Global Developments in CCS

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CCS: Options for Energy Intensive Industry

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Outline

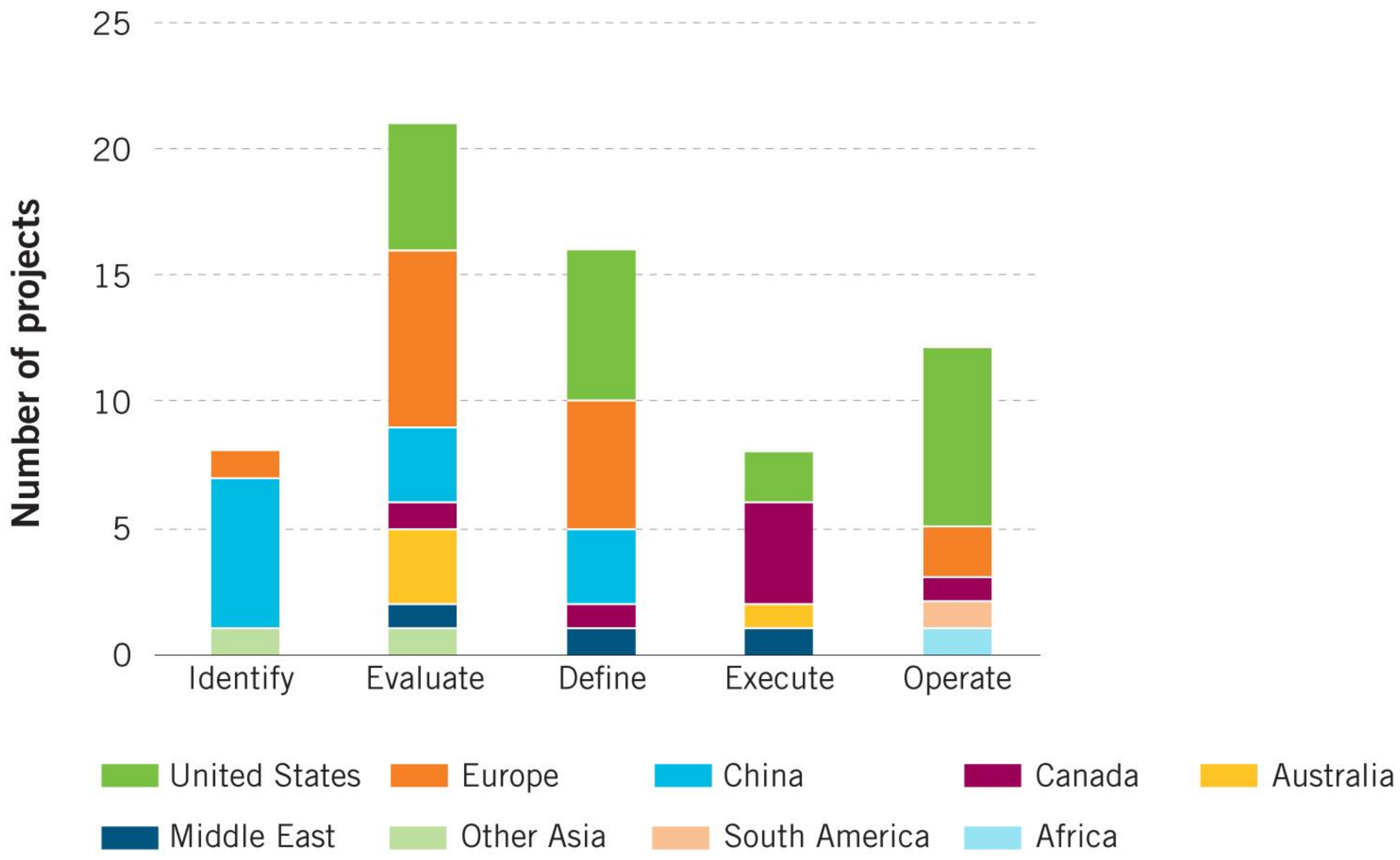
1. Overview of Large Scale Integrated Projects
2. Power generation activity
3. CCS activity in the industrial sector
    - Geological storage
    - Gas processing
    - High purity sources
    - Cement
    - Iron and Steel
    - Oil refining
4. CCS costs
5. Summary
6. The role of the Institute

Achieving a low carbon future: A call to action for CCS

The Global Status of CCS: 2013 – The key Institute publication

- 2013 edition: released 10 October
- Comprehensive coverage on the state of large scale CCS projects, policy settings and technologies
- Recommendations for moving forward based on experience
- Project progress outlined since 2010

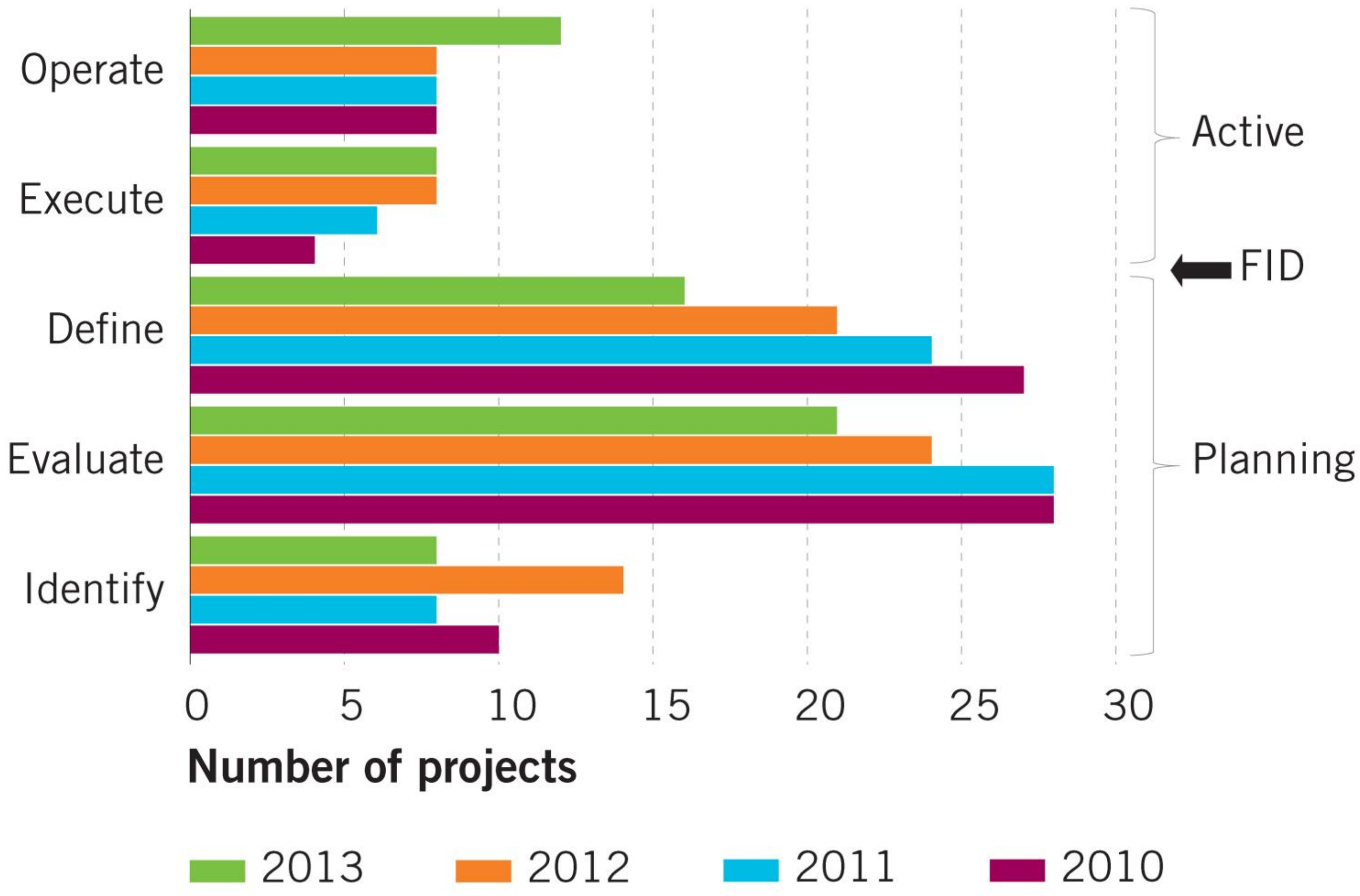
CCS well understood and a reality



Large–scale integrated projects by project lifecycle and region/country

Source: Global CCS Institute, 2013, Status Report

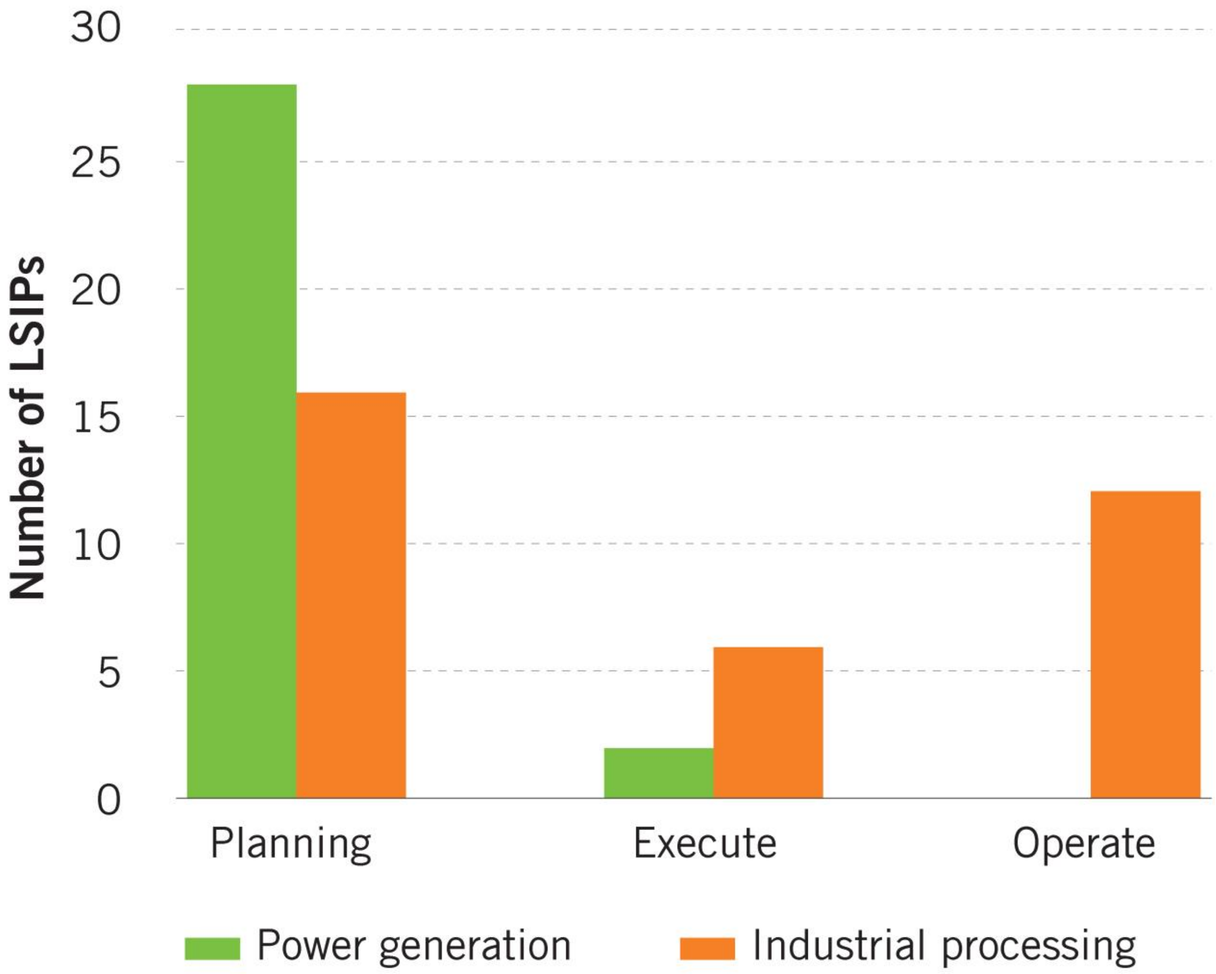
Important gains but project pipeline reduced



Large–scale integrated projects by project lifecycle and year

Source: Global CCS Institute, 2013, Status Report

Some power generation projects are in the pipeline



Breakdown of large–scale integrated projects by sector

Source: Global CCS Institute, 2013, Status Report

Power generation projects in the pipeline

Boundary Dam (Canada)

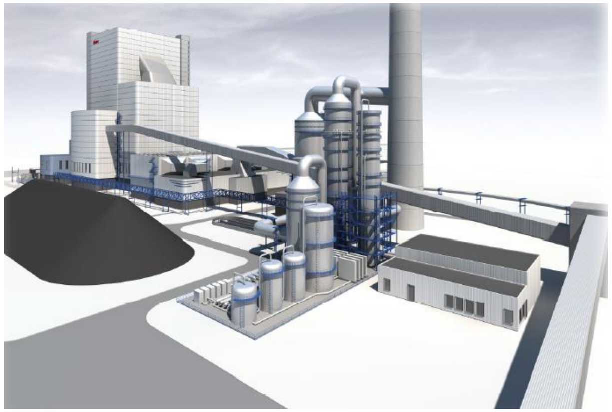
- Repowering and retrofit of power station.
- Capture up to 1 million tonnes of CO_2
- Power plant is operational
- Capture plant to be operational in 2014.
- Cansolv technologies.
- This CO_2 mainly used for EOR, but also in Aquistore.

Kemper County (US)

- New 582 MW IGCC power station being built in Mississippi.
- Capture 65% of its emissions, equivalent to 3.5 million tonnes of CO_2 per annum.
- Under construction, to be operational in 2014.
- Selexol process.
- The CO_2 will be used for EOR.

Other power generation projects at advanced stages of design include:

- ROAD (the Netherlands)
- FutureGen, NRG Parish and Texas Clean Energy (US)
- Compostilla (Spain)
- Don Valley (UK)

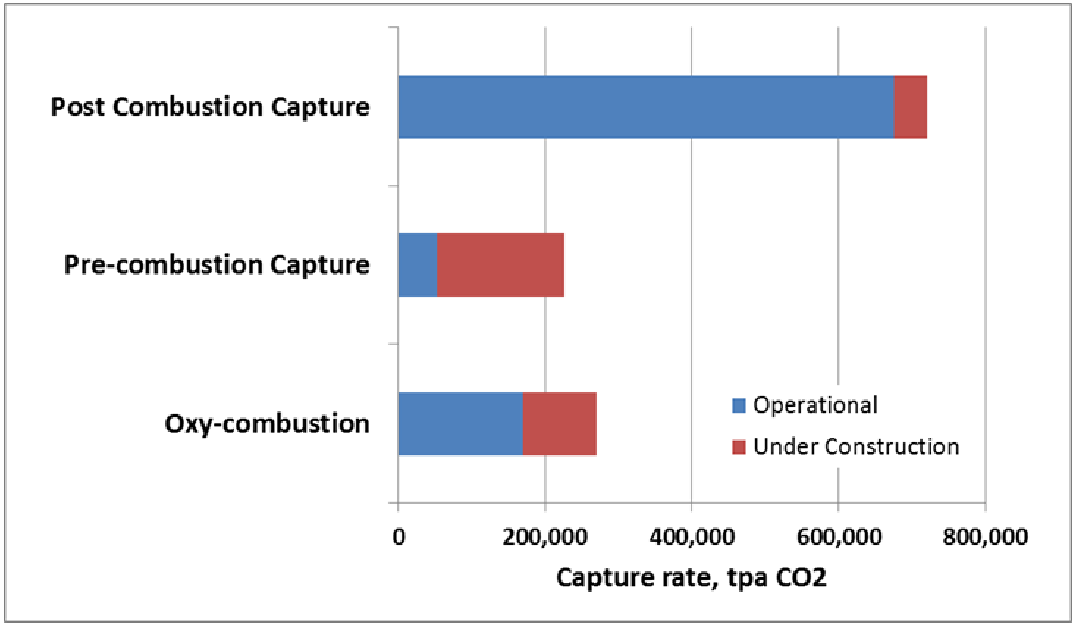


Source: Global CCS Institute, 2013, Status Report

Large scale test facilities

Main objectives:

- Demonstrating the technical feasibility of a particular technology;
- Obtaining economic data of the technology;
- Evaluating the process and how it can be integrated into a power plant;
- Gaining operational experience; and
- Gathering data to support large scale projects.



Source: Global CCS Institute, 2013, Status Report

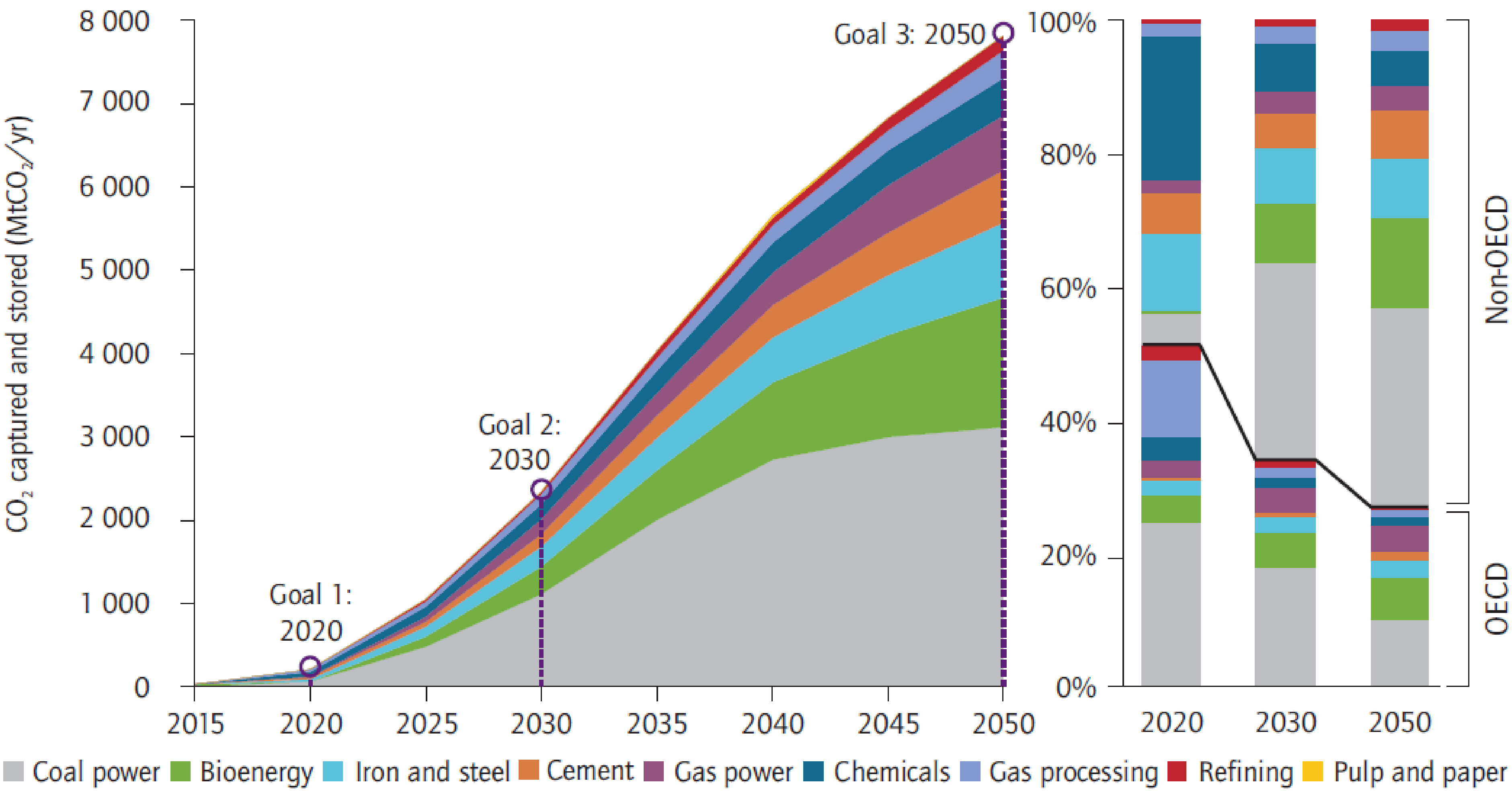
Large scale test facilities

Plant	Location	Approx. capacity (tpa CO_2)	Host	Lead technology vendor	Status
Post-combustion capture					
Aberthaw	Wales, UK	15,000	RWE nPower	Cansolv	Operational
Boryeong	Boryeong, Korea	80,000	Korean Electric Power Company	KEPCO Research Institute	Operational
Ferrybridge	West Yorkshire, UK	30,000	SSE	Doosan Power Systems, Vattenfall	Operational
Guodian	Tianjin, China	10,000	Tianjin Beitang Power Plant	China Guodian Corporation	Under construction
Hazelwood	Latrobe Valley, Australia	15,000	GDF Suez Hazelwood	CO2CRC, Process Group	Operational
Mountaineer	West Virginia, US	100,000	American Electric Power	Alstom	Completed
Plant Barry	Alabama, US	150,000	Southern Company	Mitsubishi Heavy Industries	Operational
Shand Carbon Capture Test Facility	Estevan, Canada	36,000	SaskPower	Hitachi	Under construction
Shanghai Shidongkou	Shidongkou, China	120,000	Huaneng Shanghai Shidongkou No 2 Power Plant	China Huaneng Group	Operational
Shengli	China	40,000	Shengli Power Plant	SINOPEC	Operational

Sources: Global CCS Institute, 2013, Status Report; Huaneng CERI, 2013

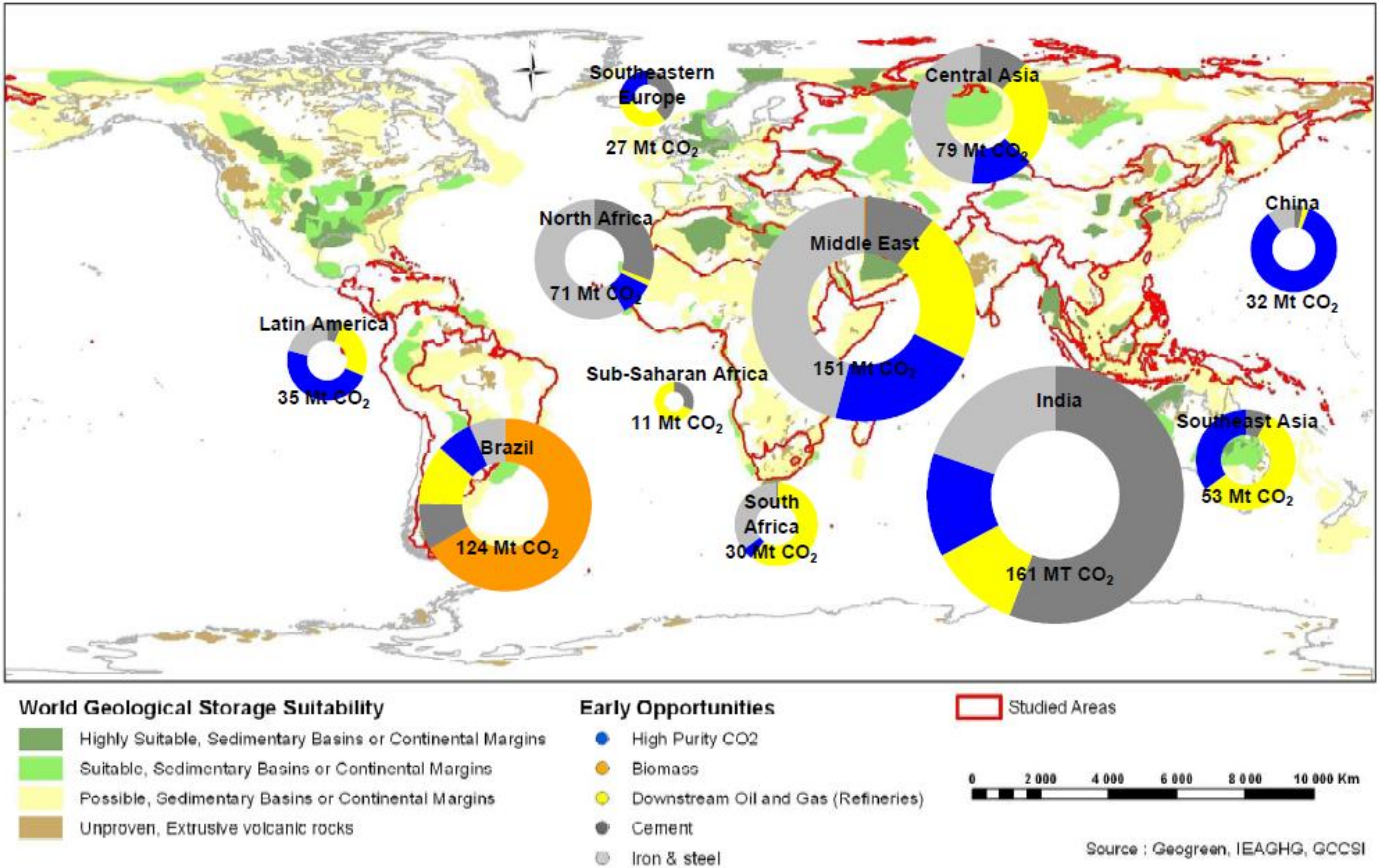
Industrial processes – need for CCS

CCS represents the most important new technology option for reducing direct emissions in industry.



Sources: IEA, 2013, CCS Technology Roadmap; IEA, 2012, Energy Technology Perspectives

Industrial processes – geological storage



Source: Geogreen, 2012, Sectoral Assessment: Source-to-sink matching

Industrial processes – gas processing

Carbon dioxide is produced from:

a. the separation of CO_2 from the reservoir gas to meet market specifications for energy content

b. CO_2 is also produced from use of gas to provide on site energy

Activity

- Eight LSIPs are currently in operation with two more currently under construction.
- Nearly 20 Mtpa currently captured with an additional 4.2 Mtpa by 2015.
- This is a commercial process and has demonstrated large scale capture since 1972.

Sources: Global CCS Institute, 2013, Status Report; Gorgon Project Update, Aug 2013

Industrial processes – high purity sources

Carbon dioxide is produced in high purity form from:

a. Hydrogen production
b. Fertiliser production
c. Chemical/ ethanol production

Activity

- Three LSIP hydrogen production projects supplying hydrogen to refining sector. NorthWest Redwater and Quest in Canada; Air Products in US.
- Two LSIP fertiliser projects in operation (Enid and Coffeyville in US) and another under construction (Agrium in Canada).
- Illinois CCS project in US planning to capture up to 1 Mtpa from 2014.

- Current activity focussed at commercial scale where CCS only requires dehydration, compression and transport. Favourable project economics due to carbon credits and EOR.

Source: Global CCS Institute, 2013, Status Report

Industrial processes – cement

Carbon dioxide (flue gas between 20 & 30% CO_2) is produced from:

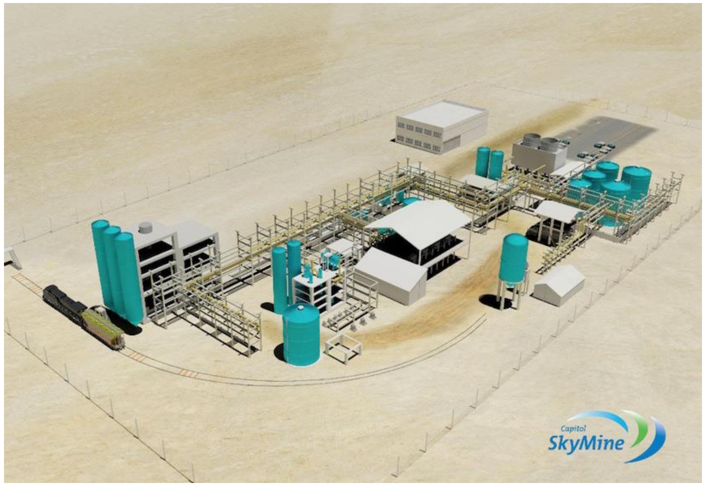
a. Calcination of limestone
b. Combustion of fossil fuels
c. Indirect emissions from electricity, transport, etc

Activity

No LSIP identified in the global cement sector.

Current activity focussed at desktop and laboratory scale

- Norcem PCC project, Norway
- Taiwan Cement calcium looping, Taiwan
- Skyonic Skymine, US
- ECRA Phase IV, Europe



Source: Van Puyvelde, 2013, Carbon Capture from Cement Production

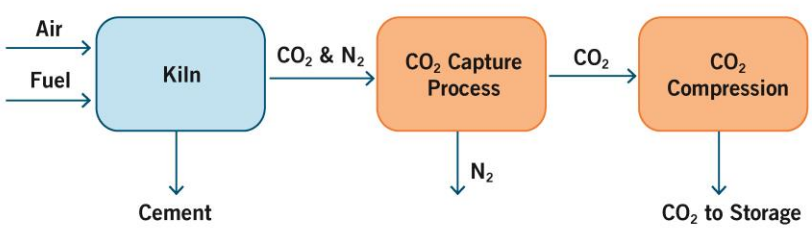
Industrial processes – cement

IEAGHG/ ECRA study titled "Deployment of CCS in the cement industry" being prepared

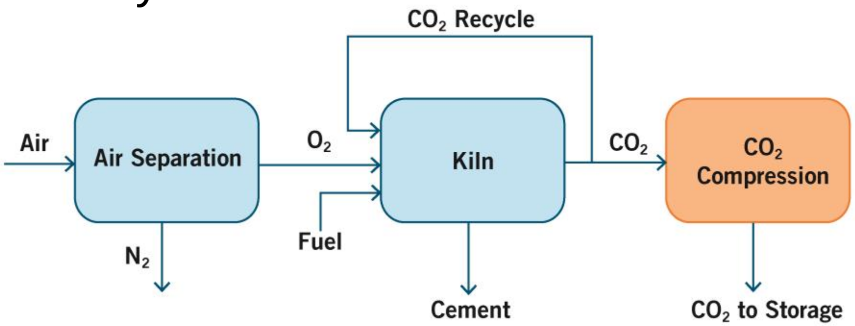
- To be published early 2014.

Technology options include:

a. Post combustion capture



b. Oxy-combustion



CEO for Heidelberg Cement Northern Europe:

"We have a vision that our product in a life-cycle perspective will be carbon neutral by 2030, and we believe that carbon capture from cement production is an important part of and long step toward achieving this vision."

Source: Van Puyvelde, 2013, Carbon Capture from Cement Production

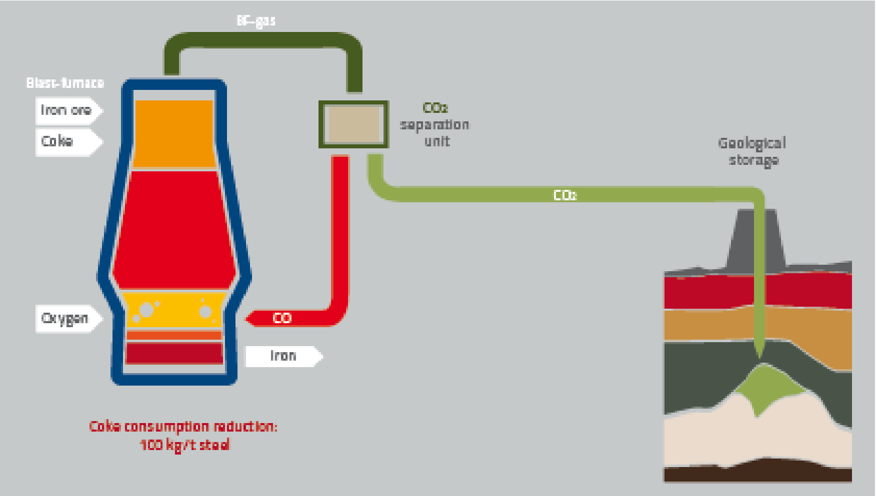
Industrial processes – iron and steel

Carbon dioxide is produced from:

a. production of coke in coke ovens
b. reaction of iron ore with coking coal to produce iron and
c. on-site power generation using gas or coal.

Activity

- Emirates Steel Industries project in United Arab Emirates aims to capture up to 0.8 Mtpa from direct reduction of iron.
- Low-Impact Steel project (previously ULCOS-BF) in Europe aims to capture up to 0.8 Mtpa from blast furnace top gas.
- ULCOS consortium continuing R&D in Europe
- COURSE50 project doing R&D in Japan
- Posco in Korea blast furnace trials



Source: Global CCS Institute, 2013, Status Report

Industrial processes – oil refineries

Carbon dioxide is produced from a range of disperse sources across a refinery including hydrogen production, process heating, catalytic crackers, etc.

Activity

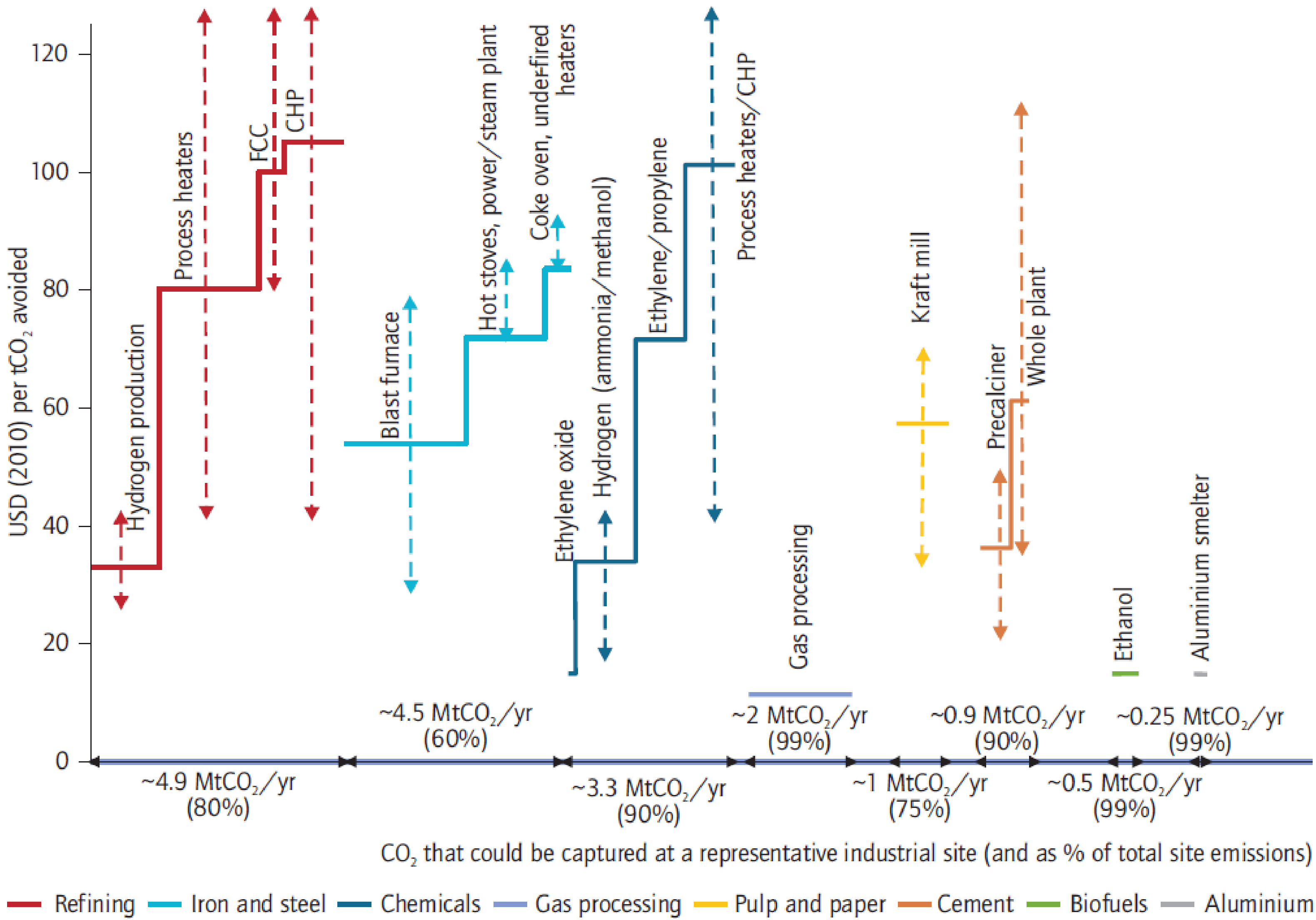
Operational large scale projects from hydrogen production in Canada and US

No LSIPs on refining process components

- Pilot scale post combustion capture using amine and chilled ammonia in Norway at Mongstad
- Fluid catalytic cracker demonstration project using oxyfuel technology in Brazil
- Once through steam generator using oxyfuel combustion in Canada

Source: Global CCS Institute, 2013, Status Report

Costs of capture for industrial processes



Source: IEA, 2013, CCS Technology Roadmap

Summary

1. CCS is necessary for decarbonising the industrial sector

2. CCS demonstrated at commercial scale in gas processing and in industries that produce a high purity stream of CO_2
    - Chemicals
    - Fertilisers
    - Hydrogen production.

3. Capture demonstrated at large scale (100,000 tpa) for coal-fired power generation and will be operational at commercial scale (1 Mtpa) in 2014

4. Storage is a national/ regional issue while capture is an industry specific issue

5. Capture being studied at research and pilot scale in:
    - Cement
    - Iron and steel
    - Oil refining

6. Early costs indications show that it is competitive with power generation on a \$/t CO_2 avoided basis.

7. More work at pilot and demonstration scale urgently needed in the industrial sector

How the Institute is committed to the challenge

OUR MISSION

To accelerate the development, demonstration and deployment of CCS globally

1 Authoritative knowledge sharing

- **1.1** Drive knowledge transfer
- **1.2** Build on our world–leading CCS knowledge base
- **1.3** Optimise global collaboration and dissemination of high quality information

2 Fact–based influential advice and advocacy

- **2.1** Improve public awareness and understanding of CCS
- **2.2** Position CCS as a key low–carbon technology
- **2.3** Equip Members to make better informed decisions

3 Create favourable conditions to implement CCS

- **3.1** Help develop supportive policies, standards and frameworks
- **3.2** Encourage collaboration on business cases
- **3.3** Develop enabling capabilities

Status report recommendations

1. Implement sustained policy support that includes long-term commitments to climate change mitigation and strong market–based mechanisms that ensure CCS is not disadvantaged.
2. Boost short-term support for the implementation of demonstration projects. This will require targeted financial support measures that enable first mover projects to progress faster through development planning into construction and provide necessary support during operations
3. Implement measures to deal with the remaining critical regulatory uncertainties, such as long-term liabilities. This will involve learning from the efforts of jurisdictions within Australia, Canada, Europe and the US, where significant legal and regulatory issues have been, and continue to be, resolved
4. Continue strong funding support for CCS research and development activities and encourage collaborative approaches to knowledge sharing across the CCS community
5. Create a positive pathway for CCS demonstration by advancing plans for storage site selection
6. Encourage the efficient design and development of transportation infrastructure through shared hub opportunities to become ‘trunk lines’ for several carbon dioxide capture projects

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