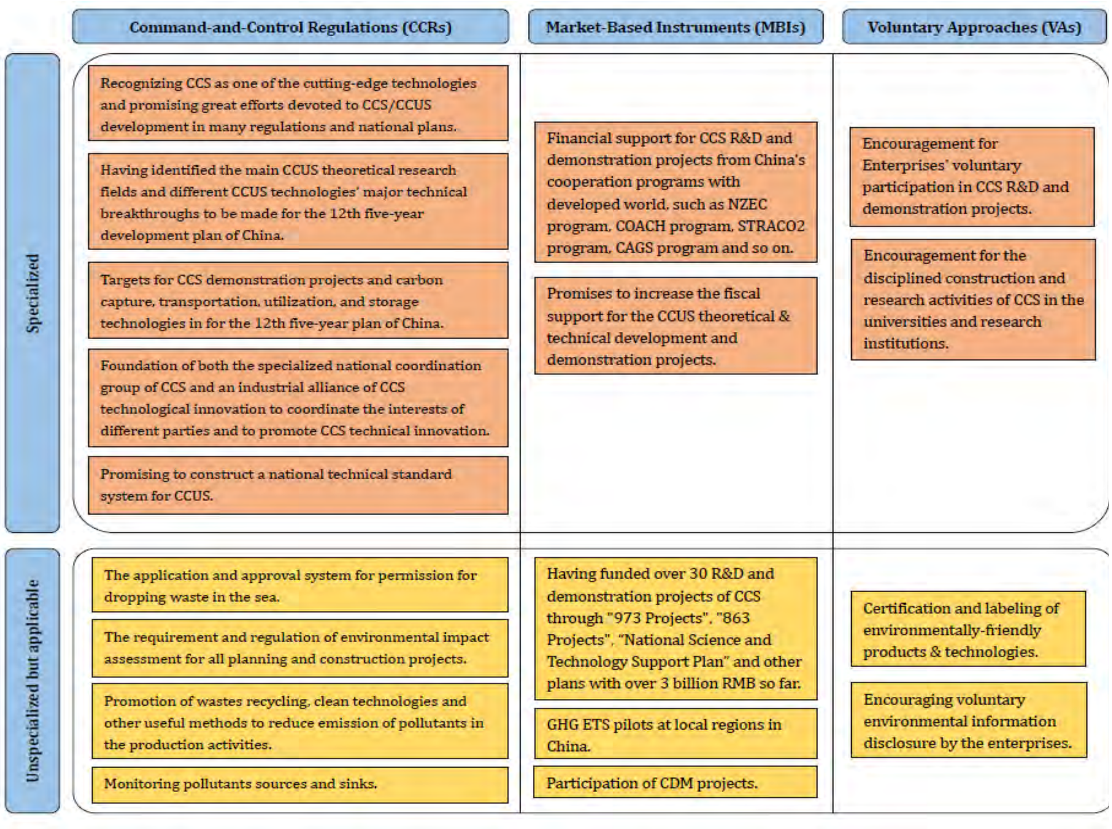
The PRC has encouraged the voluntary participation in CCS R&D and demonstration projects in many regulatory documents, including *Scientific & Technological Actions on Climate Change* (2007), *Outline of National 12th five-year economic and social development plan*, *Outline of National Midterm & Long-term Science and Technology Development* (2006-2020), etc. The *National 12th Five-year Specialized Scientific and Technological Development Plan for Carbon Capture,*

Utilization and Storage (CCUS) encourages universities and research institutes to undertake "disciplined construction" of CCS projects and research activities.

In addition to these formal documents, many other laws, though not specific to CCS projects, could help encourage voluntary participation in CCS R&D and demonstration projects in the PRC. For example, CCS technologies could be identified as environmental-friendly technologies by *the Environmental protection product certification regulation in the PRC*, which would encourage CCS-related researches. The *Law of Environmental Information Disclosure Methods* (EIDM) could also help encourage voluntary environmental information disclosure from the CCS projects, and thus help protect the public and environment from adverse impacts associated with CCS. However, these laws have not yet been amended to specifically include CCS technologies.

A summary of regulations for CCS development in the PRC is shown in Figure 2 below.

Figure 2: Summary of regulatory framework for CCS development in the PRC



Note: The "Specialized" category means the regulations are specialized for CCS development, and the "Unspecialized but applicable" category means the regulations can be applied to promoting CCS development though not specialized for CCS.

2 Regulatory Gaps and Barriers

In this section, we identify important gaps in the PRC's regulatory environment for CCS. In general, we identify three major gaps/barriers: (1) lack of technical & management standards, (2) lack of efficient policies for information disclosure and public engagement, and (3) financial barriers and lack of efficient economic incentivizing policies to cover commerciality gap.

2.1 Technical & Management Standards

Technical & management standards normalize the operation of industrial projects and clarify liabilities in order to protect the interests of both society and the environment. To promote the development of CCS/CCUS in the PRC, basic regulations required include a national plan combined with targets and priority areas, with a series of technical & management standards to guide the actual project construction and operation. With the national plan for CCS/CCUS research and demonstration development (i.e. the *National 12th Five-year Specialized Scientific and Technological Development Plan for Carbon Capture, Utilization and Storage (CCUS)*), the PRC has made a great progress in promoting CCS development. However the necessary technical & management standards (e.g. storage site selection, environmental impact assessment, long-term liability and so on) still need to be put in place. In relation to environmental impact assessment (EIA) approvals, while the PRC has issued the *Law of the People's Republic of China on Environmental Impact Assessment* to regulate the requirements and standards for environmental impact assessment of construction operation of industrial projects, no specific amendment has been made for the deployment of CCS. Tsinghua University and the World Resources Institute have jointly published *Guidelines for Carbon Dioxide Capture, Utilization and Storage (CCUS) in the PRC (2011)* and that the PRC's National Standards Committee has publicly announced an intention to develop national standards, incorporating the work of ISO's Technical Committee for CCS. These efforts will advance the process of setting appropriate technical and management standards, but it is important that ultimately they are incorporated in regulations that promote and enable delivery of CCS projects.

2.2 Information Disclosure and Public Engagement.

There is little public awareness in the PRC regarding CCS technologies and, to date, there has not been a concerted effort by Government or industry to help the public better understand CCS in the context of environmental benefits and considerations.

Internationally, the failure to include the general public in early stages of CCS project development has led to strong opposition against the CCS projects in Germany, the Netherlands and United States (Donath, 2010; Forbes et al., 2010).

2.3 Financial Barriers & Lack of Efficient Economic Incentivizing Policies

In the PRC, as elsewhere, CO_2 emission constraints are currently insufficient to bridge the commerciality gap and incentivize investment on their own. While the PRC Government has provided significant support to research and development of CCS technologies, additional financial support measures will be required to provide the commercial and strategic rationale for industry to commit the necessary resources into deploying CCS projects at scale.

3 Non-Financial CCS Support Policies

In this section we explore the potential CCS policies to fill previously identified regulatory gaps in the areas of technical, management standards and promoting efficient public engagement.

3.1 Construction of Technical and Management Standards

With the national plan for CCS/CCUS research and demonstration development, the PRC has made a great process in promoting CCS development, however development of technical and management standards will assist in normalizing the operation of CCS projects and clarify liability obligations, with the benefit of protecting the interests of society and the broader environment.

Technical and management standards for CCS have been developed in other jurisdictions. The U.S. *Guidelines for Carbon dioxide Capture, Transportation and Storage*, the US EPA's Class VI regulations for geologic sequestration provide detailed technical standards for CCS technologies, monitoring methods standards and procedures. The *Guidelines for Carbon dioxide Capture, Transportation and Storage,* which predated these EPA regulations, also clearly detail the risks and impacts analysis of EIA in all the capture, transportation and storage processes of CCS projects.

In Europe, the EU. *Directive 2009/31/EC of the European Parliament and of the Council on the geological storage of carbon dioxide* (*Directive 2009/31/EC* for short below) identifies the main contents for the risk assessment, including hazard characterization, exposure assessment, effects assessment, risk characterization and stipulates minimum standards for storage site selection, storage permitting, field operational management and long-term liability. *Directive 2000/60/EC* and *Directive 85/337/EC* stipulate technical standards for CO_2 sequestration fields and CCS equipment. Besides, *Directive 2009/31/EC, Directive 2000/60/EC* and *Directive 85/337/EC* all contribute to environmental impact assessment and risk assessment standards for CCS projects, and it is stated that only when the projects pass these assessments, can they get the permit of operation and can the CO_2 stream be accepted. It is recommended that the PRC develop technical & management standards to cover the following five aspects of CCS project development.

1) **Technical performance standards for carbon capture, utilization and storage technologies.** Technical standards should ensure that the technologies used are mature enough to guarantee the interest of the investors and safe enough to prevent huge damages to the society and environment.

2) **Standards for storage site selection and management covering**

a) Standards for site selection and site risk assessment methods based on the geological components of the site, fragility of biological environment around the site, the potential of natural hazards, the presence of any existing wells or other underground infrastructure that could provide a leakage pathway for the CO_2, and the health status and opinions of people around the site. One of the important standard for site selection should be minimizing the potential of CO_2 leakage. And the risk assessment should provide contingency plans for any serious incident.

b) A long-term recording, managing and reporting mechanism that stipulates the parameters to be monitored, monitoring technologies, warning lines for each parameter, and the data management and reporting mechanism. The monitoring and reporting mechanism should continue after the site is shut down.

c) Long-term liability definition and penalty standards covering the ownership and liability of storage site at different stages (e.g. construction stage, operation stage of the project, closure stage and post-closure stage.

3) **A whole-process monitoring mechanism** devoted to monitoring operations and regulating the recording and reporting of data including the amount of CO_2 captured, the amount of CO_2 utilized and stored, the leakage rate of CO_2, emission of other pollutants and emergency plans for accidents

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* has identified all the potential processes of different categories, where CO_2 emission might occur, in the CCS projects. Also it provides detailed methods to estimate CO_2 emissions in different processes of a CCS project. For example, Table 3 comes from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and shows potential emission pathways from geological reservoirs.

Table 3: Potential emission pathways from geological reservoirs

POTENTIAL EMISSION PATHWAYS FROM GEOLOGICAL RESERVOIRS		
Type of emission	**Potential emissions pathways/ sources**	**Additional comments**
Direct leakage pathways created by wells and mining	• Operational or abandoned wells	• It is anticipated that every effort will be made to identify abandoned wells in and around the storage site. Inadequately constructed, sealed, and/or plugged wells may present the biggest potential risk for leakage. Techniques for remediating leaking wells have been developed and should be applied if necessary.
	• Well blow-outs (uncontrolled emissions from injection wells)	• Possible source of high-flux leakage, usually over a short period of time. Blowouts are subject to remediation and likely to be rare as established drilling practice reduces risk.
	• Future mining of CO_2 reservoir	• An issue for coal bed reservoirs
Natural leakage and migration pathways (that may lead to emissions over time)	• Through the pore system in low permeability cap rocks if the capillary entry pressure is exceeded or the CO_2 is in solution	• Proper site characterization and selection and controlled injection pressure can reduce risk of leakage.
	• If the cap rock is locally absent	• Proper site characterization and selection can reduce risk of leakage.
	• Via a spill point if reservoir is overfilled	• Proper site characterization and selection, including an evaluation of the hydrogeology, can reduce risk of leakage.
	• Through a degraded cap rock as a result of CO_2/water/rock reactions	• Proper site characterization and selection can reduce risk of leakage. Detailed assessment of cap rock and relevant geochemical factors will be useful.
	• Via dissolution of CO_2 into pore fluid and subsequent transport out of the storage site by natural fluid flow	• Proper site characterization and selection, including an evaluation of the hydrogeology, can determine/reduce risk of leakage.
	• Via natural or induced faults and/or fractures	• Possible source of high-flux leakage. Proper site characterization and selection and controlled injection pressure can reduce risk of leakage.
Other Fugitive Emissions at the Geological Storage Site	• Fugitive methane emissions could result from the displacement of CH_4 by CO_2 at geological storage sites. This is particularly the case for ECBM, EOR, and depleted oil and gas reservoirs.	Needs appropriate assessment.

Separately, in WRI's CCS Guideline, a Measurement, Monitoring, and Verification (MMV) system has been suggested for the geological storage part of the CCS project. This MMV system clarifies the parameters needed to monitored, the monitoring techniques and requirements, and other key information. Both the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and WRI's CCS Guidelines, as well as the US EPA's regulations and the European Union Directive provide adequate references to develop a whole-process monitoring mechanism for CCS projects.

4) Requirements and standards for environmental impacts and risks assessment

EIA law in the PRC has not been updated provide a suitable framework for risk assessment of CCS projects or emergent plans for to deal with potential hazards and incidents. CCS activities present potential hazards and risks that occur across the project chain (e.g. capture, transport, injection, storage). These risks, associated *inter alia* with the potential release of CO_2, can have potentially significant impacts upon human health, safety and the environment. Because CO_2 has the potential to escape (through long-term seepage and/or sudden unintended release) from a geological storage site after injection has ceased, the scope of an environmental impacts assessment and risk analysis for a CCUS project must also consider all phases of a project life-cycle e.g. from construction through normal operations to site closure and post-operation.

Operators should take steps to avoid the following identified potential environmental impacts and potential sources of hazard:

- Common co-constituents in the captured CO_2 from any industrial facility include trace amounts of sulfur dioxide (SO_2), nitrogen oxides (NO_X), hydrogen sulfide (H_2S), carbon monoxide (CO), methane (CH_4), nitrogen (N_2), argon (Ar), and oxygen (O_2). The quantity of each co-constituent varies depending on the type of industrial facility and type of capture and compression units. Because H_2S poses human health and safety risks at low concentrations, its presence requires due diligence and extra precautions, although it should be noted that Canada has experience in safely transporting and injecting H_2S-rich gases. Oxygen can also introduce technical challenges during storage by stimulating growth of microbiological organisms in the subsurface.

- Increased energy use associated with (predominantly) capture stage giving rise to additional GHG and non-GHG atmospheric emissions

- Surface water quality impacted by produced water treatment and discharge

- Groundwater quality impacted in the event of abnormal CO_2 leakage

- Soil acidification as a result of an abnormal CO_2 release

- Induced seismicity or other geologic impacts as a result of poor pressure management

- Global air quality impacted/project undermined in the event of an abnormal CO_2 release

The environmental risks and hazards for CCS projects are identified and managed through a series of steps. These steps are a modified version of the UNFCCC modalities and procedures for CCS in the CDM[11] which stipulate that "Geological storage sites shall only be used to store carbon dioxide as project activities….if, under the proposed conditions of use, there is no significant risk of seepage, no significant environmental or health risks exist, and the geological storage site will comply with all laws and regulations of the host Party".

1. Site selection based on site-specific geologic information

In general, the analysis of the suitability of a potential storage site must be based on site-specific geological details whereby an operator can demonstrate that the target formation has the necessary features to enable injectivity of the CO_2, capacity to store the desired volume of CO_2 and containment to ensure that the injected CO_2 does not migrate to contaminate groundwater or endanger human or ecosystem health. There are a number of guidelines, regulatory frameworks and standards that have been designed to ensure safe, secure CO_2 storage. The CZ741-12 Standards and WRI CCS Guidelines for example outline criteria that should exclude a site for use as a CO_2 storage site. These include:

- Failure to demonstrate capacity, injectivity and containment criteria for the storage reservoir
- Located in areas where seismic activity is likely to affect the security of the CO_2 stored
- Located in areas with extensive, high-density faulting and fracturing that are provide trans missive pathways for CO_2 migration
- Over-pressured systems where CO_2 injection would create conditions for fracturing the geologic seal providing containment for the CO_2 stored
- Located in an area where existing wells penetrate the storage formation and cannot be remediated to ensure secure storage.

2. Risk assessment, including hazard identification and management

[11] UNFCCC (2011) Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities. Decision 10/CMP.7

In addition to outlining the geologic criteria necessary for safe storage, existing regulatory frameworks for CCUS outline the need for an integrated risk assessment for the CCUS project. Such a risk assessment should be based on a geologic model of the site and be updated as information is gathered during site characterization and operation. Regulators should require periodic submission of the risk assessment. Although injected CO_2 is expected to remain in the target formation, unanticipated leakage could occur, through wells that are poorly constructed or improperly plugged and abandoned or through unidentified transmissive faults and fractures that provide a pathway for CO_2 leakage from the target formation to another reservoir, which could ultimately lead to groundwater or the surface. The initial risk assessment should provide the basis for evaluating the environmental and socio economic impacts of the project.

3. Monitoring, including operational monitoring and post-injection monitoring for unanticipated leakage or seepage.

Numerous references exist in respect of best practice for identifying, assessing and monitoring CO_2 storage sites, including recent publications from the US National Energy Technology Laboratory (NETL), Det Norske Veritas (DNV) and others, as well as guidance produced by the International Panel on Climate Change (IPCC). Furthermore, in December 2011, Modalities and Procedures (M&Ps) were adopted within the UNFCCC process for CCS projects under the CDM, providing high level guidance, among other issues, on storage site characterization and risk assessment.[12] All these sources have been reviewed and together they provide a best practise framework for undertaking EIA of CCS and CCUS projects.

The monitoring plan is also critical to the safety and effectiveness of a CCUS effort. Because different monitoring tools will prove more successful at different sites, most regulatory frameworks outline performance-based criteria for monitoring, rather than establishing numeric standards or requiring an operator to prove a quantity of CO_2 contained in a formation. For example, the WRI Guidelines recommend a monitoring plan include techniques that monitor the following parameters:

- Project footprint at depth is measured with information gathered on CO_2 and pressure geometry and location
- Reservoir pressure and temperature are monitored to evaluate the integrity of the confining unit(s) and wells

[12] UNFCCC (2011) *Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities*. Decision 10/CMP.7

- In-situ stress is measured to evaluate the integrity of the confining units and wells
- Well performance and integrity is measured to evaluate the integrity of wells, monitoring CO_2.
- Surface and near-surface CO_2 concentrations and fluxes are measured to identify unanticipated leakage, with a goal of early detection and mitigation measures in place beforehand

Regulations for Permit Application, Verification and Issuance

An effective system is required to cover the application, verification and issuance of permits necessary for construction and operation of a CCS project as is likely to encompass the previous four aspects of technical and management standards. Application processes would document project background and plans, detailed technical reports, EIA report, application sheets, expect profits report and other important documents. During the verification process, the government sector would verify the authenticity of the documents and assess whether the CCS projects should be permitted. Issuance procedures cover permit issuance, periodic monitoring to confirm the project's ongoing qualification for the permits and public access to issued permits.

3.2 Promoting efficient public engagement

Public engagement continues to present risks and opportunities to CCS projects. The area covers interaction with stakeholders able to influence project progress and success such as regulators and site communities, as well as the broader public, including media and NGOs.

Three main reasons can justify the need of efficient public engagement. First, the public's incomprehension or misunderstanding of CCS technologies might lead to strong opposition against the CCS projects. Second, information disclosure and public engagement are essential to ensure the public's right to know and the public supervision of CCS projects. In addition, CCS industries seek balance between levels of general public awareness that make project communications more effective, and collaboration with local communities to understand and address their specific concerns. Thus efficient public engagement can be important for the healthy development and deployment of CCS. Many research in the area calls for more efforts in this regard (*e.g.* P. Ashworth *et al.*, 2012; C. Oltra *et al.*; 2010, M. Prangnell, 2013).

Many countries and international institutions have paid much attention to promoting

efficient public engagement in CCS projects. For example, in the 2013 version of CCS roadmap, IEA has stated that efforts must be significantly increased to improve understanding among the public and key stakeholders of CCS technologies and the importance of its deployment. IEA also specifically points out that important public engagement efforts are needed prior to making final decisions regarding storage. Also, in Australia's *Environmental Guidelines for Carbon Dioxide Capture and Geological Storage – 2009*, it is stated that the risk assessment process, monitoring process and approval process of the CCS projects have to be public and available for the public. The World Resources Institute convened an international group of public engagement experts with experience working on CCS project and published the Guidelines for Effective Community Engagement in CCS projects in 2010. Another good example is South Africa. South Africa is developing its own CCS education plans, including a national education plan and a local national plan (Brendan Beck et al., 2013). The national education plan focuses on providing the basic principle of CCS technologies as well as potential benefits and risks of their application, while a local education plan emphasizes the communication about key information of local CCS projects among local government, local CCS projects and the local community.

To achieve efficient public engagement, the following policy suggestions are listed below for consideration and further evaluation:

1) Providing education of basic scientific knowledge of CCS/CCUS for the public, carried out by both the government and CCS projects. This public education should include information about how the CCS can help alleviate the global warming, and improve the public understanding of CCS's value and risks.

2) Requiring disclosure of the basic information of CCS projects from both government and CCS projects, such as an introduction of the project, an introduction of the specific CCS technologies used in the CCS projects, environmental impact assessment reports, emergency plans and other information. This information should be available for the public in many different ways, such as through internet and traditional publication.

3) Ensuring efficient public engagement platforms for the public, including colloquia between the project managers and the public representatives, public hearings, projects publicity and other platforms. For example, each CCS project should hold the public hearings to collect and respond to the public opinions and public engagement should be an important part for EIA report of CCS projects.

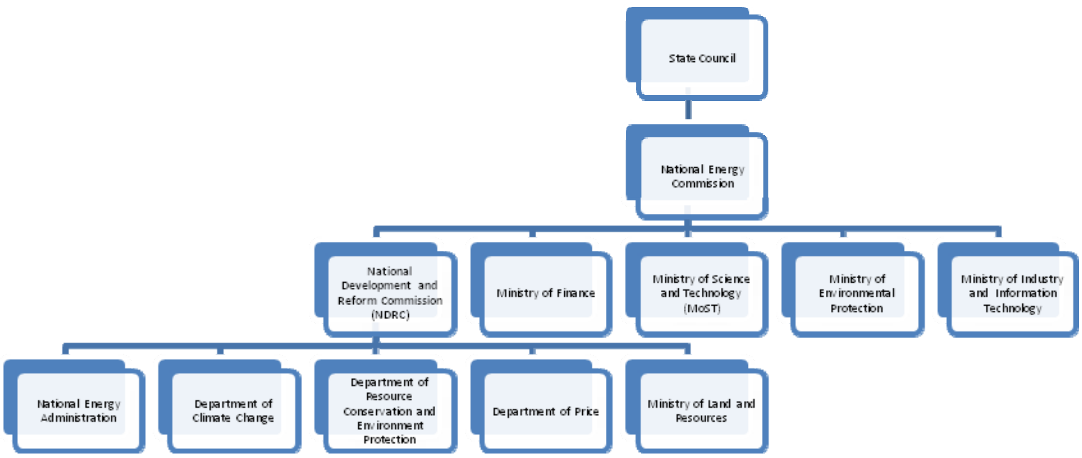
4 Key Stakeholders

Domestic governments, CCS project developers in electricity and coal sectors, and entities able to utilize concentrated CO_2 streams (such as oil companies in enhancing oilfield production), along with finance institutions are important domestic stakeholders.

Domestic Government

Key government stakeholders are shown in Figure 3 below. The National Energy Commission formed by the State Council is a high level organ to consolidate energy policy among the various agencies under the State Council. The National Development and Reform Commission (NDRC), a department under the State Council, is the primary policymaking and regulatory authority in the energy sector. The National Energy Administration (NEA) under the NDRC is the major government agency charged with approving new energy projects in the PRC, setting domestic wholesale energy prices, and implementing the central government's energy policies, among other duties. The Department of Climate Change under NDRC is responsible for organizing and coordinating the formulation of key strategies, plans and policies dealing with climate change, including taking the lead in the implementation of United Nations Framework of Climate Change Convention (UNFCCC).

Figure 3: Key Government Stakeholders



Project Developers

Potential project developers across the value chain of CCS are dominated by the large, state-owned enterprises (SOEs). Figure 4 summarizes the major players.

Figure 4: Project developers across the value chain

Generator/CTX → CO_2 → CaptureCo → CO_2 → TransportCo → CO_2 → StorageCo

- Power Generation:
  - Five Bigs: Huaneng, Datang, Guodian, Huadian, and China Power Investment Corporation
  - Other major power companies: China National Nuclear Corporation, China Three Gorges, Guangdong Yuedian Group, Zhejiang Provincial Energy, Shenhua, and China Resources Power Holdings
  - Smaller generators invested by provincial or municipal governments
  - Two main grid companies: State Grid Corporation of China and China Southern Grid
- Coal companies
  - 10 large and 10 medium-sized coal companies are emerging

- Oil companies
  - the China National Petroleum Corporation (CNPC)
  - the China Petroleum and Chemical Corporation (Sinopec)
  - The China National Offshore Oil Corporation (CNOOC)
  - The Sinochem Corporation and CITIC Group

Moving beyond R&D investments, large CCS projects will require larger additional pools and funds for CCS directed by SOEs. The prominance of SOEs presents both challenges and opportunities in the context of controlling CO_2 emissions. On the one hand, the government may be able to significantly influence the adoption of certain technologies through its central planning, policies and national budgets. Government ownership implies that SOEs are at least in part directed by the Chinese nation in a way that serves the interests of the nation. SOEs can behave differently as a function of their state ownership and presume non-commercial orientation. Some of the larger SOEs are spearheading a drive to publish their reports on corporate social responsibility (CSR). In addition, SOEs typically have direct access to funding, including for low-carbon investments. Their operations are taken to be funded by the state, subsidized by borrowing from state banks at subsidized rates and soft repayment terms. So Chinese SOEs has advantages to implement CCS projects with their non-commercial orientation, arising corporate social responsibility and funding facilities.

Domestic Banks

Chinese banks hold a unique position in the PRC's financial system. Until in 2012 the direct Renminbi loan provided by banks made up over 50% of the nation's funding aggregate. The PRC's financial sector is dominated by five large, state-owned commercial banks: the Bank of China, the Industrial and Commercial Bank of China; the China Construction Bank; the Agricultural Bank of China; and, to a lesser extent, the Bank of Communications. Three policy banks, China Development Bank (CDB), the Agricultural Development Bank of China, and the Export-Import Bank of China, undertake government-directed spending functions. While the CDB is transitioning from a policy-based bank to a commercial bank, it retains a mandate to advance the PRC's national interest.

The PRC's large commercial banks have a lending bias towards the SOE's due to a view that, as state owned borrowers, the SOEs are likely to have "strong business positions, resulting from monopolistic or oligopolistic power, superior business models or other factors", which enhances their credit risk profile. Consequently, the domestic commercial banks have shown a positive inclination to lend to CCS projects with SOE involvement.

Commercial banks have a relatively conservative attitude to debt financing terms. According to a stakeholder consultation conducted by UK-EU-PRC Near Zero Emissions Coal Initiative (NZEC) in 2009 in the PRC (16 key stakeholders were selected and consulted, including 5 chief financial officers from power and oil industries, 7 commercial bankers, and 4 development bank energy specialists):

- The average required perceived ratio of (equity capital) / (total capital) was 47%, much higher than the 20% to 25% value that is common in conventional thermal power projects. Commercial bankers believed much lower capital leverage would be required to create a more stable capital structure, in order to compensate for the extra operating risks involved in CCS demonstrations.

- Measures such as NPV, IRR or payback-period are frequently applied in evaluating the economics or capital budgeting of a power project in the PRC. Development banks and state-owned energy firms, suggested that hurdle rates lower than 10% and payback periods of higher than 10 years were appropriate, as they might consider CCS projects to be a non-commercial investment; Commercial banks, required higher reference rates and shorter return periods to reflect the risk premium relative to conventional thermal power investment.

5 Financial Policies for Incentivizing CCS Development

CCS projects can struggle to attract investment due to high capital costs, operating cash flow and revenue risk considerations. A variety of incentivizing policies and financial support measures can be used to help overcome these barriers. The following section examines the underlying barriers to investment in CCS projects and the potential impact of CCS-specific financial support polices in the PRC.

5.1 Financial Barriers to Investment

Global experience suggests that despite ambitious projections and sizeable government initiatives to support demonstration programs, the CCS project landscape continues to face challenges and, consequently, investment in CCS remains largely at demonstration/early commercial deployment phase. Regardless of jurisdiction, a consistent set of barriers are apparent that are hampering deployment of CCS projects. To date, provision of Government support to CCS has occurred on an ad hoc basis

Lack of Commerciality and Revenue Certainty

In most instances, CCS applications are currently not commercially viable. The most obvious exceptions are situations where a tight carbon constraint needs to be met for the project to proceed (e.g.: Sleipner CO_2 reinjection in response to Norwegian government CO_2 tax on the gas extraction industry), where exposures to potential future CO_2 liabilities outweigh the cost of abatement (e.g.: Gorgon natural gas extraction and LNG processing project in Australia) or where the value of captured CO_2 outweighs the processing costs (e.g.: Weyburn enhanced oil recovery project). However, in general there is a significant gap between the incremental capital and operating costs (primarily energy consumption) associated with the technology and the baseline revenue that may be achieved by the underlying installation and the sale of captured CO_2 or excess emissions allowances (CO_2 avoided), which needs to be covered through additional financial support. Therefore, faced with constraints or CO_2 emissions or another form of CO_2 price penalty, a CO_2 emitter has the option of (i) paying the CO_2 price penalty (business as usual), (ii) ceasing operations or (iii) implementing CCS. The decision as to which of the three options to pursue will in most cases be determined by commercial drivers, and at present most generators are taking the business as usual approach.

Solving the fundamental economics and ensuring positive project cash flows, however, will be central to any stakeholder's decision to invest in a large scale CCS project and will require both a reduction in the overall cost of abatement as well as

market-based incentives or policy frameworks to tighten constraints on CO_2 emissions.

While many industrial processes produce relatively high purity CO_2 effluent streams, in the power sector the majority of total incremental costs of CCS are associated with separation, and compression of CO_2. A number of technology developers have identified opportunities for cost reductions of up to 60% in next of a kind applications, driven by technological improvements, increased scale of deployment, learning by doing and lower risk premia required by investors reducing the cost of capital.

The global constraint on carbon has, so far, not proven tight enough to support the development of CCS. The EU Emissions Trading System, whereby a maximum number of emission certificates are traded on an open market, was introduced by the European Union in 2005 to help meet the region's Kyoto Protocol commitments. However, as yet the scheme has not stimulated investment in low carbon technologies to the extent policymakers had originally hoped as energy efficiency measures and reduced economic activity has meant that emission targets have been met at relatively low cost, depressing the trading price for emission certificates. A relatively low certificate price outlook has meant that private sector investors are unable to underwrite investment in large scale CCS projects.

In the absence of near term carbon constraints sufficient to justify investment in CCS, interest has grown in the possibility of deriving alternative revenue streams from the utilization of captured CO_2. Building on relevant experience in the North American oil and gas industry, one focus area has been on the use of captured CO2 to assist in the extraction of oil from underground reservoirs ("Enhanced Oil Recovery" or "EOR"). In an EOR project, CO_2 is injected into a producing oil field to increase the amount of oil that can be economically extracted, justifying a price that an emitter can sell CO_2 to the oil producer. Current prices being paid for CO_2 in EOR situations in North America are in the range of $30 per tonne. Permanency of storage remains an issue for such projects, as a portion of injected CO_2 becomes entrained in the produced oil and the long term applicability of CO_2 for EOR beyond certain "niche situations" remains uncertain.

Technical Risk

While each of the components making up the CCS value chain have been established as technically feasible technologies, financiers continue to express concern about potential scale-up issues and the current limited experience in integrating these components at scale. During the early phases of commercial demonstration and deployment, sufficient commercial incentive needs to be in place

for entities to absorb these types of risk. Perceived technical risks can be resolved through demonstration at scale

Legal and Regulatory Risks

Investors require adequate and stable legal and regulatory frameworks to provide security in the forthcoming rollout of CCS. In the absence of greater certainty over the timing, completeness, and stringency of future policy frameworks and given their high absolute costs, risks, and complexities, private industry cannot justify investment in large-scale CCS projects. In addition, the uncertainty or failure of emerging regimes to sufficiently address the issue of long-term storage liability continues to be a critical issue for CCS project proponents

Counterparty Risk

Intermittent forms of clean energy, such as wind and solar place some demands on counterparties such as transmission companies, which require commercial negotiation, CCS requires an even close integration of several unique businesses, often with different return expectations and operating cultures. While capture and compression are typically undertaken by a single entity or a joint venture, the transport and storage components may be operated by separate entities. The interdependence of the different CCS elements introduces the issue of counterparty risk, as a failure in one part of the chain may have a knock-on effect on the entire project. This includes CO_2 volume or deliverability risk, as well as credit risks. In view of the potential fragility of individual links in the chain and the distinct business profiles of the different project stakeholders, the appropriate allocation of risk and the establishment of adequate safeguards across the chain will be crucial to the success of integrated CCS projects.

Lack of Incentive to Invest

Other than the risks described above, perhaps a more important barrier to private sector investment in CCS today is the absence of basic incentives to do so. Realising a CCS project requires significant organizational commitment and a fundamental belief that it is worth pursuing now, justified for example by the prospect of an early mover advantage or future carbon constraints.

Setting aside the project economics, technology integration and risk allocation issues as well as the immature policy and regulatory framework globally, CCS is still not an obvious investment proposal for many of those considered as necessary investors. At the emitter end and in the absence of binding emissions reduction targets, stringent regulations and carbon constraints, the fossil fuel combustion and other emissions intensive industries are not incentivised to deviate from a “business as usual”

strategy. For likely transport and storage operators, the costs and risks surrounding CO_2 emissions are considered to be the emitter's problem and are content with the current "polluter pays" approach to CCS. Aside from governments, the only stakeholders enjoying a more obvious incentive to invest in CCS are the CO_2 capture technology providers, as the early innovators are more likely to shape future market standards. However, barring a few exceptions, most providers are not in a position to act as lead proponents on large scale projects, securing extensive financing or deploy their own balance sheet for large scale demonstration projects.

It is clear that the obstacles to investment in CCS deployment are substantial and considering the long lead times necessary to plan, permit and commission projects, near term deployment of CCS infrastructure will not be possible without government direction and support.

Beyond the universal financial barriers to investment described earlier, implementation of CCS in the PRC presents some special impediments. These obstacles need to be understood in order to gauge the true potential of CCS and determine feasible business development pathway in the PRC.

In the PRC, CCS support programs have tended to focus on research and development, with the main fiscal support mechanisms available being national science-technology plans (such as 973 Program, 863 Program, National Science and Technology Support Plan and so on), the PRC's cooperative programs with the developed world (such as the PRC-EU CCS collaborative research projects COACH, PRC-UK project NZEC, PRC-Australia project, CAGS, etc) and the international CDM mechanism. This has resulted in over 3 billion CNY being invested in CCS research and demonstration projects over the past 6 years.

As the PRC's central planners confront the PRC's energy challenges, CCS investments have to be understood not only in terms of their own system-wide costs but also in terms of potential opportunity costs in foregone alternatives. The PRC is now experiencing a boom in clean-energy development. Wind power grew from 0.76 GW in 2004 to over 75GW in the end of 2012 and the Chinese government has a plan to reach 200GW of wind in 2020, which requires more than CNY 1 trillion in additional investment. Deployment of solar is planned to reach 50GW in 2020, and around CNY 500 billion is estimated to be required from 2012 in order to achieve that target. Nuclear is on track to account for 3-4% of the energy mix in 2020, for which over 500 billion CNY of investment is required.

5.2 Illustrative Financials for Prototype CCS Projects

In order to examine the potential impact of financial support measures on CCS project viability, four generic CCS project are considered – three power-based and one coal-to-liquids facility:

- Integrated Gas Combination Cycle (IGCC) Plant – 430 MW
- Pulverized Coal Plant (PC) – 600 MW
- Oxy-fuel Plant – 200MW
- Coal-to-Methanol facility – 1,100 tonnes per day (methanol)

A dynamic Discounted Cash Flow (DCF) model has been developed in order to evaluate the impact of financial support mechanisms on the overall costs and revenues of CCS (including transport and storage) for each of the respective project scenarios. The model uses a Levelised Cost of Electricity (LCOE)[13] methodology, which indicates the price at which electricity (or methanol in the coal-to-liquids scenario) must be sold to make the project economically viable while taking into account the full **capital**, **operating** and **financing costs** of building and operating each respective facility. The model is also capable of accommodating a selection of financing instruments (e.g. debt and equity from government, private investors or banks) and support mechanisms (e.g. capital cost subsidies, operating cash flow support and risk mitigation). A Debt Service Coverage Ratio (DSCR) constraint has also been incorporated to ensure that each respective project has sufficient cash flow to meet its debt service requirements.

Reference Plant Technical Parameters and Cost Data

The reference configuration is based on data acquired that details the respective IGCC, PC, Oxy-fuel and Coal-to-Methanol facilities. For purpose of comparison, "w/CCS" and "No CCS" scenarios were developed - the "w/CCS" case assumes that 90% of produced CO_2 is captured and transported by pipeline 100 km for either long term storage or for beneficial reuse in enhanced oil recovery (EOR). Detailed reference plant technical parameters and cost data can be found in the Appendix D.

Transport and Storage Costs

Table 4 below is summarizes capital and operating costs for transport and storage in

[13]Levelised Cost of Electricity defined as the average price at which electricity generated in the plant under consideration would need to be sold overthe projected project lifetime such that investors receive their expected returns (measured in $/MWh). This includes covering the capital expenditure,operating costs (fixed, variable and fuel costs), cost of CO2 transport and storage, and the cost of capital (debt service and return to equity investors).

the reference case scenario. It is assumed that at a distance of 100km or less, no additional booster stations would be required. For both the base case w/CCS scenarios, it is assumed that each facility will capture 90% of its respective CO_2 emissions per year, and that captured emissions will be transported an injected into a saline aquifer for long term storage.

Table 4: Transport and storage costs

Financing Scenarios	Capital Costs	Fixed / Variable O&M
Transport (14 in. 100km pipeline)	CNY 474.7 million	3% / 0.025MWh/tCO_2
Storage (5 well – Saline Aquifer)	CNY 434 million	10%

Base Case Financing Scenarios

The "Base Case" financing scenario developed incorporates input from financial institutions and project proponents. The resulting LCOE for the underlying facilities was chosen as the reference for comparing various financial incentives.

While it is possible that some early CCS projects, particularly in non-power applications, will be financed through corporate balance sheet facilities, this analysis considers projects financed on a limited-recourse basis in order to separate corporate and project-specific effects. The Base Case structure seeks to optimize the cost of finance for each component of the chain and assumes that the Base Plant & Capture, Transport and Storage are financed as separate entities, reflecting their individual business models and risk profiles. Again, it is possible that an integrated project with a single lead developer may be financed on an overall basis.

Based on discussions with industry stakeholders, it has been assumed that a traditional power generation project with no CCS can be financed with up to 80% leverage. The real and perceived risks associated with early CCS projects, however, are likely to limit the leverage available with 70% leverage being indicated as a maximum. An interest rate of 6.5% for projects without CCS is consistent with the current lending environment in the PRC. For the purposes of this analysis, it is assumed that projects with CCS will be eligible for the 0.55% interest rate deduction, currently mandated for clean energy projects. In the Base Case, remaining financing is assumed to come from an equity contribution by the project developer. Discussions with various stakeholders indicate that project would need to earn an Internal Rate of Return ("IRR") on equity of 12% in order to attract investment, while the equivalent

plant without CCS would require an equity return of approximately 9.5% (calculated as a 3% premium to the nominal debt interest rate). Financing scenarios are summarized in Table 5 below.

The analysis does not take into account any fees or transaction costs relating to sourcing financing as arranging fees for finance are not standard practice in the PRC.

Table 5: Base case financing scenarios

Financing Scenarios	Power		CTL	
	No CCS	W/ CCS	No CCS	W/CCS
Total Leverage	80%	70%	80%	70%
Interest Rate	6.5%	5.95%	6.5%	5.95%
Debt Tenor	18 years	12 years	18 years	12 years
Min. DSCR	1.4X	1.6X	1.4X	1.6X
Return on Equity	9.5%	12%	9.5%	12%
WACC	5.41%	6.67%	5.41%	6.67%

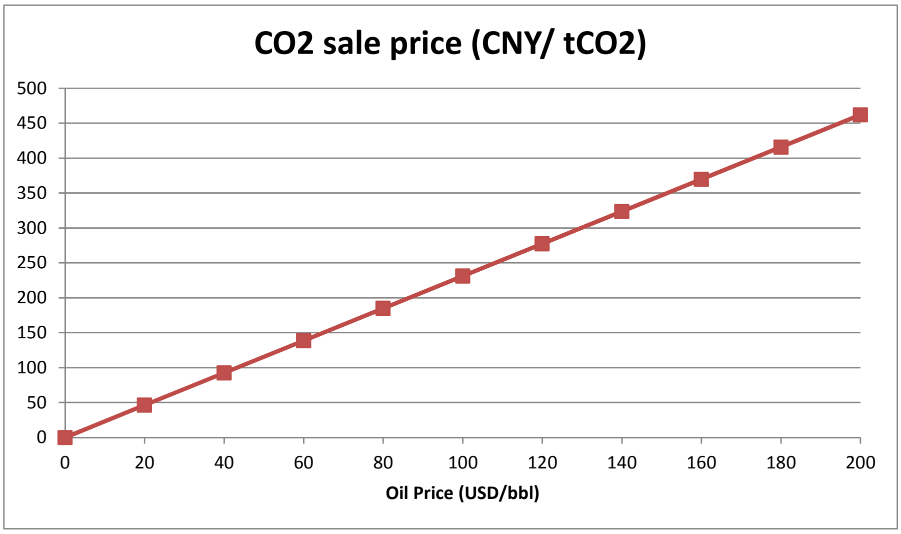
Given the investment amounts involved, it is highly unlikely that such projects would get financed with 100% equity, even if the potential equity returns would exceed more than 18%. The impact on LCOE due to changes in financial terms is significant. The deterioration of financing terms alone may lead to an increase in LCOE of more than 20%, compared to a project with access to finance at the same terms as a plant without CCS. This implies that to reduce LCOE for first mover project the government could support them by supporting effective de-risking of such projects.

Impact of CO_2-EOR on base case costs

CO_2-EOR is a thirty year old practice used widely in the Permian Basin of Texas and the Gulf Coast region of the United States. CO_2-EOR is a tertiary stage of oil recovery whereby, under the right geological conditions, CO_2 can be injected into mature fields and result in significant volumes of incremental oil production. While conventional oil production practices can typically produce roughly 35-50% of an oil reservoir's original oil in place (OOIP), CO_2-EOR can yield an additional 5-17% of OOIP. In the PRC, many demonstration projects have utilized technologies of utilization of captured CO_2, such as PetroChina's CO_2-EOR Research and pilot Injection in Jilin Oilfield, China United Coalbed Methane Co. Enhanced Coal-Bed Methane (ECBM) Pilot Project, and Jinlong-CAS CO_2 utilization pilot in chemical production in Jiangsu.

While the market price for CO_2 utilized in EOR in the United States is impacted by the prevalence of naturally occurring CO_2 sources, the price (in units of mcf) is seen to be tied to roughly 2%-3% the price of oil, with most long term contracts being written in the range of USD20-30/tonne CO_2.[14] This relationship is highlighted in Figure 5 below.

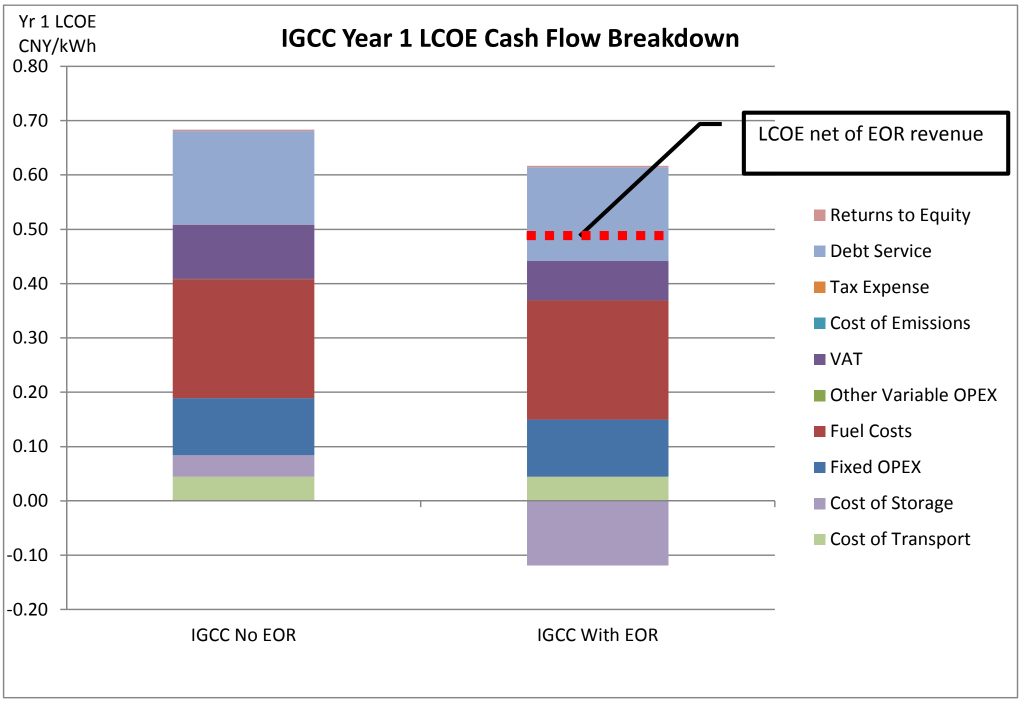
Figure 5: Indicative relationship between oil price and CO_2 sale price in the US



In early mover CCS projects, project revenues from CO_2 sales can be used to offset capture costs. Figure 6 below shows the positive of year one cash flows, not only eliminating storage costs, but also providing a revenue stream to offset other costs.

Figure 6: Potential impact of EOR on levelized cost of power for IGCC with CCS

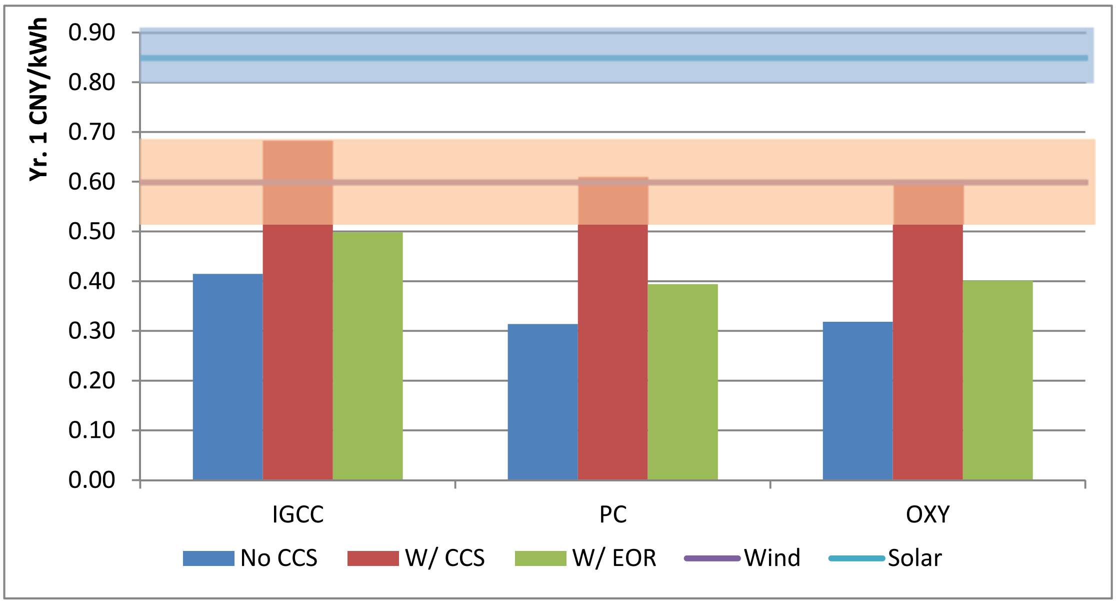
[14] http://www.netl.doe.gov/energy-analyses/pubs/Storing%20CO2%20w%20EOR_FINAL.pdf



5.3 Benchmarking CCS against Alternative Technologies

Figure 7 below shows the resulting LCOE of the reference scenarios benchmarked against existing revenue support measures currently offered for new power generation technologies in the PRC. These support measures, in the form of a feed-in-tariff for both wind and solar PV, and set at CNY 0.6/kWh and CNY 0.85/kWh respectively, can be considered as a proxy for revenue support in this analysis. As demonstrated below, the resulting LCOE of each of the respective reference case scenarios falls below or between the benchmarked feed-in-tariff levels.

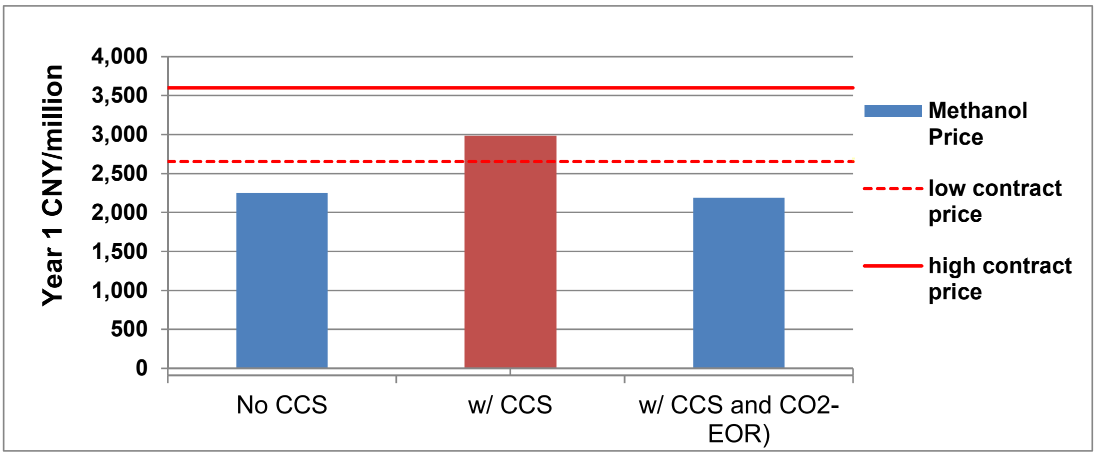
Figure 7: Benchmarking CCS against alternative power generation technologies



IGCC= integrated gasification combined cycle, PC=pulverized Note: EOR assumes a CO2 sales price of CNY 120 per million ton of CO2

In the coal-to-methanol reference scenario, the levelized cost of methanol production is benchmarked against the 12 month monthly average Asian Posted Contract Price (APCP)[15]. As shown in Figure 8 All reference costs fall firmly within or below the contract price range posted during the past 12 months.

Figure 8: Benchmarking against 12 month APCP trading range

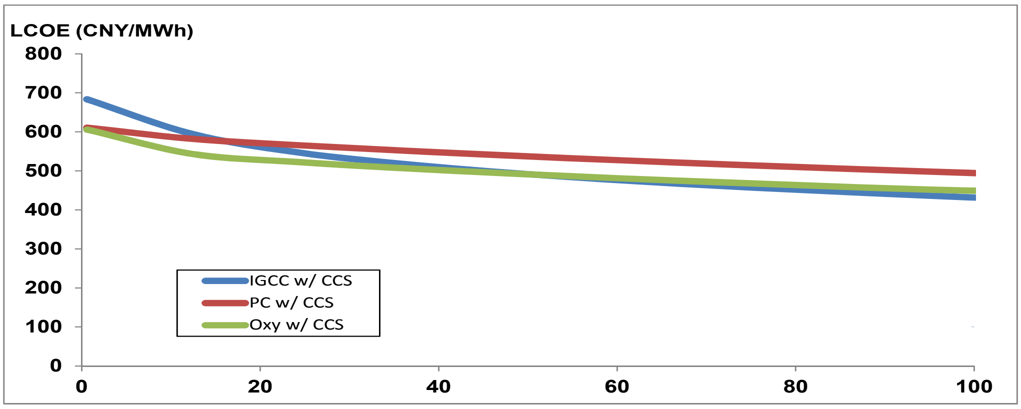


[15] Methanex Monthly Average Regional Posted Contract Price History", September 2013-September 2014, https://www.methanex.com/our-business/pricing

5.4 Learning Curve

For CCS to have a future as a meaningful emission reduction tool, it will need to become viable on a standalone basis without technology-specific government support policies. The potential volume of emissions that may be captured from point sources dwarfs that which may be utilized by the hydrocarbon extraction industries, meaning that long term CCS scenarios should not assume a revenue stream from EOR sales. Therefore, CCS investors will only deploy CCS at scale when they feel investment is warranted by their view on a carbon price trajectory or it is mandated by government and the underlying plant is able to remain economically viable with the CCS cost penalty. Figure 9 below indicates that currently power produced by an IGCC plant with CCS is expected to be more expensive than equivalent supercritical plant, the relative immaturity of IGCC technologies presents opportunities for greater cost reduction as capacity builds out. As the potential volume of CO_2 to be stored through CCS is orders of magnitude larger than the potential opportunity of storage via EOR and, therefore, the following charts do not assume any revenues from EOR.

Figure 9: Evolution of levelized cost of electricity in PRC generation plant with CCS



5.5 Impact of Economy-Wide Support Measures

Provided that long-term government emission reduction policies are sufficiently aggressive and implementable, it is expected that an economy-wide price on emissions that is administered by way of taxation, trading schemes or regulation will ultimately be required to underwrite the economics of CCS projects.

Carbon Tax / Emission Trading Scheme (ETS)

A carbon tax requires an economic entity to pay a certain amount of tax per unit of

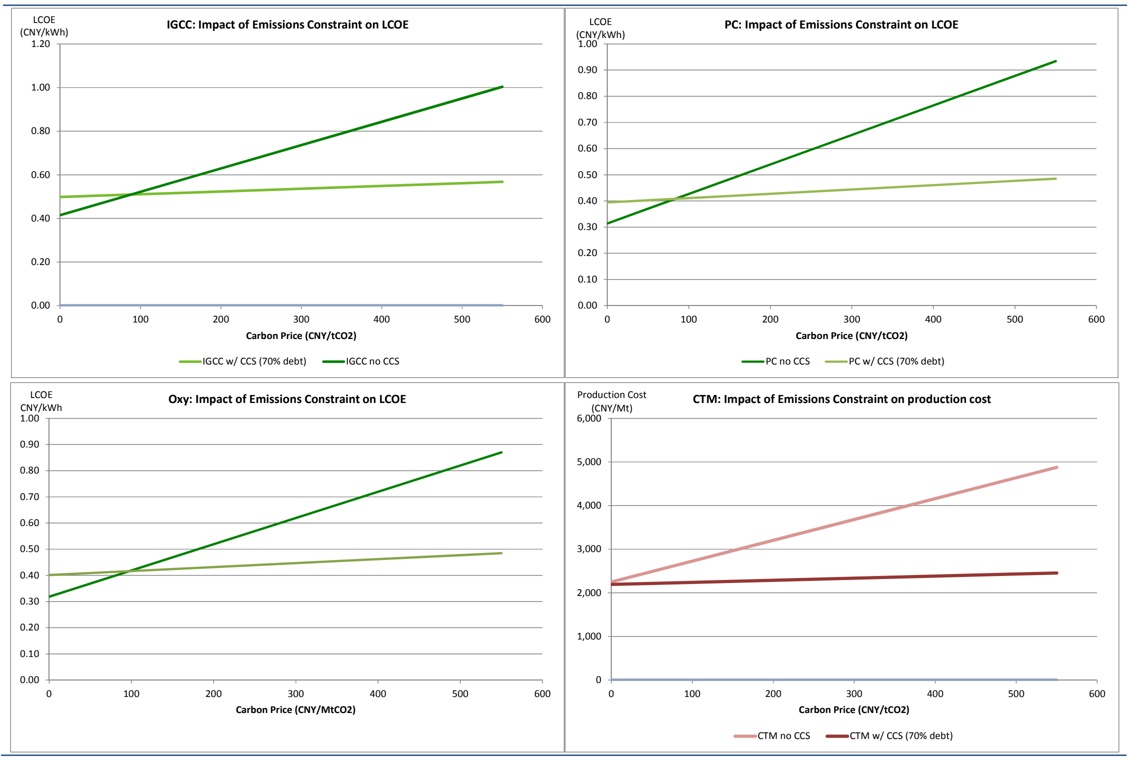
CO_2 (or equivalent) emitted to the atmosphere beyond a preset limit. For projects in which CO_2 is deemed to have been permanently stored, the tax is not payable, reducing ongoing costs enhancing competitivity relative to non-CCS plant required to pay for emissions. An emission trading scheme (ETS) works in a similar way to a carbon tax, with emitters being charged per unit of CO_2 emitted. A key difference is that the under an emission trading scheme, the price paid for CO_2 emitted is set by the market in response to a government-decreed volume allowance.

International experience: A number of developed countries have introduced a carbon tax or ETS to drive the uptake of low-carbon technologies, including CCS. One high profile example is Norway, which designed its carbon tax policy in 1991. The tax rate varies between industries, with offshore petroleum production currently taxed at the highest rate of NOK410/tonne CO_2 emitted. The policy is seen to have had a great effect in increasing the greenhouse gas efficiency of the economy as a whole. The UK has applied a policy of a minimum carbon tax to its energy sector and economic regions such as the European Union have had emission trading schemes in place for over a decade. At present, many carbon ETS systems have taken action to explicitly include CCS. For example, the CDM mechanism has included carbon capture and storage in geological formations into the system, and EU-ETS includes CCS among allowable emissions reduction technologies. The EU-ETS also attempted to support CCS with income from auctioning carbon emission permits.

Domestic precedents: In the PRC, carbon ETS pilot schemes commenced in 2012 in Guangzhou, Shenzhen, Shanghai, Beijing and other cities. Promoting CCS development by including CCS into the trading system could provide additional incentive.

Illustrative impact: Figure 10 below illustrates the impact of a carbon price (whether through a tax or ETS) on the relative economics of the respective reference plants with and without CCS. For modeling purposes, the CO_2 price is assumed to rise at 2% per annum in real terms. The LCOE for plant with and without CCS are seen to cross at approximately CNY 175/tCO_2 CNY100/tCO_2 and CNY375/tCO_2 initial carbon price for the reference IGCC, PC, and Oxy-fuel plants respectively. As previously seen, revenue derived from CO_2-EOR sales helps to close the commerciality gap in early mover projects and is therefore assumed to for part of the base case for all support measure evaluations.

Figure 10: Impact of emissions constraints on cost of production for power and CTM technologies



Note: assumes a CO_2 sales price to EOR of CNY120/t

Bonus Allowances

The policy of bonus allowances refer to that the government will offer a certain amount of free carbon emission permits for CCS projects, and the CCS projects can get income from selling or auctioning these permits in the carbon market.

International experience: Although bonus allowances have been discussed and proposed in the US, they are yet to be adopted. In the EU, a pool of 300 million credits were set aside as part of the New Entrants Reserve, however ultimately these credits were not allocated to CCS.

In the PRC, depending on the success of the pilot ETS systems and the eventual structure of an ETS, bonus allowances policy could also be applied to support CCS development.

Emission performance standards

By applying stricter carbon emission performance standards for different industries (e.g. power sector and petrochemical industry), the government can force an enterprise to implement emission reduction strategies including low-carbon technologies like CCS.

International experience: The policy of stricter emission performance standards has been proposed by some developed countries to promote CCS technologies. In the

USA, the Environmental Protection Agency (EPA) has proposed new emission performance standards for the newly-constructed fossil fuel power plants of less than 1000 pounds of CO_2 per megawatt hour, which would effectively require partial CCS (approximately 50% capture) at future coal plants.

In Canada, the national Government published for public comment its proposed regulations to reduce CO_2 emissions from coal-fired electricity generators in the latter half of 2011. Under these proposed regulations, new coal-fired generators and mature units nearing retirement, will be required to abide by stringent performance standards based on the emissions performance of high-efficiency NGCC plants. In the 2012, the Canadian government has finalized new greenhouse gas emissions performance standards for coal-fired power plants[16]. Under the final regulations, all new and end-of-life coal units must emit less than 926 pounds of CO_2 per megawatt-hour of electricity beginning in July 2015, similar to the emissions intensity of an unmitigated natural gas combined cycle unit. The final rulemaking represents a loosening of expectations compared to the 827 lb/MWh standard the government initially proposed in August 2011, as well as a move towards the U.S. standard, which is currently proposed at 1,000 lbs/MWh for new fossil fuel-fired units.

In UK, the emission performance standard (EPS) has been updated in 2012 to promote CCS and other low-carbon technologies development, and the new EPS was set as 0.45kg CO_2 per kilowatt hour.

Mandatory quotas

In the mandatory quotas policy, the government will require a certain level of share of the low-carbon technologies, including CCS technologies, in the industries. For example, the government will require a certain share of electricity from renewable energy in the power sector, or restrict the production of power plants without CCS technologies. This policy does not provide direct economic incentives, but can also encourage the low-carbon technologies utilization.

In UK, the new fossil fuel power plants over 300MW are required to have CCS-Ready design. A certain share of electricity from renewable energy has been required in UK, and any enterprise which fail to fulfill the mandatory quotas will face a penalty of 0.045euro/kWh.

In the PRC's regulation of on-grid price, the National Development and Reform Commission stated in 2005 that the PRC will apply the policy of mandatory quotas to

[16] http://ghgnews.com/index.cfm/canada-unveils-softened-final-ghg-performance-standard-for-coal-units/
http://www.globalccsinstitute.com/insights/authors/davidhanly/2012/12/04/emission-performance-standards-old-option-new-incentive-ccs

renewable energy to promote renewable energy's development in the future. Mandatory quotas can be similarly used to promote the deployment of CCS in the PRC.

5.6 Targeted Government Support Mechanisms

The analysis, having already set for the reference plants, cost and other economic assumptions as well as base case financing scenarios, now examines the financial impact of targeted government support mechanisms on the levelized cost of electricity (CNY/kWh).

As mentioned previously, CCS projects can struggle to attract investment due to capital cost, operating cash flow and revenue risk considerations. A variety of financial support measures can be used to mitigate these barriers and have been trialed internationally in various combinations, as shown in Table 6 below.

Table 6: Support measures for international CCS projects in various stages of development

Business Case Features		Operate			Execute			Defined		
		Sleipner	In Salah	Snøhvit	Gorgon	Illinois	Quest	ROAD	Don Valley	TCEP
Capital Cost	Capital Grant					✓	✓	✓	✓	✓
	Tax Incentives									✓
Operating Cash Flow Support	CO_2 Emission Price / Tax	✓		✓	✓			✓	✓	
	EOR Revenue / CO_2 Use	×	×	×	×	[✓]	×	×	✓	✓
	Premium Power Price / Regulated Returns								✓	

	Commercial / Technical Imperative for Capture	✓	✓	✓	✓	[✓]	×	×	✓	×
Risk Mitigation	Gov. Backed Lending / Export Credit Agencies								×	✓
	LT Supply Offtake Agreements									✓
	Credible Suppliers / EPC Guar.									✓

The following section examines a number of these financial support measures in the context of CCS deployment in the PRC. It should be noted that for illustrative purposes, these incentives have been applied to the base plant and capture units only; the transport and storage financing scenarios and resulting tariff to the reference plant remain unchanged from the base case scenario.

<u>Revenue Support Mechanisms</u>

Revenue support can be structured to fulfill either or both of two important functions: (a) provision of revenue certainty, that project proponents (and their investors) can have confidence in the volume of product they will be able to sell and price at which they will be able to sell it and (b) as a form of financial support to reduce the commerciality gap. Revenue support can be delivered in a number of forms:

- Feed in Tariff – typically applied to the power generation sector, whereby generators receive a guaranteed price for power sold
- Contract for Difference / Fixed price policy – Power generator/industrial manufacturer sells product at underlying commercial price and government underwrites the difference between that price and a pre-agreed level. Can be structured so that government receives a rebate if the commercial price rises above the pre-agreed level

- CCS Certificate – Project receives a fixed price for each tonne of CCS abated

In the PRC, feed in tariffs have been widely used for supporting new power generation technologies, and are therefore considered as a proxy for revenue support in this analysis.

Feed-in-Tariff / Premium

Feed in Tariffs (FiTs) are typically applied to the power generation sector, whereby generators receive a guaranteed price for power sold. For example, the government can provide a feed-in premium for the electricity by power plants equipped with CCS technologies. Revenue support can also be applied to the sale of industrial products, for example a bonus payment made to coal-to-chemical manufacturers utilizing CCS.

FiTs can be structured to provide different levels of revenue support for different technologies, however experience has shown that the level of support needs to be regularly monitored and adjusted to ensure the public/consumer receives good value for money. FiTs have been used to great effect in facilitating the deployment of renewable energy technologies in the PRC and elsewhere. For example, Germany has set the prices of electricity from wind power, solar power and biomass as 0.09~0.1euro/kWh, 0.46~0.57euro/kWh, and 0.105~0.15euro/kWh respectively, in order to promote the development of renewable energy. FiTs can be paid for via central government funds, or through a surcharge or levy on consumers.

Domestic precedent: The PRC‘s rapid deployment of renewable energy since the enactment of the Renewable Energy Law has been primarily funded through a national surcharge on electricity consumption. In 2006 the NDRC issued the Interim Measures on Renewable Energy Electricity Prices and Cost Sharing Management which directed NDRC‘s pricing department to set a nationwide renewable surcharge levied on electricity users at a uniform rate based on the users‘ consumption of electricity. In addition to that, a Renewable Energy Development Special Fund was created in 2006 through central government budget allocations for renewable energy and the surcharge program.

In 2006, the surcharge was set at CNY 0.001/kWh, but it has doubled every two years for industrial users, who, as of 2009, were paying CNY 0.004/kWh. According to incomplete statistics, subsidies for electricity generated from renewable energies suffered from deficit of CNY 1.3 billion in 2009. This figure further increased to CNY 2.0 billion in 2010, and then rose to over CNY 10 billion in 2011. In 2012 it is even increased to CNY 20 billion. Consequently the surcharge was increased to CNY 0.008/kWh in 2011. In August 2013 the surcharge was again doubled from 0.008 CNY per kWh to 0.015 CNY per kWh for industrial users.

Government support measures, such as Feed-in-Tariffs, established as part of the Renewable Energy Development Special Fund, and financed by a national surcharge on electricity consumption17, have been critical in developing and deploying wind, biomass and solar PV industries in the PRC. To incentivize the deployment of solar PV, for example, a feed-in-tariff was introduced in 2011 and is now set at CNY 1/kWh. Currently, CCS power projects are not qualified to receive funding from the special fund. However, given the potential to increase the surcharge on electricity consumption in the future, it seems possible to consider the Special Fund as a potential source of financing for CCS by way of a feed-in tariff for CCS power projects. According to ADB's evaluation, a 400 MW IGCC facility with CCUS would require a tariff of USD 0.112/kWh to achieve a market financial return (ADB, 2011). The required tariff is 23% higher than tariffs currently available for wind power in the PRC (approximatelyUSD0.09/kWh).

Certification system for CCS

The policies of certification system for CCS refer to the government establishing a mandatory ratio of carbon supply for CCS projects in the carbon emission trade system, to help guarantee the CCS projects can get enough funds from the ETS mechanism.

Right now, ZERO has proposed a certification system for CCS projects in the EU, shown in Figure 11. As shown in the figure, a mandatory CCS% of carbon supply has been stipulated to guarantee income from ETS for CCS projects, and the tradable certification of these mandatory carbon supply will divided among all the CCS projects in EU according to the documentation of fulfillment of obligation. In this example, more fulfillment and more CCS projects will mean less certifications for each "clean" unit produced and less certification each CCS projects can get, since the total amount of carbon supply is certain. However, this policy has not t been available in any international ETS the PRC is involved in, such as CDM.

Compared with other two potential incentivizing policies related to carbon ETS (i.e. Participation in Emission Trading Scheme (ETS) and Bonus Allowances), the certification system for CCS can include mandatory action while also enabling flexibility through certificate trading concurrently.

Figure 11: CCS certificate system designed by ZERO

---

[17] In 2006, the surcharge was set at CNY 0.001/kWh, but it has doubled every two years for industrial users, who, as of 2009, were paying CNY 0.004/kWh. According to incomplete statistics, subsidies for electricity generated from renewable energies suffered from deficit of CNY 1.3 billion in 2009. This figure further increased to CNY 2.0 billion in 2010, and then rose to over CNY 10 billion in 2011. In 2012 it is even increased to CNY 20 billion. Consequently the surcharge was increased to CNY 0.008/kWh in 2011. In August 2013 the surcharge was again doubled from 0.008 CNY per kWh to 0.015 CNY per kWh for industrial users.

Capital Costs Reduction

Capital Grants – Direct investment

Capital Grants, typically released during the construction phase of a project, are structured as a portion of capital expenditure, thereby lowering the overall costs of the project. They can also be structured as preferred equity. As the cost of capital for government is often lower than that of a private sector project, capital grants are commonly seen as an effective support measure from a value-for-money to government perspective. As evidenced by existing programs in Europe, Australia, Canada and the US, capital grants are a popular form of support.

International experience: In OECD countries, direct investment has also been an important policy to promote the CCS development. For example, between 2008 and 2012, 'policy leader' governments committed more than US$22 billion in direct funding to large–scale CCS demonstration projects. Through European Energy Program for Recovery (EEPR), EU has funded the six full scale CCS demonstration projects with 1 billion Euros, out of which 399.5 million Euros has been paid for the beneficiaries of CCS projects by the end of 2013. But three out of the six CCS projects have been terminated due to financial, political and cultural reasons; only one of the remaining three projects can complete without additional financial support. Alongside other support measures, the US has directly provided 3.4 billion dollars to support the development of CCS/CCUS in the American Recovery and Reinvestment Act. In Canada, over 2.5 billion Canadian dollars have been provided to directly support 3 CCS demonstration projects. Japan has provided about US$1.16 billion to support

CCS research and demonstration projects.

Domestic Precedents: This polity has been the main economic policy applied by the PRC to promote CCS demonstration and research projects so far. By the end of 2011, Chinese government had invested over 3 billion CNY, 0.6 billion CNY out of which comes directly from the public financial system, into CCS demonstration projects. This policy has been also among main incentivizing policies utilized to promote renewable energy development in the PRC. In the near future, this policy will continue playing an important role in promoting CCS demonstration and development in the PRC.

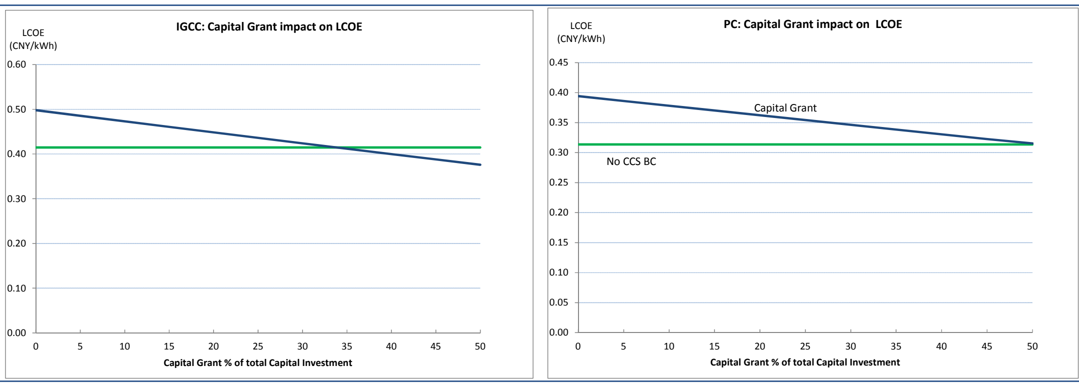
The PRC's central-government has introduced a number of policies aimed at supporting CCS R&D and demonstration projects throughout the country. These policies have been instituted through a variety of national science and technology programs that include: MOST's National High-tech R&D Program (863), the National Basic Research Program (973), and those of the National Science Foundation of the PRC.

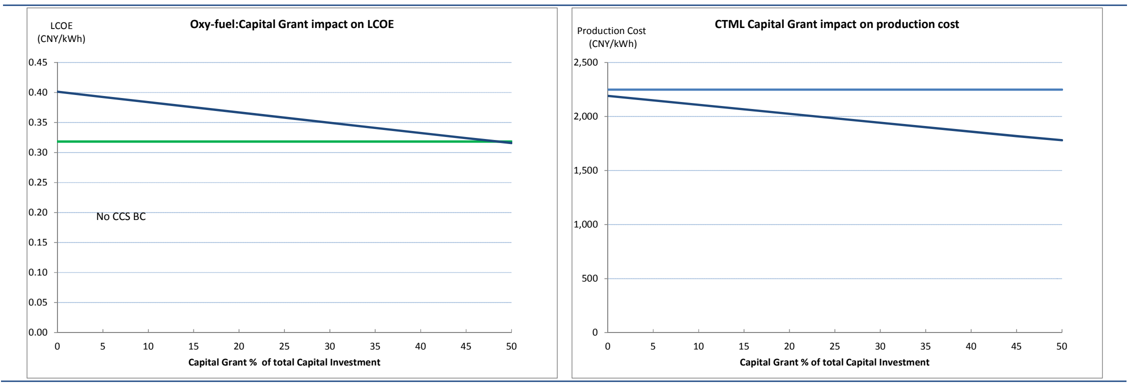
Having established a base of CCS R&D activities, the PRC is now paying greater attention to policies that are meant to incentivize the large-scale deployment of carbon capture, utilization and storage (CCUS) technologies.

Illustrative impact: The analysis assumes that the capital grant is paid to the Base Plant & Capture prior to construction with no repayment requirements, and is drawn on an "as-needed" basis in line with the plant's capital expenditure schedule during construction.

The scenario modeled is a capital grant equivalent to 25% of the plant's total funding requirement.

Figure 12: Impact of capital grants on net cost of production for power and CTM technologies





Note: assumes a CO_2 sales price to EOR of CNY120/t

Government & Development Bank Loan / Concessional Finance

Repayable Concessional Finance is an alternative capital reduction measure. The Government, or development bank, would provide a form of repayable finance, such as a subordinated loan, and offer it at rates lower than would be commercially available. The structure is similar to a capital grant with regards to repayment and would lower the overall cost of the project by reducing the blended cost of finance.

Domestic precedent: The Chinese Government offers low-interest loans and large credit lines through the China Development Bank (CDB), to finance clean energy development. The CDB is primarily responsible for raising funds for large infrastructure projects and serves as the engine that powers the national government's economic development policies. In 2010, CDB provided over 232 billion yuan (USD 35.5billion) low-interest loans to Chinese companies for clean energy projects, which constitute about 28% of all CDB lending. It also provided the PRC's major solar panel manufacturers with a combined total of 203 billion yuan (US$32.2 billion) in loans to assist them in increasing production capacity and expanding overseas operations. The China Development Bank has implemented the national green-credit policy that favours the environmentally friendly projects in its lending practice. In 2010 and 2011 CDB extended lines of credit to major companies in the renewables sector- mainly manufacturers. CDB's loans to the renewables sector have different interest rates depending on the currencies and loan maturities. They may even be more expensive than the ones companies find on the market. Therefore, the competitive advantage CDB offers is not the interest rate, but rather the high volume of the credit lines, serving as a guarantee to obtain more short-term loans from commercial banks.

Illustrative impact: The scenario analyzed considers a concessional financing scenario consistent with what would be likely be provided by an institution such as the ADB. For an individual CCS project, the ADB may offer up to $150 million USD in loans with an additional $20 million USD in grant funds. The ADB provides loans to the PRC through the bank's ordinary capital resources (OCR). These loans are libor-based plus

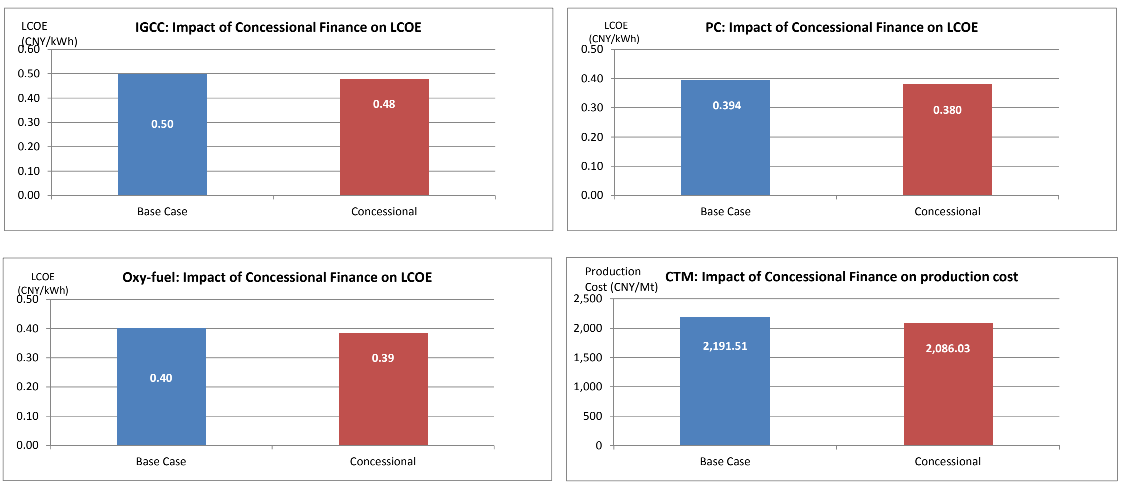
a 50 basis point margin and an average loan maturity premium, minus a discount. New projects are offered OCR loans with a 25 year tenor (including a 5 year grace period). An additional commitment charge of 15 basis points per year is levied on non-dispersed balances of respective loans.

Table 7: Concessional finance terms

% Debt	70%	**% Equity**	30%
Debt Rate	5.4%	**Return on Equity**	12%
Debt Tenor (years)	25 (5 years grace	**WACC**	6.19%

The figure below shows the impact of applying the financing terms to the reference plant LCOE. The demonstrated resulting impact of concessional finance on plant LCOE is relatively limited.

Figure 13: Impact of concessional finance on net cost of production for power and CTM technologies



Note: assumes a CO_2 sales price to EOR of CNY120/t

Tax Concessions – Direct Tax Reduction

Additional government support measures in the form of reduced corporate income taxes, value added tax exemptions and rebates, and other tax incentives based on the treatment of depreciation, may be available to renewable energy projects in the PRC. Tax incentives can decrease the project's tax liability while strengthening cash flow.

International experience: In the developed world, tax reduction policy has been applied to encourage investment in CCS projects. For example, in America, Carbon Reduction Technology Bridge Act of 2008 provided up to US$30/ton CO_2 for CCS

projects, and the $700 Billion Bailout launched in 2008 provided about US$10/ton CO_2 for carbon capture and EOR projects. Sweden has provided carbon dioxide tax reductions for CCS projects based on the amount of CO_2 sequestrated. This policy is also used in renewable energy development. For example, America reduces production tax by 1.7cents/kWh for wind power generation, and Portugal, Ireland and Belgium charge no income taxes from personal investment of renewable energy utilization.

Domestic Precedents: The Chinese government has provided tax incentives for clean energy in the form of a reduced Corporate Income Tax (CIT) rate as well as a Value-Added Tax (VAT) refund.

Corporate Income Tax (CIT)

A reduced CIT rate of 15 percent is given for qualified advanced and new technology enterprises. Applicable fields include solar energy, wind energy, biomaterial energy, and geothermal energy

Value-Added Tax (VAT)

A 50 percent refund of VAT is paid on the sale of wind power; 100 percent refund of VAT is paid on the sale of biodiesel oil generated by the utilization of abandoned-animal fat and vegetable oil.

Table 8: Value-added regime in the renewable energy sector

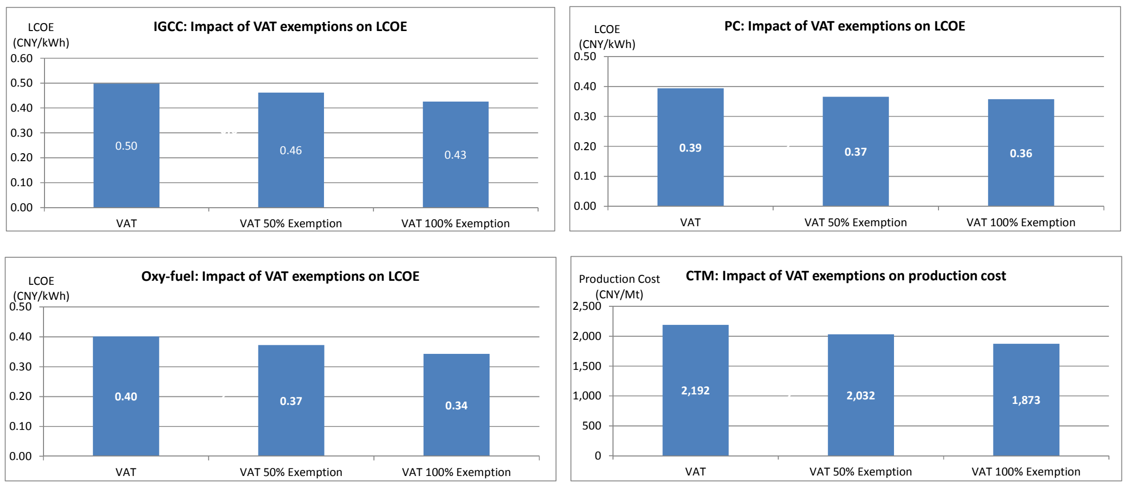
Items	Value-Added Tax	Value-Added Annex Tax	Income Tax
General	17%	8% of VAT	33%
Biodiesel	0%	8% of VAT	15%
Wind	8.5%	8% of VAT	15%

Illustrative impacts: VAT Exemption & Accelerated Depreciation

VAT Exemption

The base case assumes a standard 17% value added tax (VAT) rate charged to the sale of electricity. The following scenario considers both a 50% discount on the VAT rate (similarly applied to new energy technologies in the PRC), as well as a full exemption of VAT charged on the sale of electricity.

Figure 14: Impact of VAT exemptions on net cost of production for power and CTM technologies



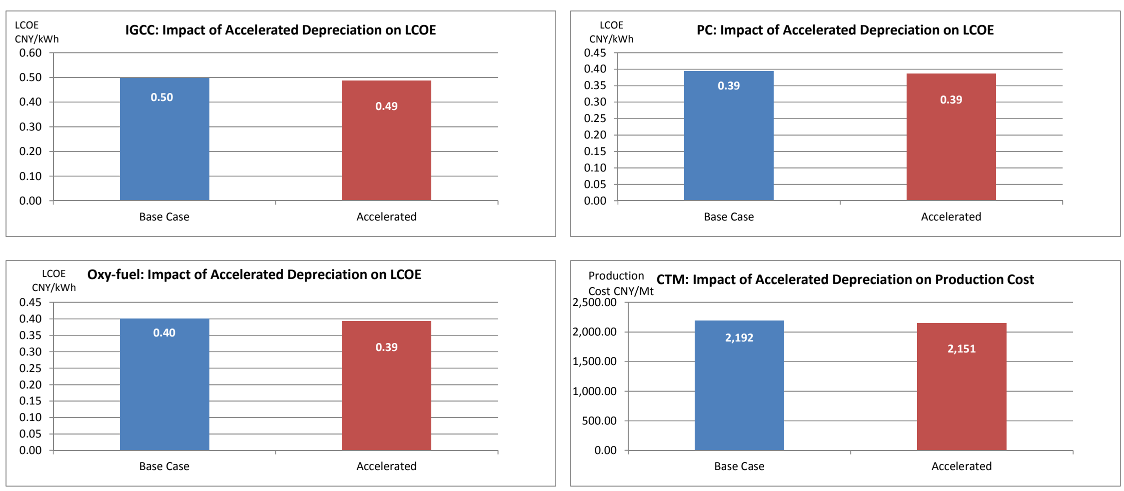
Note: assumes a CO_2 sales price to EOR of CNY120/t

Accelerated Depreciation

The base case assumes depreciation is charged under the straight line method over a period of 20 years. The project is assumed to have no residual value. In addition, the depreciation charge in each year in credited against enterprise income tax payable in that year and any unutilized credits are eligible to be carried forward for the next 5 years. This is the depreciation treatment currently adopted by qualifying special equipment related to environmental protection, energy, or water conservation and production safety.

The figure below shows the limited impact of accelerating depreciation over a period of 10years.

Figure 15: Impact of accelerated depreciation on net cost of production for power and CTM technologies



Note: assumes a CO_2 sales price to EOR of CNY120/t

Loan Guarantee

Loan Guarantees could be offered by the government to provide added security for commercial loans including potential export credit facilities on imported plant and equipment. This will increase the proponent's access to debt finance and, in the case of export credit, increase the tenor of the loan and reduce the interest rate.

International experience: In many developed countries, this policy has been applied to CCS development and renewable energy development. In America, an $8 Billion loan guarantee program is now being provided for CCS projects. UK provides discount loans with very low interest rate (i.e. 2.5%-5.1%) for wind power generation and PV projects, and Italy launched its discounted loans with zero interest specialized for small-scale PV system investment to help investors cover up to 85% of total investment. Also, discount loans are also available in France and Spain for renewable projects.

Case in the PRC: In the PRC, discounted loans have been used in encourage renewable energy development (e.g. middle- and large-scale biogas utilization projects, solar energy and so on) in rural areas. The policy of credits and discount loans support is a key policy the government can apply to CCS development, especially in the research and demonstration projects.

5.7 Combination of Measures

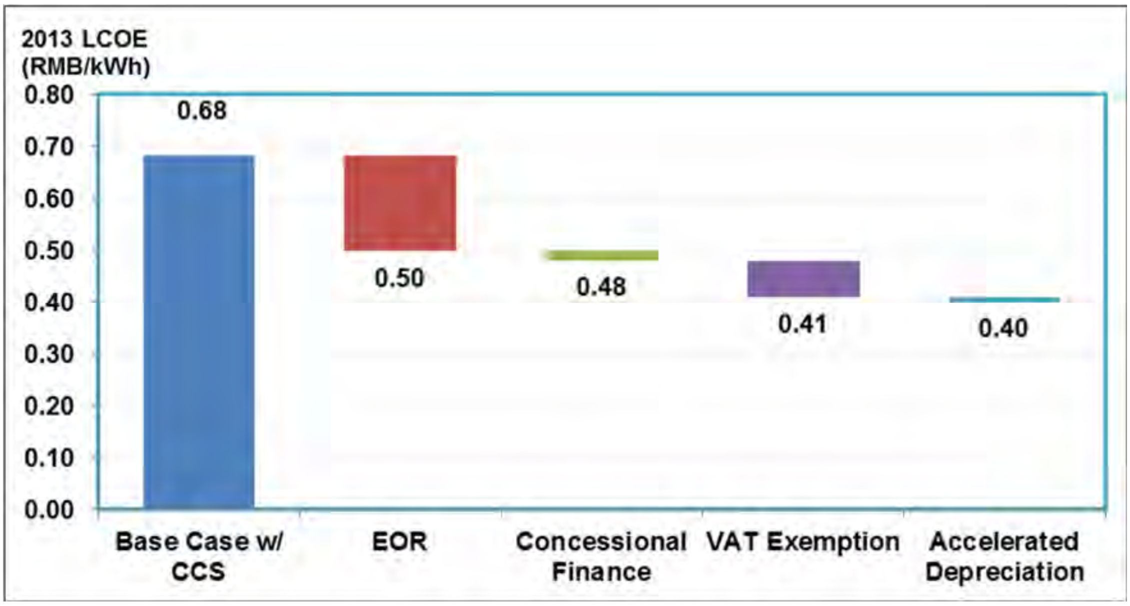
The analysis has considered a series of measures potentially available to CCS projects in the PRC that are aimed at driving down the respective plants LCOE to a commercially viable level. While it is clear that some of these measures can, even in isolation, have a meaningful impact on plant LCOE, others present a more limited effect.

The Government of the PRC has a long history of utilizing specific support measures including tax incentives and technology-specific feed in tariffs in order to support new power sector technologies. Wind and Solar PV are two industries that have recently benefited from these incentivizing polices. In addition to government support, development banks have also been prepared to provide access to concessional finance for early mover projects in the clean energy space.

Figure 16 below shows the cumulative impact of combining these measures. The EOR assumption has the most significant impact on cost of delivered power and does, and does so at no cost to government or power consumers, indicating that it may be advantageous to site early-mover CCS projects relatively close to where captured CO_2 can be used in oil recovery. VAT exemptions provide additional support, and the impacts of concessional financing and accelerated depreciation, while important, are

more moderate. Figure 16 also shows how such measures in combination can reduce the cost of power from a hypothetical IGCC plant with CCS to a coal-fired power plant without CCS. Thus, CCUS demonstration projects can be combined with smart policy incentives and low-cost financing with no additional burden on power consumers.

Figure 16: Illustrative Incentives Waterfall for IGCC Plant with CCS



6 Addressing Project Integration Barriers

For projects with multiple equity stakeholders, the appropriate allocation of risk between parties and the provision of adequate safeguards remain some of the fundamental challenges to CCS commercialization. For developments in which each of the proponents has a strong commercial or strategic rationale to participate, risk allocation is usually determined through commercial negotiations. However for early mover CCS projects, experience has shown the level of commercial/strategic incentive may not be sufficient to persuade proponents to take on additional risk. While integrated projects led by a single developer may prove easier to deploy in the near term, the pool of suitable potential projects with developers with sufficient experience to adequately assess and hold risk across the CCS value chain is likely to prove to be small and multi-developer projects are likely to be required to ensure rollout targets are met.

General Structuring Principles

When structuring a greenfield or brownfield project development, it is important that risks are placed with the party best placed to understand, price and mitigate them. This holds true for projects involving technology risk and/or exposure to relatively immature regulatory regimes.

A key assumption underpinning the proposed business structures for CCS project development in the PRC, is that government will seek to minimize its level of involvement, while acknowledging that early mover projects will require a level of public sector support and involvement to ensure successful project delivery. As the commercial drivers for CCS evolve, technology develops and regulatory regimes mature, the need for government support should reduce. Therefore in considering business structures, different structures are likely to be required for the 13th Five Year Plan period (2016-2020) and the broader rollout envisioned over 2021-2030.

Storage Characterization

Relative to total emissions capable of being captured from large scale emission point sources, the potential CO_2 storage capacity in oilfields suitable for enhanced oil recovery is grossly inadequate, and as indicated in the Roadmap it is expected that a broad takeup of CCS technologies will require characterization of significant CO_2 storage capacity within saline aquifers. The characterization process is costly, time consuming and entails considerable exploration risk, while providing no guarantee of a revenue stream, even if successful. In order for geosequestration of CO_2 to be cost-competitive with low emission alternatives, it is probable that operators of pure

CO_2 storage sites will only achieve a low, regulated return for acting as site operator. This is likely to prove incompatible with the costs and risks of storage characterization. In this respect, the operator of a CO_2 well has a business investment model unlike that of an investor in a hydrocarbon production well, for whom exploration costs and risks are expected to be offset by high operating profits generated from commodity sales. It is therefore proposed that the government commence the process of comprehensive storage characterization in order that sufficient storage be fully characterized.

Consistent with the principle that each party manages the risks that it is best placed to manage, it is proposed that in general capture, transport and EOR/storage entities hold the bulk of the cost overrun, technical and operating performance risk for their respective piece of the CCS chain. For projects with multiple equity stakeholders, the appropriate allocation of risk between parties and the provision of adequate safeguards remain some of the fundamental challenges to CCS commercialization. As illustrated in Table 9 below, in an integrated a role for government exists in mitigating stakeholder interface and long term containment risks.

Table 9: Allocating risks between counterparties

	Risk	Capture	Transport	EOR/Storage
Future	**Technology obsolescence**	Capture company	Transport company	EOR/Storage company
Cost	**Operating Performance shortfall**	Capture company	Transport company	EOR/Storage company
Cost	**Cost of construction**	Capture co.	Transport company	EOR/Storage company
Interface	**Interparty volume delivery**	Government	Government	Government
Interface	**Counterparty life**	Government	Government	Government
Environmental	**Operating environmental risk**	Capture company	Transport company	EOR/Storage company
Environmental	**Long-term liability containment**	n.a. (low)	n.a. (low)	Government

Finance	**Debt and equity access and terms**	Capture company	Transport company	EOR/Storage company
	Refinancing risk	Capture company	Transport company	EOR/Storage company

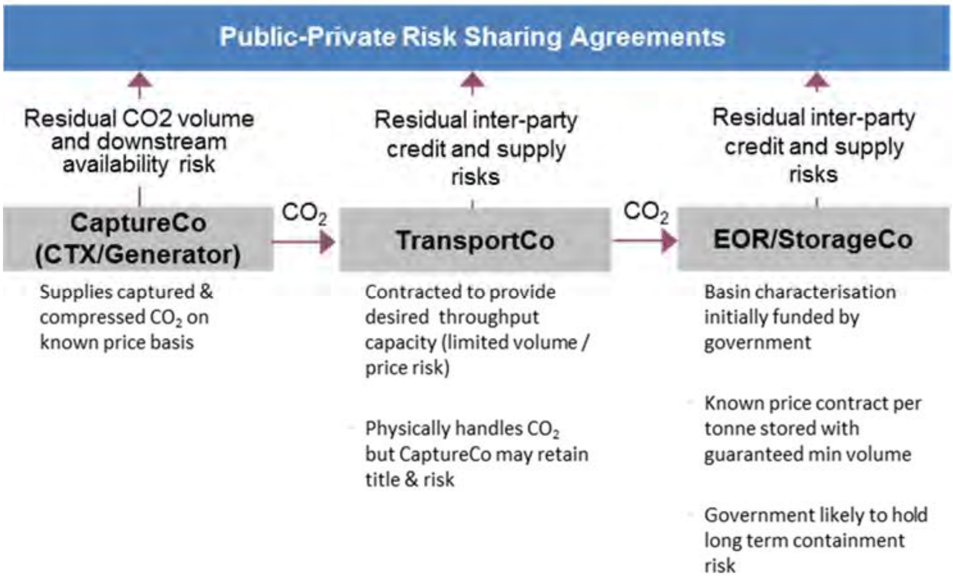
n.a. = not applicable.

To address these interface risks, it is proposed that the government provide a selective backstop through a "Public-Private Risk Sharing" model, analogous to a build-own-operate agreement where responsibility for capital investment and ongoing operations rests with the project developer, but revenue certainty is underwritten by government agreements.

During operations, project proponents will interact directly and assume normal operating and interface risks, with the public-private risk sharing agreements only becoming active once certain loss limits are breached. As a result, proponents for each of the elements in the CCS chain are incentivized to work cooperatively to resolve commercial issues, while being protected from unconstrained downside, particularly from risks that they do not have control over.

Figure 1 below shows conceptual relationships between corporate operators in a hypothetical integrated CCS project, with the government providing partial underwriting on counterparty risk. In terms of risk reduction, the government can have risk backstop arrangements with each of the separate operating companies to support project returns for adequate performance. This crucially limits each company's exposure to the operational performance of other elements in the chain. As an aside, it is noted that while the diagram illustrates a scenario in which each element is controlled by a separate entity, in reality it is possible that a single entity will control multiple elements of the CCS chain.

Figure 17: Public-Private Risk Sharing Agreements


Public-Private Risk Sharing Agreements
Residual CO2 volume and downstream availability risk
Residual inter-party credit and supply risks
Residual inter-party credit and supply risks
CaptureCo (CTX/Generator)
CO_2
TransportCo
CO_2
EOR/StorageCo
Supplies captured & compressed CO_2 on known price basis
Contracted to provide desired throughput capacity (limited volume / price risk)
Physically handles CO_2 but CaptureCo may retain title & risk
Basin characterisation initially funded by government
Known price contract per tonne stored with guaranteed min volume
Government likely to hold long term containment risk

7 References

[1]. The Climate Group, 2010. CCS in China: Towards market transformation. The Climate Group, London.

[2]. IEA (International Energy Agency), 2010. Technological Roadmaps: Carbon Capture and Storage 2009. OECD/IEA, Paris.

[3]. IEA (International Energy Agency), 2013. Technological Roadmaps: Carbon Capture and Storage 2013. OECD/IEA, Paris.

[4]. China's Ministry of Science and Technology, 2011. Carbon Capture, Utilization and Storage development in China. Ministry of Science and Technology, Beijing.

[5]. Global CCS Institute, 2010. *The Global Status of CCS: 2010*. Melbourne, Australia.

[6]. Global CCS Institute, 2011. *The Global Status of CCS: 2011*. Melbourne, Australia.

[7]. Global CCS Institute, 2012. *The Global Status of CCS: 2012.* Melbourne, Australia.

[8]. Global CCS Institute, 2013. *The Global Status of CCS: 2013*. Melbourne, Australia.

[9]. Han Guifeng, Zhang Ming, Bao Li, 2012. Analysis of technical approaches and development prospect of CCUS technology. Electric Power Technology and Environmental Protection, 28(4): 8-10 (in Chinese).

[10]. World Resources Institute (WRI), 2008. CCS Guidelines: Guidelines for Carbon Dioxide Capture, Transport, and Storage. Washington, DC: WRI.

[11]. The European Parliament and the Council of European Union, 2009. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide: Guidance Document 4.

[12]. The European Parliament and the Council of European Union, 2009. DIRECTIVE 2009/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the geological storage of carbon dioxide. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF .

[13]. National Development and Reform Commission (NDRC), 2008-2012. Annual Report of China's policies and actions on climate change: 2008-2012. National Development and Reform Commission, Beijing.

[14]. National 12th Five-year Specialized Scientific and Technological Development Plan for Carbon Capture, Utilization and Storage (CCUS), 2012, Beijing.

[15]. Li Junfeng, Shi Jingli, 2006. International and Chinese incentive policies on promoting renewable energy development and relevant proposals. Renewable Energy, 1: 1-6 (in Chinese).

[16]. Xie Zhiguo, Hu Huakai, Zhang Feng, 2005. Development of Chinese Renewable Energy Policies after the Foundation of the State. China Soft Science, 9: 50-57 (in Chinese).

[17]. Qin Tian-bao, Cheng Han, 2010. International Law Issues on the Technology Using of Carbon Capture and Sequestration. Journal of China University of Geo-sciences (Social Sciences Edition), 10 (5): 37-40 (in Chinese).

[18]. Qu Jianping, Zeng Jingjing, 2007. Carbon Dioxide Capture and Storage: Technology, Demonstration, and Legal Aspects--An Analysis on the Legal Related Issues of International CCS Efforts. World Sci-Tech Research & Development, 29 (6): 78-83 (in Chinese).

[19]. Zou Lele, Zhang Jiutian, Wei Yimin, 2010. Review and analysis of CCS related international policies. Energy of China, 32 (4): 15-18 (in Chinese).

[20]. Dennis Best, Brendan Beck, 2011. Status of CCS Development in China. Energy Procedia, 4: 6141-6147.

[21]. Zhao Rongpin, Ding Minglei, Huang Xianjin, 2013. Research on policy system for Carbon Capture, Utilization and Storage in China. Scientific and Technological Management of Land and Resources, 30 (3): 116-122 (in Chinese).

[22]. L. Zheng et al, 2011. The necessity of and policy suggestions for implementing a limited number of large scale, fully integrated CCS demonstrations in China. Energy Policy, 39: 5347-5355.

[23]. ZHU Fagen, CHEN Lei, 2011. CCS in China: Status Quo, Prospect and Obstacles. Energy Technology and Economics, 23 (1): 46-49 (in Chinese).

[24]. Guo Mingxiao, Cai Wenjia, 2013. Status of global CCS technological development and related policies. Energy of China, 35 (3): 39-42 (in Chinese).

[25]. Zhong Ping, Peng Sizhen, Jia Li, Zhang Jiutian, 2011. Development of Carbon Capture, Utilization and Storage Technology in China. China Population, Resources and Environment, 21 (12): 41-45 (in Chinese).

[26]. Chen Zheng-ao, Li Qi, Zhang Xian, 2013. The Implementation of European Energy Program for Recovery CCS Demonstration Projects and Inspirations to China. China Population, Resources and Environment, 23 (10): 81-86 (in Chinese).

[27]. Xiang Zhen, 2010. Issues in Development of CO_2 Storage Technology. Environmental Science and Technology, 23 (2): 71-78 (in Chinese).

[28]. IEA, 2010. Carbon Capture and Storage Legal and Regulatory Review Edition1. OECD/IEA, Paris.

[29]. Fan Ying, Zhu Lei, Zhang Xiaobing, 2010. An Analysis on Carbon Capture and Storage Technology, Regulations and Its Emission Reduction Potential. ADVANCES IN CLIMATE CHANGE RESEARCH, 6 (5): 362-269 (in Chinese).

[30]. Liu Lancui, Cao Dong, Wang Jinnan, 2010. Environmental Impacts of Carbon Capture and Storage Technology and Some Suggestions. ADVANCES IN CLIMATE CHANGE RESEARCH, 6 (4): 290-295 (in Chinese).

[31]. Donath, J., 2010. Not Under My Backyard: One German Town's Fight against CO_2 Capture Technology. Der Spiegel, Hamburg.

[32]. Forbes, S.M., Almendra, F., Ziegler, M., 2010. Guidelines for Community Engage-

ment in Carbon Dioxide Capture, Transport, and Storage Projects. World Resources Institute, Washington D.C.

[33]. National Development and Reform Commission (NDRC), 2007. National actions to climate change in China. National Development and Reform Commission, Beijing.

[34]. Peng Sizhen, 2013. Domestic and international development of CCUS projects and related policies. Low Carbon World, 01: 18-21 (in Chinese).

[35]. The International Renewable Energy Agency (IRENA) & The Global Wind Energy Association (GWEA). 30 years of policies for wind energy – China. Masdar: IRENA. 2013

[36]. Qi Ye etc. Report on China low carbon development 2013. Beijing: publishing house of china's social sciences, 2013

[37]. Qi Ye etc. Report on China low carbon development 2014. Beijing: Publishing house of china's social sciences, 2014

[38]. Li Junfeng. Report on China’s wind development 2012. Beijing: China environmental science press

Appendix A – Applicable PRC Command and Control Regulations

List of the PRC's Command-and-Control regulations that might be applicable for various components of CCS process.

- Environmental Protection Law of the People's Republic of China (Set by NPC, 1989)
- Law of the People's Republic of China on Environmental Impact Assessment (passed by NPC, 2003)
- Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution (passed by NPC, last amended in 2000)
- Marine Environmental Protection Law of the People's Republic of China (Set by NPC, 1982)
- Law of the People's Republic of China on Promotion of Cleaner Production
- Measures for the management of environmental monitoring
- Law on Prevention and Control of Water Pollution (passed by NPC, last amended in 2008)
- Implementing Rules on Law on Prevention and Control of Water Pollution (set by State Council, 2000)
- Groundwater Quality Standards[26] (set by MEP, 2007)
- Regulations on the Administration of the Prevention and Control of Pollution in Protected Areas for Drinking Water Sources and Groundwater (provided by the Former Administration of Environmental Protection and the Ministries of Health, Construction, Water Resource, and Land and Resources, 1989)
- Implementing Rules on Law on Prevention and Control of Air Pollution (issued by State Council, 1991)
- Emission Standards of Air Pollutants for Thermal Power Plants (issued by MEP, 2004)
- Law of the People's Republic of China on Solid Waste Pollution (Set by NPC, 2004)
- Standard for Underground Storage of Hazardous Wastes (set by Former Administration of Environmental Protection, 2002)
- Safety Management Regulation for Dangerous Chemicals (Set by the Former State Administration of Environmental Protection, 2005)

- Measures for the Safety Review of Dangerous Chemicals Production and Storage Construction Projects (Set by State Administration of Work Safety and State Administration of Mine Safety, 2005)
- Property Rights Law (passed by NPC, 2007)
- Coal Law (enacted by NPC, 1996)
- Land Administration Law (enacted by NPC, latest amended in 2004)
- Implementation Regulations for Land Administration Law (set by State Council, 1998)
- Geological Exploration Management Ordinance (set by State Council, 2008)
- Geological Exploration Registration Rules (Set by State Council, 2006)
- Mineral Resources Law (passed by NPC, latest amended in 1996)
- Implementation Rules for Mineral Resources Law (set by State Council, 1994)
- Urban and Rural Planning Law of the People's Republic of China (set by NPC, 2007)
- Production Safety Law of the People's Republic of China (Set by NPC, 2002)
- Regulations for Protection of Oil and Natural Gas Pipeline (issued by State Council, 2001)
- Regulations Governing Pressurized Pipelines In Chemical Companies (set by Former Ministry of Chemical Industry, 1995)
- Procedures for Test of Pressurized Pipelines In Chemical Companies (set by Former Ministry of Chemical Industry, 1995)
- Temporary Provisions for Safe Supervision and Management of Petroleum and Natural Gas Pipelines (set by former State Committee of Economy and Trade, 2000)
- National Standard GB16201-1996: Health standard for carbon dioxide in the air of workplace (set by Standardization Administration of China (SAC) under ASQIQ, 1996)
- National Standard GB6052-1993: Commercial Liquid Carbon Dioxide (set by SAC under AQSIQ, 1993)
- Regulations for Governing the Laying Of Submarine Cables and Pipelines (issued by State Council, 1989)

- Implementation Rules for Regulations for Governing the Laying Of Submarine Cables and Pipelines (issued by SOA,1992)
- Regulations for Protections of Submarine Cables and Pipelines (issued by SOA, 2004)
- Water Law (passed by NPC, 2002)
- Construction Law of the People's Republic of China (Set by NPC, 1997)
- Tort Law of the People's Republic of China (Set by NPC, 2009)

Appendix B – CCS R&D and Demonstration Projects in the PRC

Important CCS/CCUS R&D projects in the PRC (MOST, 2011; L. Zheng et al, 2011)

No.	CCS/CCUS R&D Projects	Source of Support	Date
1	Utilization of greenhouse gas as resource in EOR and storage it underground	**National Basic Research Program (973 Program)**	2006-2010
2	Basic study of CO_2 emission reduction, storage and utilization as a resource		2011-2015
3	CO_2 capture and storage technologies	**National High-Technology Program (863 Program)**	2008-2010
4	Key technology research of CO_2 EOR utilization and storage		2009-2011
5	Research of CO_2-algal oil-biodiesel key technologies		2009-2011
6	Research and demonstration of CO_2 capture, utilization and storage technologies in IGCC plants		2011-2013
7	Research and demonstration of super gravity method of CO_2 capture and purification technology	**National Science and Technology Support Plan**	2008-2010
8	Research and demonstration of 35MWth oxy-fuel combustion carbon capture technology and related equipment		2011-2014
9	Development and demonstration of caputre and geological storage technologies of highly concentrated CO_2 in coal-to-liquid plants		2011-2014
10	Development of CO_2 emission reduction and utilization technologies in blast furance ironmaking		2011-2014
11	Assessment and demonstration of nationwide CO_2 geological storage potentials	**Ministry of Land and Resources**	2010-2014
12	Secure development of natural gas field containing CO_2 & CO_2 utilization technologies	**National major special projects for large oil-gas fields and coalbed methane development**	2008-2010
13	Development and demonstration projects of natural gas fields containing CO_2 in the volcanic rocks of the Songliao Basin		2008-2010
14	Development of key technologies of CO_2 EOR utilization and storage		2011-2015
15	domenstration of CO_2 EOR utilization and storage in Songliao Basin		2011-2015

Important CCS/CCUS demonstration projects in the PRC (MOST, 2011; L. Zheng et al, 2011)

No.	CCS/CCUS demonstration projects	location	scale (tCO_2/year)	status
1	CO_2 EOR research and demonstration by PetroChina in Jilin oilfield	Jinlin	100,000	started operation in 2007
2	CO_2 chemical utilization project by Zhongke Jinlong	Taixing, Jiansu	about 8000	started operation in 2007
3	Carbon capture demonstration in Beijing's thermal power plant by China Huaneng Group	Gaobeidian, Beijing	3000	started operation in 2008
4	Demonstration of CO_2 utilization in degradable plastics' production by China National Offshore Oil Corporation (CNOOC)	Hainan	2100	started operation in 2009
5	Carbon capture demonstration by China Huaneng Group in Shidongkou, Shanghai	Shidongkou, Shanghai	120,000	started operation in 2009
6	CO_2 capture demonstration in a refinery plant by SinoPec	Beijing	270,000	started operation in 2010
7	Carbon capture demonstration by China Power Investment Corporation in Shuangkui power plant of Chongqing	Hechuan, Chongqing	10,000	started operation in 2010
8	Demonstration of CO_2 capture and small-scale EOR utilization in Shengli oil field by SinoPec	Shengli oil field	40,000	started operation in 2010
9	CO_2 capture and storage demonstration project in a coal-to-liquid plant by Shenhua Group	Ordos, Inner Mongolia	100,000	started operation in 2011
10	CO_2 capture, utilization and storage demonstration in an IGCC power plant by Huaneng's GreenGen Project	Tianjin	60,000-100,000	started operation in 2011

Appendix C – Policy Analysis and Comparison

Technical & management standards

The technical and management standards, including five aspects discussed in section 4, are essential for each CCS projects to protect the social and environmental interests. But these standards should be updated in accordance with the development of key CCS technologies and the commercialization progress in different stages.

CCS incentivizing policies

1) Criteria for incentivizing policies analysis and comparison

About 15 CCS incentivizing policies have been discussed in section 4, so it won't be easy to analyze which stage of the roadmap each incentivizing policy should be implemented in. Thus to solve this question, we pick up four features/criteria to help us analyze and compare all the potential CCS incentivizing policies: Directness, Certainty & Risk, Experience in the PRC, and Transaction and other social costs.

a) Directness

The "directness" refers how direct the policies will provide economic incentives for the CCS projects. Here we define four level of directness: 1. direct fund support; 2. fund support in forms of subsidies, tax reduction and other indirect ways; 3. providing financing channels support; 4. incentives from the escape from punishment of mandatory regulations. Generally speaking, higher level of directness will justify early implementation of the policies when other criteria are the same.

b) Certainty & Risk

The "Certainty & Risk" tries to assess how stable the incomes the CCS projects can get in the policies are and the level of risk CCS projects should take to get these incomes. Here we define four level of directness: 1. little uncertainty and risk; 2. some uncertainty and little risk; 3. high uncertainty or moderate risk; 4. high uncertainty and risk. Higher level of certainty and lower level of risk will justify early implementation of the policies when other criteria are the same.

c) Experience in the PRC

This criterion assesses the PRC's successful experience in implementing the CCS incentivizing policies. Here we define four level for this criterion: 1. the PRC has enough experiences; 2. the PRC has been experiencing the policy in other fields, but without promising outcome; 3. there is not enough experiences or lack of a solid economic base in the PRC, but enough experience in the developed world; 4. there is little experiences in the PRC, and some experience with controversies in

the developed world. More successful experience in the PRC can justify early implementation of the policies when other criteria are the same.

d) Transaction and other social costs

This criterion tries to assess the transaction costs and other social costs of the incentivizing policies qualitatively when they are implemented right now. Here we define four level for this criteria: 1. low transaction and other social costs; 2. moderate transaction and other social costs which can have been greatly decreased by development and deployment of CCS technologies by the second stage; 3. high transaction and social costs mainly due to lack of a mature economic base in the PRC; 4. huge social costs with a large range of industrial sectors involved. Lower transaction and other social costs will justify early implementation of the policies when other criteria are the same.

When deciding which stage of the roadmap each incentivizing policy should be implemented in, we almost equally weighted these four criteria. But when levels of four criteria are quite different for a certain incentivizing policy, we believe that “Experience in the PRC” and “Transaction and other social costs” can be more important than the rest criteria in the PRC’s case. That is because policies with more successful experience and lower costs, like a familiar habit, would be relatively more acceptable to both the policy-makers and the investors, compared with the rest two criteria.

2) Result of CCS incentivizing policies analysis

All the potential CCS incentivizing policies have been analyzed and compared based on the four criteria mentioned above, and the detailed results are shown in table 1 and 2.

Table 1 results of CCS incentivizing policies analysis

Policy	Directness		Certainty & Risk		Experience in the PRC		Transaction and other social costs	
	explanation	level	Explanation	level	explanation	level	explanation	level
Providing a research support mechanism	In this policy, the government provides direct funds for the researches of CCS technologies.	1	Whether the CCS projects can get the fund depends on the valuation, reasonability and expected outcome of the researches. As the fund is provided by the government, it is always stable and CCS projects don't take much risks.	1	The PRC has applied this policies to promoting the development of CCS technologies and other cutting-edge technologies, such as renewable energy technologies and gained plenty of experience in the past.	1	With currently enough experience, developing a specialized research mechanism for CCS has relative small costs.	1
Direct investment	In this policy, the government provides direct funds for CCS demonstration projects.	1	Whether the CCS projects can get the fund depends on the CCS technologies, efficiency and expected outcome of the projects. As the fund is provided by the government, it is always stable and CCS projects don't take much risks.	1	The PRC has applied this policies to promoting CCS demonstration projects and renewable energy technologies, accumulating lots of experience.	1	With currently enough experience, direct investment for CCS projects has relative small costs. And the direct investment for CCS has been increasing in the past few years.	1

Feed-in tariff	Instead of providing direct fund, this policy provide incentives in form of subsidies for the products.	2	The subsidies provided have high stability and certainty. But the amount of income the CCS projects can get in this policy relies on both the features of CCS projects (e.g. the kind of products, business model, and efficiency of CCS projects) and market condition that has uncertainty. Thus income for CCS projects in the policy faces some uncertainty.	2	The PRC has applied this policies to promoting the development of wind power, hydropower and other renewable energy. But the outcome hasn't reached the targets.	2	With previous experience, the costs for establishing policy specialized for CCS is small. But as a market based policies, it relies on the commercialization of CCS technologies to have a better performance, and the relative small scale of CCS deployment can lead to a high transaction cost per unit.	2
Direct tax reduction for CCS projects	Instead of providing direct fund, this policy provide incentives in form of tax reduction.	2	It has high certainty and little risk.	1	The policy of direct tax reduction has already been applied to promote the development of renewable energy in The PRC. For example, added-value tax of wind power generation has been reduced by 50% since 2003.	1	similar to feed-in tariff, it has a low regulation cost, but has better performance with low transaction costs when CCS technologies have been utilized in large scale or even commercialized.	2

Application of carbon tax	Instead of providing direct fund, this policy provide incentives in form of tax reduction.	2	It has high certainty and little risk.	1	The PRC hasn't implemented the carbon tax before. In the developed world, carbon tax has been applied in Norway and UK, but faces some controversies. There isn't enough experience in the world now.	4	The carbon tax, as a new tax with coerciveness, probably brings a huge social costs, since it involve almost all the industrial sectors and would increase the production cost in all the industrial sectors. Only when the CCS technologies are mature and available commercially, can the social cost be declined greatly.	4
Specialized public and trust fund for CCS	The public and trust funds always provide direct fund or cover costs of certain operation in the CCS projects, to support CCS development.	1	Supported by multi sponsors, including large international organizations, developed countries and large NGOs, fund from international CCS public and trust funds has high certainty and low risks. As for a domestic trust fund, if supported by the government, it has relatively high certainty. Of course, the CCS projects	2	Right now, the PRC has received financial support from international CCS trust fund developed by World Bank and ADB, but has no experience in establishing a domestic CCS trust fund. The developed world has gain its experience in domestic CCS trust fund,	2	With current experience and the mature mechanisms in the international CCS trust funds, cooperation with international CCS public and trust fund has high economic efficiency with lower transaction costs. But with little experience and a pre-mature financial	1 or 3

			have to compete for these financial supports.		such as US.		market in the PRC, developing a domestic will need a long time of exploration with high costs right now.	
Credits and discount loans support	This policy lowers the requirement of loans for the CCS projects.	3	Good stability as long as the CCS projects can get the loans. But the CCS projects have to pay back the loans with no or little interests. That is to say that CCS projects and government share the risks of the loan.	3	Previously, the PRC has been providing concessional loans for renewable energy development, but the effects wasn't as good as expected.	2	the PRC's previous experience in renewable energy development isn't enough to developing this policy for CCS. More researches should be done in the regulations design and more experience should be gather. Thus there are relative high regulation and transaction costs in developing this policy for CCS now.	2

Participation in Emission Trading Scheme (ETS)	This policy help CCS projects raise fund by enabling CCS projects to trade its carbon emission permits in the ETS.	3	The amount of fund raised in the ETS relies on the CCS technologies, business model, trading skills and other aspects of the CCS projects. Also, carbon price and the whole ETS are highly affected by many domestic and international factors, resulting in a relative high uncertainty in ETSs around the world now. In this case, income from the ETS for CCS projects can have high uncertainty and risks.	3	Right now, the only ETS available for the PRC's CCS projects is CDM. The domestic ETS pilots have just begun in the PRC, and the PRC still has little experience in developing its own ETS. In the developed world, many large and mature ETSs have tried to incorporate CCS technologies, and gathered much experience.	1 or 3	With the mature mechanism in CDM, participating in CDM can be a good option with relative low costs for the PRC's CCS projects. As for incorporating CCS into the PRC's domestic ETS can be very costly, as the PRC is still in extremely short of experience in a mature ETS and incorporating CCS can also be costly in time and capital according to experience of EU ETS.	1 or 3

Bonus Allowances	Compared with the policy of "Participation in Emission Trading Scheme", bonus allowances provide direct income, which comes from the direct sale of free permits, for the CCS projects.	1	The amount of fund raised by selling the free permits in the ETS relies on the carbon price and status of the ETS, which can be highly affected by many domestic and international factors and have relative high uncertainty. Thus the fund the CCS projects can raise in this policy can be highly uncertain.	3	The implementation of this policy relies on a highly developed domestic ETS, such as EU ETS. However, the PRC's is still in short of experience of domestic ETS development. In the developed world, this policy is mainly utilized in EU and the experience isn't enough.	4	This policy can costly for the PRC now for two reason. First, the PRC's domestic ETS is still in pilot stage, that is to say the base for this policy isn't ready yet. Second, setting the amount of bonus allowances for CCS will probably need a series of negotiation by different interest party in the ETS in order to balance the interest of different parties in this policy.	3
Fixed price policy	This policy set higher price for products from CCS projects to increase income for CCS projects, instead of providing direct fund or subsidies.	3	The policy is certain, but the amount of income the CCS projects can get in this policy relies on both the features of CCS projects (e.g. the kind of products, business model, and efficiency of CCS projects) and market condition that has uncertainty. Thus income for CCS projects in the policy faces some	2	Both the PRC and the developed world have gather experience in this policy. Since 2005, the electricity price of wind power and geothermal power is set at a fixed level by the government in the PRC.	2	similar to feed-in premium, it has a low regulation cost with previous experience, but will have better performance with low transaction costs when CCS technologies have been utilized in large scale or even commercialized. The small scale of CCS deployment will increase	2

			uncertainty.				the transaction cost per unit.	
Promoting commercial utilization of captured CO_2	This policy doesn't provide direct fund or subsidies, instead promote commercial utilization of captured CO_2 as a way to increase income for CCS projects.	3	This policy works as a platform to help the CCS projects to find them business partner to buy the captured CO_2. CCS projects have to take the risks in their cooperation with the business partners, though the policy can help lower the risks.	3	Among the PRC's current CCS demonstration projects, many have utilized the CO_2 utilization technologies. These utilization of captured CO_2, though isn't commercial, can also provide experience for this policy. In the developed world, especially US, have gained much experience in the implementation of this policy.	3	This policy relies on the commercialization of the CO_2 utilization technologies, which is still not available. And the construction of commercial rules for this policy still need lots of exploration in the PRC. Thus, this policy can be costly right now and have better performance in the expansion and commercial stages.	2

Promoting CCS through Emission performance standards	This policy, as a mandatory policy, force the enterprise to utilize CCS technologies to fulfill the stricter carbon emission standards and doesn't provide any direct incentives. And its incentives come from the escape from penalties by reaching the mandatory requirements.	4	This policy doesn't help the CCS projects raise the fund, and the investment of the CCS projects have to be supported by themselves. In this case, the CCS projects have to take all the risks of raising fund and the whole investment of CCS projects, which is only achievable in the commercial stage.	4	the PRC hasn't implemented this policy before, but in the developed world, many countries have tried to establish this policy.	3	This policy involves almost all the industrial sectors in the society. When the CCS technologies and other low-carbon technologies are not available for large scale commercialization, almost all the industrial sector will fail to fulfill the new standards. Thus this policy with high coerciveness, would increase the production cost in almost all industrial sectors and brings huge social costs currently. These social costs can be greatly decreased only in the commercial stage.	4

Mandatory quotas	This policy, as a mandatory policy, directly require the enterprise to utilize CCS technologies or other low-carbon technologies and doesn't provide any direct incentives. And its incentives come from the escape from penalties by reaching the mandatory requirements.	4	This policy doesn't help the CCS projects raise the fund, and the investment of the CCS projects have to be supported by themselves. In this case, the CCS projects have to take all the risks of raising fund and the whole investment of CCS projects, which is only achievable in the commercial stage.	4	the PRC hasn't implemented this policy before, but the National Development and Reform Commission (NDRC) stated in 2005 mandatory quotas would be used promote the development of renewable energy in the future. In the developed world, many countries have tried to establish this policy, including UK, US, Australia and other countries.	3	Similar to "Promoting CCS through Emission performance standards", this policy involves almost all the industrial sectors in the society and would increase the production cost in almost all industrial sectors and brings huge social costs currently. These social costs can be greatly decreased only in the commercial stage.	4

Certification system for CCS	Similar to the policy of "Participation in Emission Trading Scheme (ETS)", this policy help CCS projects raise fund by enabling CCS projects to trade its carbon emission permits in the ETS.	3	The amount of fund raised in the ETS relies on the CCS technologies, business model, trading skills and other aspects of the CCS projects. Also, carbon price and the whole ETS are highly affected by many domestic and international factors, resulting in a relative high uncertainty in ETSs around the world now. However, the mandatory CCS% of carbon supply can guarantee the income for CCS projects, increasing the certainty and lowering the risks for CCS projects.	2	This policy relies on a highly developed carbon ETS, and The PRC hasn't implemented this policy before. In the developed world, only EU has implemented this policy and more experience is needed.	4	The costs for this policy in The PRC could be very high now. First, the domestic ETS pilots just started in the PRC, and there is no base for the development of this policy currently. Second, incorporating CCS into the ETS could be costly in time and capital. Third, the setting of the ratio for carbon supply from CCS will need time- and capital-consuming negotiations to balance interests of different parties in the ETS.	3

International cooperation	The international programs the PRC cooperates with can provide direct fund to support CCS projects in the PRC.	1	The amount of fund from these international programs for CCS projects relies on the CCS technologies, business model, trading skills and other aspects of the CCS projects. As the fund provided can be guaranteed by cooperation between the PRC and international programs, it is always stable and CCS projects don't take much risks.	1	Right now the PRC has established cooperation with many international CCS programs, including COACH, STRACO2, MOVECBM, the PRC-UK project NZEC and so on.	1	With mature mechanism of the international projects and the PRC's previous experience, this policy can be applied to CCS development with relative little transaction costs and other social costs.	1

APPENDIX

stages	Technical & management standards	CCS incentivizing policies	Policies to promote ficient public ngagement
Preliminary stage	1) Technical standards for carbon capture, utilization and storage technologies 2) Standards for storage site selection and management. 3) A whole-process monitoring mechanism. 4) Environment impact assessment standards. 5) Regulations for permit application, verification and issuance system.	1) Providing a research support mechanism 2) Direct investment 3) Specialized public and trust fund for CCS (the focus of this policy in this stage is receiving financial support from international CCS public and trust funds.) 4) Participation in Emission Trading Scheme (ETS) (the focus of this policy in this stage is to promote Chinese CCS projects' participation in CDM.) 5) International cooperation	1) Providing education of basic scientific knowledge of CCS/CCUS for the public, especially the site communities and high school pupils
Expansion stage	1) Technical standards for carbon capture, utilization and storage technologies 2) Standards for storage site selection and management. 3) A whole-process monitoring mechanism. 4) Environment impact assessment standards. 5) Regulations for permit application, verification and	1) Feed-in premium 2) Direct tax reduction for CCS projects 3) Specialized public and trust fund for CCS (the focus of this policy in this stage is developing a domestic CCS trust fund.) 4) Participation in Emission Trading Scheme (the focus of this policy in this stage is to incorporate CCS into the domestic ETS.)	1) Requiring disclosure of the basic information of CCS projects from both government and CCS projects; 2) Ensuring efficient

	issuance system.	5) Fixed price policy 6) Credits and discount loans support 7) International cooperation 8) Promoting commercial utilization of captured CO_2 9) Certification system for CCS (if the domestic ETS is not mature enough to support this policy, it can be delayed to the next stage.)	public engagement platforms for the public.
Commercial stage	1) Technical standards for carbon capture, utilization and storage technologies 2) Standards for storage site selection and management. 3) A whole-process monitoring mechanism. 4) Environment impact assessment standards. 5) Regulations for permit application, verification and issuance system.	1) Application of carbon tax 2) Specialized public and trust fund for CCS (the focus of this policy in this stage is funding CCS development with both domestic and international CCS trust fund.) 3) Participation in Emission Trading Scheme (the focus of this policy in this stage is to promoting CCS development through the domestic ETS.) 4) Bonus Allowances 5) Promoting commercial utilization of captured CO_2 6) Promoting CCS through emission performance standards 7) Mandatory quotas 8) Certification system for CCS	1) Requiring disclosure of the basic information of CCS projects from both government and CCS projects; 2) Ensuring efficient public engagement platforms for the public.

Appendix E – International Financial Support Measure Precedents

Name	Location	Key Proponents	Description	Primary Business Case Driver
Sleipner CO_2 Injection	North Sea, Norway	Statoil	• CO_2 separated from gas produced at the Sleipner T platform and re-injected into the Utsira formation, a deep saline formation above the hydrocarbon reservoir zone • Operational since 1996, with 16MtCO_2 injected to date	• Commercial / Technical imperative for CO_2 separation • CO_2 Offshore Tax
Snøhvit CO_2 Injection	Barents Sea, Norway	Statoil, Petoro, Total, GDF Suez, Norsk Hydro, Hess Norge	• CO_2 separated from the gas stream and piped 152 km back to the field for injection into an offshore deep saline formation through a dedicated well • Gas production since 2007 and CO_2 injection of approx. 0.7MtCO_2/yr since 2008	• Commercial / Technical imperative for CO_2 separation • CO_2 Offshore Tax

In Salah CO_2 Injection	Wilaya de Ouargla, Algeria	BP, Sonatrach, Statoil	• CO_2 separated from gas produced at the In Salah Oil Field and stored in nearby Krechba formation • 4MtCO_2 injected between 2004-2011	• Commercial / Technical imperative for CO_2 separation
Name	Location	Key Proponents	Description	Primary Business Case Driver
Gorgon Carbon Dioxide Injection Project	Barrow Island, Australia	Chevron AUS, ExxonMobil, Shell, Tokyo Gas, Osaka Gas, Chubu Electric	• Pre-combustion capture of 3.4-4.0MtCO_2/yr from a natural gas processing plant as part of the larger gas production and LNG processing project • In situ storage in a deep saline formation • Operation expected in 2015	• Commercial / Technical imperative for CO_2 separation • CO_2 Offshore Tax

Illinois Industrial CCS Project	Central Illinois, USA	Midwest Geological Sequestration Consortium	• Capture of c.1MtCO_2/yr from existing ethanol production plant and storage in Mt Simon Formation (1.5km pipeline) • Potential for later use in EOR operations • Operation expected in 2013	• Public Funding / Capital Grant [(c.68% total requirement)] • Potentially, EOR Revenues
Quest	Central Alberta, Canada	Shell Canada, Chevron, Marathon Oil	• c.1.1MtCO_2/yr to be captured from 3 hydrogen manufacturing units at the Scotford Heavy Oil Upgrader facility • Transport by 84km pipeline and injection into deep saline formations • Injection expected in 2015	• Public Funding / Capital Grant (c.50% total requirement)
Name	Location	Key Proponents	Description	Primary Business Case Driver

ROAD	Rotterdam, The Netherlands	E.ON, Electrabel (GDF Suez)	• Post combustion capture of 1.1MtCO_2/yr from flue gases of a new 1100MWe coal-fired power plant • Transport by pipeline 25km for storage in North Sea depleted gas field • FID on CCS expected in 2013 and CO_2 capture targeted for 2015	• Public Funding / Capital Grant • CO_2 Emissions Price
Don Valley Power Project	South Yorkshire, UK	2CO Energy, Samsung, BOC	• Pre-combustion capture of c.5MtCO_2/yr from flue gases of a new 920MW IGCC • Transport by pipeline (390km) for EOR injection in depleting North Sea oil field • FID expected by year end 2013 and CO_2 capture targeted by 2015	• EOR Revenues • Public Funding / Capital Grant • CO_2 Emissions Price

Texas Clean Energy Project	Penwell, Texas, USA	Summit Power	• Pre-combustion capture of 3MtCO_2/yr from a 400MW IGCC (polygen) plant, sale of CO_2 for EOR in Permian Basin • Revenues fully contracted (15-25yrs) • FID expected in 2013	• Revenues from EOR and sales of urea • Public Funding / Capital Grant • ECA financing

Appendix F – Reference Plant Technical Parameters and Cost Data

Plant Profile	IGCC		Pulverized Coal		Oxy-fuel		Coal-to-Liquids	
	No CCS	w/ CCS	No CCS	W/ CCS	No CCS	W/ CCS	No CCS	W/ CCS
Gross/Net Power Output	430 MW / 375 MW	426MW/ 326 MW	600 MW / 570 MW	600 MW/ 389 MW	200 MW / 186 MW	200 MW / 89 MW		
Gross methanol Output							412,040 Mt	412,040 Mt
Net Plant HHV Efficiency / Rate	43.9%	35.9%	41%	28%			44.5%	44.5%
CO_2 Generated	2.1 mil $MtCO_2$/year	2.1 mil $MtCO_2$/year	4.1 mil $MtCO_2$/year	4.1 mil $MtCO_2$/year	0.9 mil $MtCO_2$/year	0.9 mil $MtCO_2$/year	1.6 mil $MtCO_2$/year	1.6 mil $MtCO_2$/year
CO_2 Emitted	2.1 mil $MtCO_2$/year	0.2 mil $MtCO_2$/year	4.1 mil $MtCO_2$/year	0.4 mil $MtCO_2$/year	0.9 mil $MtCO_2$/year	0.1 mil $MtCO_2$/year	1.6 mil $MtCO_2$/year	0.16 mil $MtCO_2$/year
CO_2 Captured		1.9 mil $MtCO_2$/year		3.7 mil $MtCO_2$/year		0.8 mil $MtCO_2$/year		1.4 mil $MtCO_2$/year
Emission Intensity (tCO2/MWh)	0.67	0.067	0.89	0.089	0.92	0.092	3.8 tCO2/ton methanol	0.38 tCO2/ton methanol
CAPEX								
Total O/N Capital Cost (million CNY)	3,698.3	4,229.4	2,778.8	3,417.0	946.6	1,153.1	2,358.2	2,539.5

OPEX								
Variable O&M (Equipment, Materials &Labour)	CNY 0.15/MWh	CNY 0.15/MWh	CNY 0.15/MWh	CNY 0.15/MWh	CNY 0.62/MWh	CNY 0.60/MWh		
Fuel Costs	CNY 21.87/GJ	CNY 21.87/GJ	CNY 21.87/GJ	CNY 21.87/GJ	CNY 21.87/GJ	CNY 21.87/GJ	CNY 21.87/GJ	CNY 21.87/GJ
Fixed O&M (Equipment, Materials &Labour) (million CNY)	159.4	172.6	111.2	136.7	49.8	54.9	94.3	101.6
Macro & Other								
Inflation /Fuel Price Escalation	2%							
Tax Rate	25%							
Risk Free Rate	4.60% (10 yr US T-bill)							