International Energy Agency

IEA CCS Roadmap – and what's next?

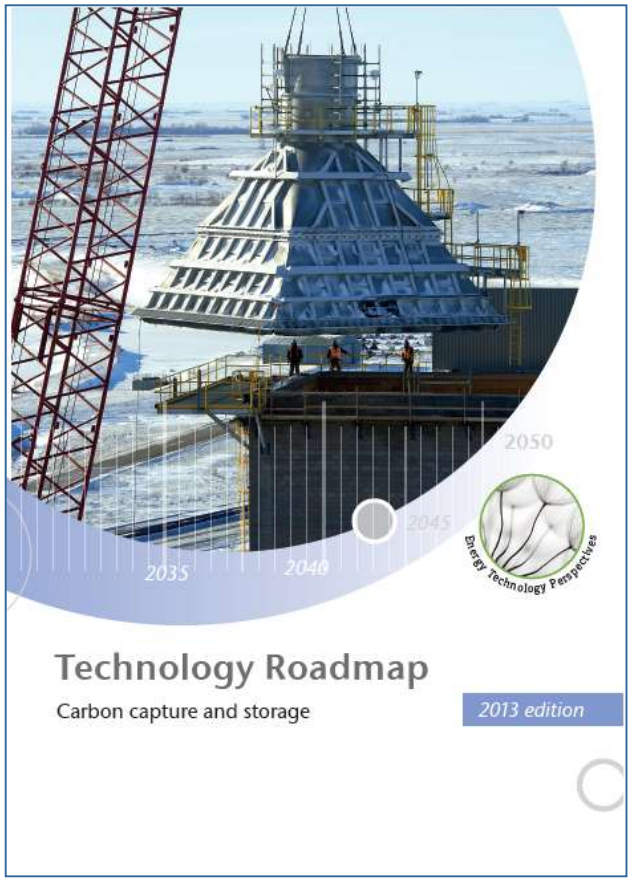
Carbon capture and storage

John Gale IEAGHG on behalf of Juho Lipponen 5th April 2015

Outline

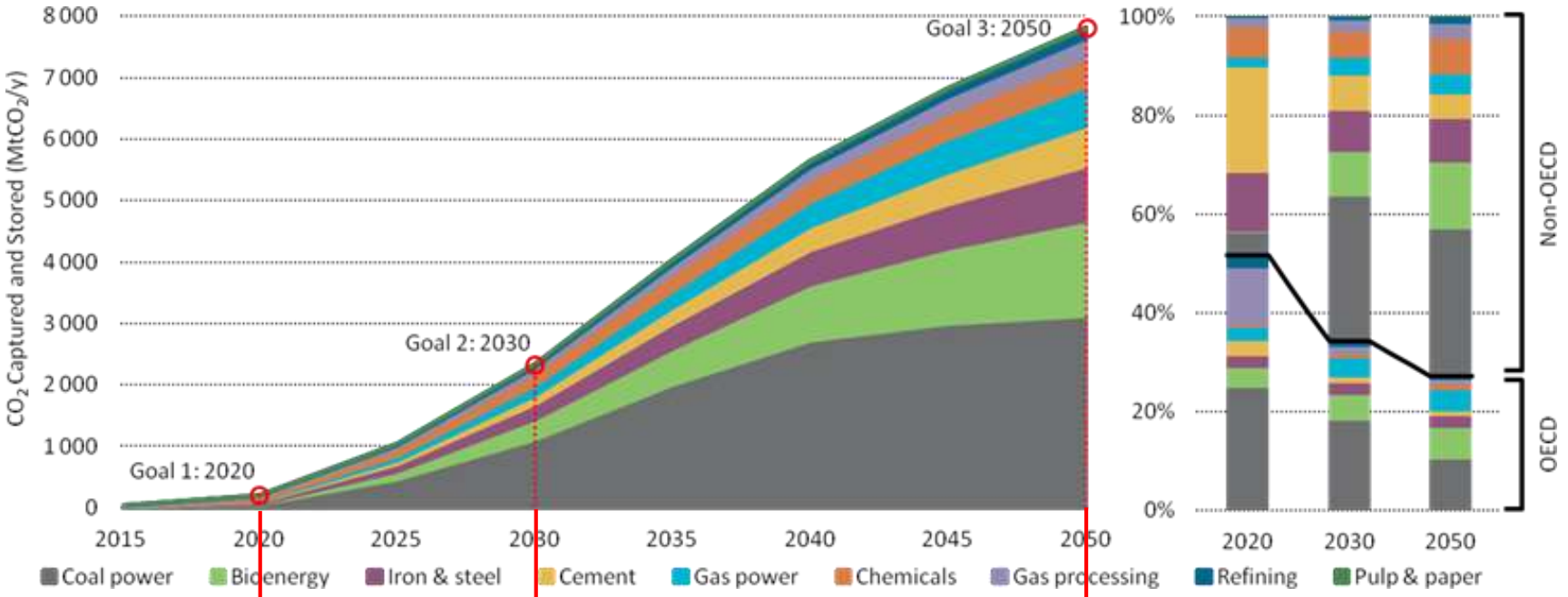
- CCS Roadmap key points and actions
- Further developments
- What's next?

2013 CCS Roadmap: Key findings



- CCS is a **critical component** in a portfolio of low-carbon energy technologies, contributing 14% of the cumulative emissions reductions between 2015 and 2050 compared with business as usual.
- The individual component technologies are generally well understood. **The largest challenge is the integration** of component technologies into large-scale demonstration projects.
- Incentive frameworks are urgently needed to deliver upwards of **30 operating CCS projects by 2020**.
- CCS is not only about electricity generation: 45% of captured CO_2 comes from **industrial applications** between 2015 and 2050.
- The largest deployment of CCS will need to occur in **non-OECD countries, 70% by 2050**. China alone accounts for 1/3 of the global total of captured CO_2 between 2015 and 2050.
- The urgency of CCS deployment is only increasing. **This decade is critical** in developing favourable conditions for long-term CCS deployment.

IEA vision: 120 Gt of CO_2 stored by 2050



Goal 1: 2020:
Over 30 large projects are in operation in power and across a range of industrial processes, storing 50Mt CO_2 per year.

Goal 2: 2030:
Over 2Gt of CO_2 is stored per year. CCS is routinely used in power and certain industrial applications.

Goal 3: 2050:
Over 7Gt of CO_2 is stored per year. CCS is routinely used in all applicable power and industry.

A pathway for wide deployment of CCS

Next seven years:
Creating conditions for wide deployment

2020-2030:
Large-scale deployment picks up speed

2030 and beyond:
CCS is mainstream

2013 — 2020 — 2030 — 2050

Vision 2020:
Over 30 large projects are in operation storing 50Mt CO_2 per year, providing experience and enabling cost reduction. Incentive policies are in place to drive early deployment.

Vision 2030:
CCS is a veritable industry. Over 2Gt CO_2 is stored per year. Continued R&D and economies of scale reduce costs significantly. Business cases are consolidated and drive private investment.

Vision 2050:
CCS is routinely used to reduce CO_2 emissions from power and all suitable industry. The total global storage rate exceeds 7 $GtCO_2$/yr. CCS projects are commercial under technology-neutral climate change policies worldwide in all sectors.

Next seven years:
Creating conditions for wide deployment

Actions in four areas:

Policy and regulation	**Storage**
Capture	**Transport**

Vision for 2020:

Over 30 large projects are in operation, providing experience and enabling cost reduction; incentive policies are in place to drive early deployment.

1. Policy and regulation conducive to integrated CCS projects

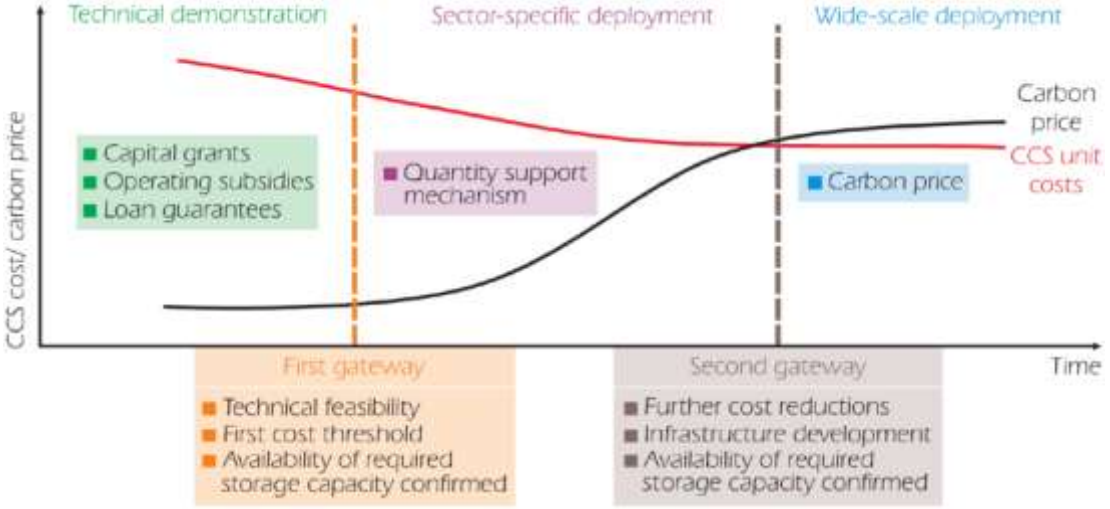
- **Action 1:** Introduce **financial support mechanisms for demonstration and early deployment** of CCS to drive private financing of projects.
- **Action 2:** Develop national laws and regulations as well as provisions for multilateral finance that effectively **require new-build power capacity to be CCS-ready.**
- **Action 3:** Significantly increase efforts to **improve understanding among the public and stakeholders** of CCS technology and the importance of its deployment.

Action 4: Governments and international development banks should ensure that funding mechanisms are in place to **support demonstration of CCS in non-OECD countries.**

Action 5: Governments should **determine their role in the design and operation of CO_2 transport and storage** infrastructure.

Creating business cases for CCS

- During this decade the focus should be on **technology learning**
- The main policy mechanisms should provide mid-term **revenue certainty**
  1. Direct financial support by governments for CAPEX: grants, loans, equity etc.
  2. Direct support for operations: feed-in tariffs, production tax credits, certificates, portfolio standards etc.
  3. Leveraging existing and potential new markets for CO_2 (such as EOR)
  4. Specific policy to incentivise sectors in global competition (cement, steel etc.)
- Follow example of successful policies for **renewables**



2. Timely identification of suitable CO_2 storage is paramount

Action 6:	Implement policies that **encourage storage exploration, characterisation and development** for CCS projects.
Action 7:	Implement **governance frameworks that ensure safe and effective storage,** encourage sound management of natural resources, and ensure that the public is appropriately consulted.
Action 8:	Continue to develop and employ **co-ordinated international approaches and methodologies** to improve understanding of storage resources and to enhance best practice.
Action 9:	Where CO_2-EOR is being undertaken as part of geological storage operations, ensure that it is conducted under a **storage-specific regulatory regime**.
Action 10:	**Support R&D into novel technologies that could utilise significant quantities of CO_2** in a manner that leads to their permanent retention from the atmosphere.

3. Improvements and cost reductions on capture technology

- **Action 11:** Reduce the cost of electricity from power plants equipped with capture through continued **technology development and the use of highest possible efficiency power generation cycles.**

- **Action 12:** Prove capture systems at **pilot scale in industrial applications** where CO_2 capture has not yet been demonstrated.

Action 13: **Support research into novel capture technologies** and power generation cycles that will dramatically lower the cost of capture and resource consumption.

4. Development of CO_2 transport infrastructure to anticipate future needs

Action 14:	Encourage **efficient development of CO_2 transport infrastructure** by anticipating locations of future demand centres and future volumes of CO_2.
Action 15:	Resolve **outstanding legal issues** pertaining to the transboundary movement of CO_2 for geologic storage under the London Protocol.
Action 16:	Ensure that **laws and regulations** are suitable **for pipelines and shipping**.
Action 17:	**Reduce cost and risk of pipeline transport** by sharing knowledge gained from experience and developing common methodologies.

Seven key actions for next seven years

Lead stakeholder	Actions
Government	Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects.
Government	Implement policies that encourage storage exploration, characterisation, and development for CCS projects.
Government	Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready.
Industry	Prove capture systems at pilot scale in industrial pilot applications where CO_2 capture has not yet been demonstrated.
Government	Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
Industry/R&D	Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles.
Government	Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2.

First commercial power plant with capture: Boundary Dam 3 launched on 2 October 2014

Boundary Dam 3 (Source: SaskPower)

(Source: SaskPower)

Size: 110 MW **Fuel**: lignite **Capture rate**: 90% of CO_2, 100% of SO_2
Capture per annum: 1 million tonnes

Air Products and Chemicals, Inc. ICCS Area 1

Steam Methane Reforming with CO_2 Capture

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90%+ CO_2 capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding ~925,000 tonnes CO_2/year
- ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
- CO_2 to Denbury "Green" pipeline for EOR in Texas at West Hastings oil field
- Total Project: $431 MM; DOE Share: $284 MM (66%)

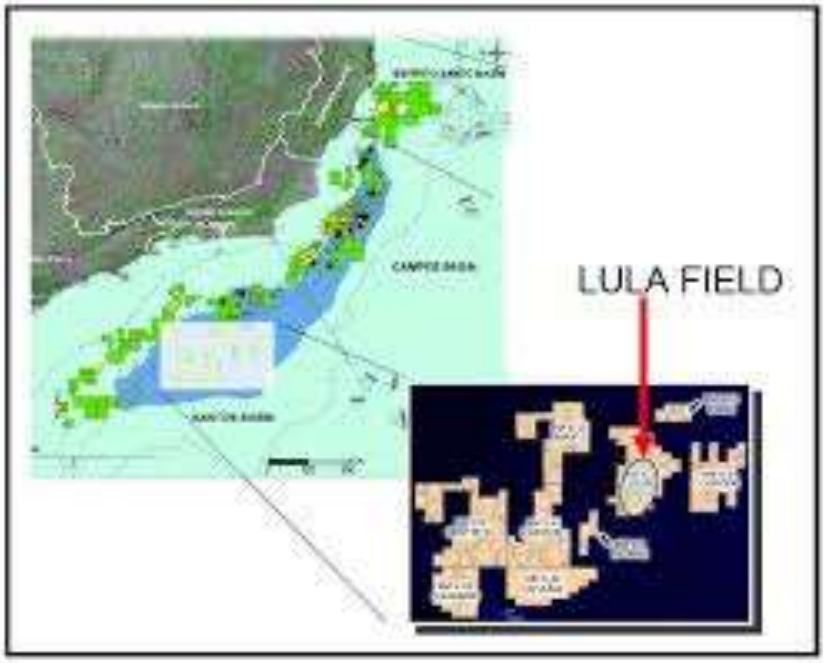
Key Dates

- Phase 2 Awarded: Jun 15, 2010
- FEED completed: Nov 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: Jul 2011
- Construction started: Aug 2011
- Operation started: Dec 2012

Status

- PA-1 initiated operation: Mar 3, 2013
- PA-2 initiated operation: Dec 16, 2012
- Full capacity achieved: Apr 2013
- CO_2 compressor trip; damage to internals; May 29, 2013; CO_2 compressor restart: July 1, 2013
- Has operated at >100% of design when necessary
- 1MM tonnes CO_2 delivered on 4/24/14
- 1,111,076 tonnes CO_2 delivered as of 6/9/14

Lula Project, Brazil First offshore EOR Project - Petrobras



- CO_2 stripped from natural gas using membrane technology
- CO_2 reinjected with salt water for CO2-EOR
- Operational since October 2014
- Injection rate 0.7 mt/y CO_2

Four other notable projects under construction or nearing start-up

KEMPER (US)
3Mt pa

Source:
Power / IGCC

Storage:
CO_2-EOR


Kemper (Source: IEA)


Gorgon (Source: Chevron)

GORGON (AUS)
3,4Mt pa

Source:
Gas / LNG

Storage:
Saline aquifer

PARISH (US)
1,4Mt pa

Source:
Power / PCC

Storage:
CO_2-EOR


Parish (Source: NRG)


Scotford Upgrader (Source: Shell)

QUEST (CA)
1Mt pa

Source:
Oil sands / H_2

Storage:
Saline aquifer

2015: opportunities for CCS

Global or "near-global" processes

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

United Nations
Framework Convention on
Climate Change

G20

Bilateral processes & deals

- Strengthened US-China collaboration
- Direct references to CCS
- Other bilateral processes

Industry, business, civil society

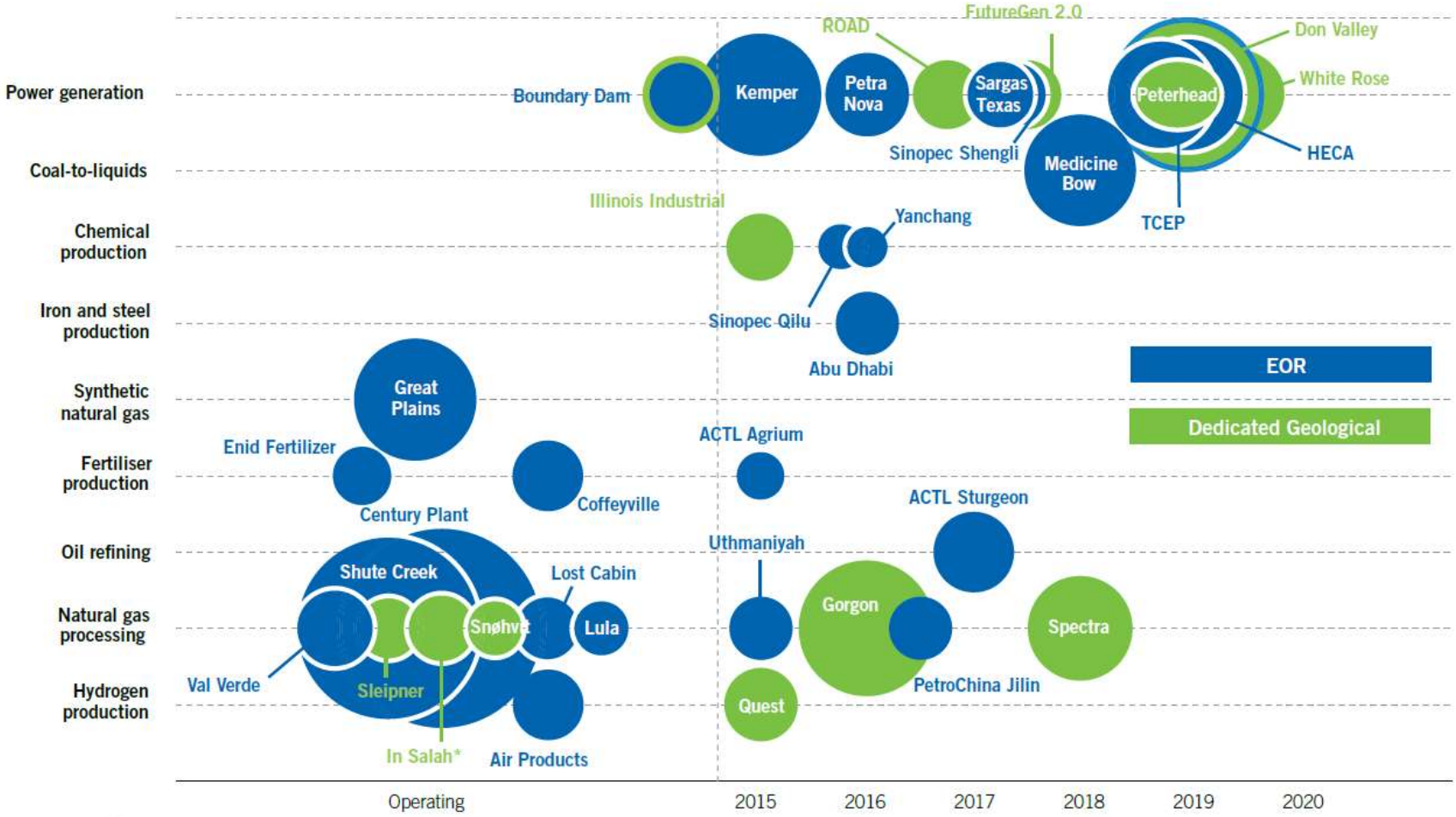
wbcsd

ENGO network on CCS

National policy

- UK CCS programme & EMR
- USA & CA: performance standards
- Other national policy

Around a dozen projects are at earlier stages of development



= 1Mtpa of CO_2 (area of circles proportional to capacity)

Source: GCCSI 2014

* Injection currently suspended

THANK YOU.

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DOWNLOAD THE ROADMAP AT:

http://www.iea.org/topics/ccs/ccsroadmap2013