POLICY BRIEF | COP 16 | Cancun | December 2010.

Global Technology Roadmap for Carbon Capture and Storage for Industry

Emission reduction and industrial development: The role of CO_2 capture and storage in industry.

Project Funders

NORWEGIAN MINISTRY OF PETROLEUM AND ENERGY

GLOBAL CCS INSTITUTE

Partners

International Energy Agency

ieaghg

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

The aim of this policy brief is to introduce the Global Technology Roadmap for carbon capture and storage (CCS) on industrial carbon dioxide (CO_2) sources with a focus on developing countries. It seeks to demonstrate that CCS for industrial CO_2 sources offers both early and long-term opportunities for greenhouse gas mitigation. In addition, this brief calls for more policy attention and a demonstration programme for CCS in industrial sectors.

Background

Currently direct industrial CO_2 emissions account for one third of total global energy use and for 40% of process CO_2 emissions (IEA Energy Technology Perspectives 2010). Industrial energy use and CO_2 emissions are projected to further grow in the coming decades. The processes in industry are diverse, and so are the options to reduce emissions, now and in the future. Much can and still should be achieved through energy efficiency. In some sectors, renewable energy can play an important role, but the transition is complex and the technology needs to mature. In industry, there are two situations in which CCS can be demonstrated and applied early. First, as many industrial CO_2 emissions are inherent to industrial processes, it is technically and economically more difficult to reduce them in industry than in other sectors. In such cases, CCS - as a mitigation option in industry - becomes relevant. Second, some industries vent high-purity CO_2 into the atmosphere. Such sources represent a relatively cost-effective mitigation options and could be early opportunities for CO_2 storage to be demonstrated. For deep emission cuts, CCS is a key emissions abatement option in industry. However, the vast majority of research and development (R&D) and demonstration funds as well as policy efforts for CCS are aimed at the power sector.

In a scenario in which technological options would be applied to reduce global CO_2 emissions by 50% between now and 2050, the industrial emissions could be reduced by 24% compared to 2007 levels (IEA Energy Technology Perspectives 2010). In this context, the CO_2 intensity of industrial production would be reduced by 60-70% between 2007 and 2050. By 2050, around 45% of the total emissions reduction would be accounted for by energy efficiency, 17% renewable energy and 19% CCS. The potential for CCS in the industry and the transformation sectors is estimated to amount to 1.7 to 2.5 Gt of CO_2 captured annually in 2050, which represents half of the total CCS potential and 10% of total global emission mitigation needs. In certain industry sectors, such as iron and steel and cement making, the share of CCS would be even higher.

Opportunities

CCS opportunities for the industrial sector exist in gas processing, refineries, iron and steel, cement, ammonia, pulp, ethanol production and emerging coal and biomass to liquids industries. Already today, certain industrial processes generate a pure CO_2 stream. Such emission source only needs pressurisation, transport and storage. Out of five CCS demonstration projects in operation today, four focus on such sources of CO_2 : three are in gas processing Sleipner, Snøhvit (both Norway), In Salah (Algeria) and one is a synfuel plant (North Dakota, USA).

The technical opportunities can be divided into three areas: (1) processing fuels prior to combustion; (2) CO2 removal from flue gas; and (3) production of concentrated CO_2 streams by replacement of air with oxygen. Table 1 provides a general overview of the most important characteristics of CO_2 capture technology in iron and steel, cement, refineries, high-purity CO_2 sources and biofuel production. Cost estimates for industrial CCS vary widely. Part of the variability is structural and depends on site specific factors.

Process characteristics (process CO_2 emissions in cement making, reduction processes in iron making) determine the optimal process design and create new CCS options. In industry, more than in power generation, opportunities exist to fundamentally re-design processes as to facilitate CO_2 capture and removal. Enhanced productivity, smaller plant footprint and process integration all help to reduce the additional cost for CCS in industry. Such opportunities do not exist in power generation. Combined heat and power generation offers interesting opportunities for combination of CCS for power generation and industrial processes.

Retrofit of CCS is possible based in chemical absorption-based post-combustion processes. This will only make economic sense in locations with availability of ample waste heat. Pre-combustion capture (hydrogen fuel) retrofit is possible in certain configurations such as refineries. Use of oxygen for retrofit is generally not possible. Retrofit will be more expensive than developing newly built, "Greenfield", facilities but may be relevant if capital stock is of young age.

Enhanced Oil Recovery: bridging storage option

Use of CO_2 for enhanced oil recovery (EOR) can generate revenues. Currently, water flooding, injection of natural gas and injection of naturally occurring CO2 are common technologies to mobilise oil from reservoirs that would otherwise show a decline in production. EOR is applied on a large scale in North America, albeit in connection with CCS only in five onshore locations (the Weyburn project in Canada and the Rangely, Sharon Ridge, Enid Fertiliser and Salt Creek projects in the USA). The price paid for the CO_2 used to enhance the oil recovery is in the range of 15 to 30 USD/tCO_2. This price would support early capture opportunities. EOR has also been tested in developing countries, in projects such as the Buracica project in Brazil, which has reinjected CO_2 in the period 1991-2009, and the Jilin Oilfield in China in 2000-2003. While the storage potential for EOR in the long term is uncertain, it can help to get early demonstration projects off the ground.

Challenges

Currently, there are few incentives for CCS from industrial CO_2 sources, even for the low-cost options. In the short term and in some regions, EOR might be a "market pull" for CO_2 capture. First, policy for industrial CO_2 reduction in industry is more challenging than in the power sector because industry more often operates on a global market, facing competition. Thus, the industry sector requires international agreements on policies and measures to prevent carbon leakage and relocation. Second, industrial CO_2 streams are typically smaller than coal power plant CO_2 streams. While the smaller scale may raise the cost per tonne of CO_2 captured, interesting integrated process designs are under development which can lower this cost. Finally, the technologies required in industry are more diverse than in power generation and therefore need a more varied demonstration programm.

Table 1. Overview of CCS enabling technologies, their estimated date of maturity, and relevant regions. (CCS Global Roadmap, Technology Synthesis report, in preparation)

Sector	Technology	Removal category	Estimated date of maturity of CO2 capture**
Iron & Steel	Post-combustion blast furnace	Fuels pre-processing	2020
	Oxyfuel blast furnace	Oxygen for air	2020-2030
	Gas Direct-reduced iron (DRI)	Fuels pre-processing	2020
	FINEX steelmaking process	Fuels pre-processing	2020-2030
	HISARNA steelmaking process	Fuels pre-processing	2030
Refineries	Hydrogen from gas reforming (SGR)*	Removal from flue gas	2010
	Hydrogen gasification residues	Removal from flue gas	2015-2020
	Fluid Catalytic Cracker (FCC)	Removal from flue gas	2020-2030
	Process heat	Fuels pre-processing	2020
Biofuel production	Ethanol*	Removal from flue gas	2010
	Fischer-Tropsch synthesis biomass (incl. black liquor)*	Removal from flue gas	2015
	Synthetic natural gas (SNG) Biomass*	Removal from flue gas	2015
Cement	Chemical absorption	Fuels pre-processing	2015-2030
	Oxyfuel	Oxygen for air	2030
	Carbonate looping	Fuels pre-processing	2030
Pulp & Paper	Chemical absorption - kraft mills	Concentrated CO2 streams	2015
	Black liquor gasification	Removal from flue gas	2015-2020
High purity	Ammonia*	Concentrated CO2 streams	2010
	Gas processing*	Concentrated CO2 streams	2010
	Liquefied natural gas (LNG) production*	Concentrated CO2 streams	2010
	Fischer-Tropsch -synthesis coal*	Concentrated CO2 streams	2010

The CO2 source has a high purity and only transport and storage need to be demonstrated.
***** If significant investments in research, development and demonstration are done.***

What needs to be done?

Industrial CCS cost could be reduced through transportation and storage infrastructure. Spatial planning aiming for industrial hubs can facilitate CCS.

Risks must be reduced. Demonstration plants are needed to prove the feasibility of industrial CCS, ascertain smooth operation and create more clarity concerning CCS cost. A regulatory or pricing system that creates an incentive for CCS and other mitigation options is required. If a global system is not possible, a policy framework must correct for trade-distorting effects. Global sectoral approaches could constitute one way ahead for the short term.

Industrial CCS should be supplemented by a long-term strategy to wean industry off carbon containing energy carriers. Electricity and hydrogen from zero-carbon sources and development of new materials and services with low energy intensity need to be pursued further.

Demonstration projects

It is recommended to build demonstration plants in developed and developing countries. Involvement of China will be critical as the country accounts for half of global primary steel, cement and clinker production. In addition, China's industry is largely coal-based. The Middle East could play a critical role in the demonstration phase because of interesting CO_2-EOR opportunities.

In order to scale-up the technology, the IEA has proposed that 100 additional commercial scale demonstration projects will be needed by 2020, in a number of countries and settings (IEA Technology Roadmap Carbon capture and storage, 2009). However, as listed in Table 1, most of these technologies still need to mature, except for high purity and biomass.

Table 2 provides a selected list of the global demonstration projects for technologies that need to be demonstrated; which are planned or are in construction phase. The incremental investment cost for these plants, transport and storage infrastructure would amount to USD 50-100 billion.

Table 2. Industrial CCS pilot, demonstration and commercial projects.
(CCS Global Roadmap, Technology Synthesis report, in preparation)

INDUSTRY SECTOR - BUSINESS MODEL & LOCATION	CAPTURE TECHNOLOGY	TRANSPORT - CO_2 USE OR TYPE STORAGE	ESTIMATED DATE OF COMPLETION	CO_2 ABATED (TONS OF CO_2 PER YEAR)
MULTISECTORIAL				
KATTEGAT/ SKAGERRAK **SWEDEN NORWAY DENMARK**	SOURCES: 3 POWER PLANTS, 3 REFINERIES, 2 CEMENT PLANTS, 1 PETROCHEMICAL PLANT, 1 PAPER & PULP MILL, 1 AMMONIA AND 1 ETHYLENE PLANT	PIPELINE GEOLOGICAL STORAGE IN SALINE AQUIFERS	UNDER CONSIDERATION	12 MILLION
MASDAR CCS PROJECT **ABU DHABI, UAE**	3 SOURCES OF EMISSIONS: GAS-FIRED POWER PLANT, AN ALUMINIUM SMELTER AND A STEEL MILL. 2 CAPTURE PLANTS USING AMINE-BASED CHEMICAL ABSORPTION TECHNOLOGY	300 KM PIPELINE INJECTED INTO ONSHORE OIL FIELDS TO BE USED FOR EOR.	2015	5 MILLION (PHASE I)
ROTTERDAM CLIMATE INITIATIVE **ROTTERDAM NETHERLANDS**	INITIAL PHASE: PURE CO_2 FROM STEAM REFORMING UNITS AT A REFINERY SECOND PHASE: PURE CO_2 SOURCES (STEAM REFORMING AND BIOFUEL PLANTS)	EXISTING PIPELINE CO_2 REUTILIZATION IN GREENHOUSES FOR PLANT GROWTH AND INJECTED TO DEPLETED OFFSHORE GAS FIELDS	FIRST PHASE 2010 SECOND PHASE 2015	1 MILLION (PHASE I) 5 MILLION (PHASE II)
IRON AND STEEL				
ULCOS BLAST FURNACE **LORRAINE FRANCE**	TOP GAS RECYCLING BLAST FURNACE (BF): FURNACE TOP GAS OF THE BF GOES THROUGH CO_2 CAPTURE AND THE SEPARATED REDUCING GAS IS REINJECTED	PIPELINE STORAGE IN A DEEP SALINE AQUIFER	2015	1.38 MILLION
ULCOS HLSARNA TECHNOLOGY **IJMUIDEN, NETHERLANDS**	BATH-SMELTING REDUCTION: COAL PREHEATING AND PARTIAL PYROLYSIS IN A REACTOR, A MELTING CYCLONE FOR ORE MELTING AND A SMELTER VESSEL FOR FINAL ORE REDUCTION AND IRON PRODUCTION	CAPTURE READY ONLY	CONSTRUCTION STARTED 2010	60,000
VOLKLINGEN, GERMANY		CAPTURE READY ONLY	EXPECTED 2010	65,000
REFINERIES				
MONGSTAD REFINERY **MONGSTAD, NORWAY**	SOURCE IS AN EXISTING CATALYTIC CRACKER. CAPTURE AMINE TECHNOLOGY AND CHILLED AMMONIA TECHNOLOGY WILL BE TESTED CHP EXHAUST GASES (CHP PLANT TO BE CONSTRUCTED BY 2010 AND CAPTURE READY BY 2014)	PIPELINE STORAGE IN A DEEP SALINE AQUIFER	TECHNOLOGY CENTRE 50 % COMPLETED TESTING PLANNED FOR 2012, DELAYED TO 2014. COMMERCIAL SCALE PLANNED BY 2020.	100,000 (TEST PHASE) 1.1 MILLION (COMMERCIAL PHASE)
QUEST CCS PROJECT **ALBERTA, CANADA**	SOURCE: STEAM REFORMING UNITS CAPTURE AMINE ABSORPTION	10 – 60 KM PIPELINE STORAGE IN A DEEP SALINE AQUIFER	2015	1.2 MILLION
ESQUISTO PRODUCTION UNIT (SIX) **PARANA, BRAZIL**	SOURCE: FLUID CATALYTIC CRACKER POST-COMBUSTION CAPTURE: HYBRID AMINE/MEMBRANE	FIRST PHASE: STORAGE IN A DEEP SALINE AQUIFER SECOND PHASE: EOR	STARTED 2009 (PHASE I)	43,000
BIOFUELS				
MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM **ILLINOIS, US**	ETHANOL PLANT	1 KM PIPELINE GEOLOGICAL STORAGE IN SALINE FORMATIONS	2012	365,000
LEUCADIA ENERGY LAKE CHARLES **LOUISIANA, US**	METHANOL PLANT	12 MILE PIPELINE EOR	2014	4.5 MILLION
PTAC - HUSKY I **ALBERTA, CANADA**	ETHANOL PLANT - FERMENTATION	PIPELINE EOR	2012	90,000
PULP AND PAPER				
CHEMREC **PITEA, SWEDEN**	BLACK LIQUOR GASIFICATION AND DIMETHYL ETHER PRODUCTION	CAPTURE READY ONLY	OPERATIONAL SEP 2010	90 % REDUCTION
CEMENT				
CEMEX **TEXAS, US**	DRY SORBENT CARBON DIOXIDE CAPTURE AND COMPRESSION UNIT	CAPTURE READY ONLY	RESEARCH PHASE COMPLETED IN 2010 -	1 MILLION
CAPITAL AGGREGATES **TEXAS, US**	MINERALISATION TECHNOLOGY FROM FLUE GASES	PRODUCTION OF CARBONATES (BAKING SODA)		75,000

Matching sources and sinks

The first group of projects in Table 2 describes "Clusters" of industrial capture projects. In these cases several CO_2 sources have been matched with a suitable CO_2 sink or reutilisation opportunity. Suitable storage sites would be considered unattractive if located far away from sources. By clustering of sources and developing single pipeline infrastructures to transport CO_2 over large distances, storage in a single suitable site could become feasible due to reduced costs. The matching of sources and sinks lies at the core of the feasibility of CCS.

A Roadmap to 2050

The United Nations Industrial Development Organization (UNIDO) is leading the development of the Technology Roadmap for Carbon Capture and Storage for Industry, funded by the Norwegian Ministry of Petroleum and Energy and the Global CCS Institute. The International Energy Agency (IEA) and the IEA Greenhouse Gas Implementing Agreement are partners in this activity. This Technology Roadmap builds on the research and publications developed by the partner organisations.

The underlying objective of this project is to advance the global uptake of low-carbon technologies in industry, particularly by involving developing countries and transition economies. It is motivated by the need to stabilise greenhouse gas concentrations in the atmosphere at a level of 450 ppm, which would prevent dangerous anthropogenic interference with the climate system.

There remain significant knowledge gaps in moving towards commercial implementation of CCS. This project seeks to address these obstacles by developing a roadmap for CCS in various industry sectors, and complements ongoing technology road-mapping exercises for other energy technologies. Key industry sectors include iron and steel, cement and clinker production, ammonia production, hydrogen production and ethanol plants, and black liquor processing.

The Global Technology Roadmap for Carbon Capture and Storage for Industry will be available on the second quarter of 2011 and will provide:

1. A review of state of the art and an outlook for industrial capture technologies.
2. Milestones, targets and policy needs.
3. Identification of early opportunities, "lighthouse" projects and work towards demonstration.

For more information on this project, including sectoral and workshop reports, please visit:
http://www.unido.org/index.php?id=1000821

www.unido.org/energy ›› Energy Efficiency ›› Selected Projects ›› Carbon Capture and Storage - Industrial Sector Roadmap

For the on-going work by the IEA on the technology roadmaps, please visit:
http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4156,

"Technology Roadmap: a guide to development and implementation"
http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2291
or contact: Thomas Kerr (tom.kerr@iea.org)

Contacts

United Nations Industrial Development Organization - Energy and Climate Change Branch:
Dolf Gielen (D.Gielen@unido.org); Bettina Schreck (B.Schreck@unido.org)