Review of current and emerging CO_2 capture technologies

Ashleigh Cousins[1], Paul HM Feron[2], Jenny Hayward[2], Kaiqi Jiang[2], Rongrong Zhai[3], Graeme Puxty[2], Monica Garcia[4]

[1] CSIRO Energy, Brisbane, QLD, Australia
[2] CSIRO Energy, Newcastle, NSW, Australia
[3] North China Electric Power University, Beijing, China
[4] IEAGHG, Pure Offices, Hatherley Lane, Cheltenham GL51 6SH, UK

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Who are we?

Our internationally recognised name is the IEA Greenhouse Gas R&D Programme (IEAGHG). We are a Technology Collaboration Programme (TCP) and are a part of the International Energy Agency's (IEA's) Energy Technology Network.

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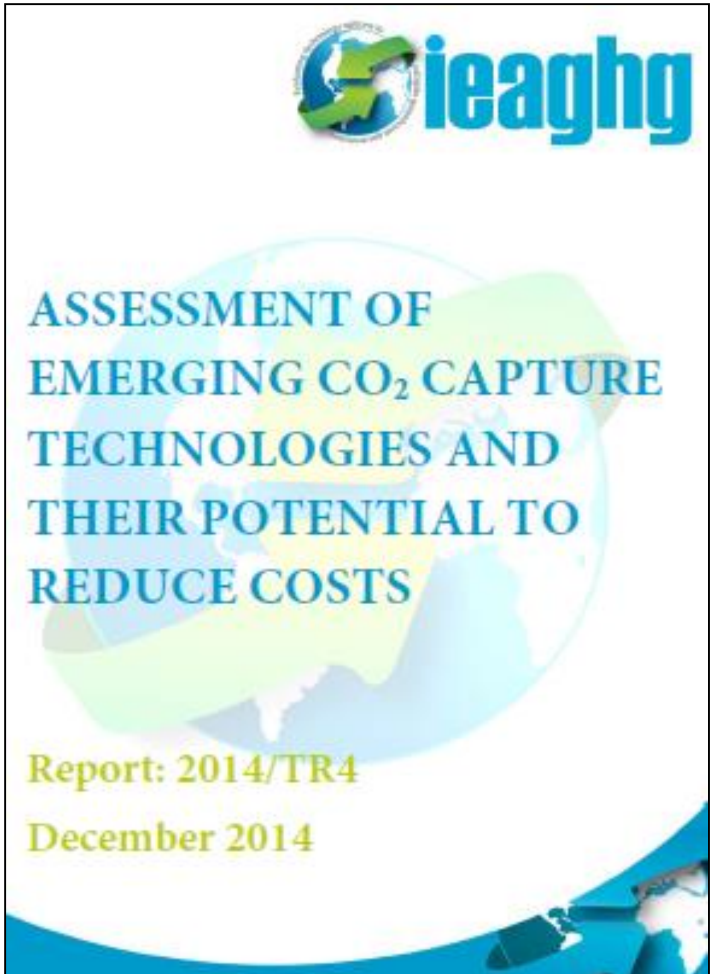
IEAGHG study-What is it about?

- To review carbon capture technologies and their development **status**;
- To update the CO_2 capture **benchmark** technology (NOT IN THIS PRESENTATION)
- To draw up a list of **promising technologies** expected to reach commercial status within the next 10 years
- To identify the potential **risks and barriers** for those technologies to reach commercial deployment
- To provide a list of conclusions and recommended areas for **future research**.

Background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ASSESSMENT OF EMERGING CO_2 CAPTURE TECHNOLOGIES AND THEIR POTENTIAL TO REDUCE COSTS

Report: 2014/TR4

December 2014

This report is from 2014.
<u>Conclusions: chemical absorption</u>

<u>Since this report:</u>

- New technologies have emerged since 2014
- New testing campaigns have taken place since 2014, other technologies are not interesting any more, ...
- Comparisons should be done with an updated benchmark

Interpretation of results

- Next tables will show a comparison of TRL estimated in this report and showed in IEAGHG (2014)
- Arrows are used to indicate the development trajectory of the technology, as follows:
- An upwards arrow indicates that the technology has commercial backing, and that larger-scale evaluation or demonstration of the technology is either current or planned.

Interpretation of results

- A sideways arrow indicates that while there may be ongoing pilot-scale demonstration of the technology, there are either no current plans for further larger-scale demonstrations, or the technology is not being progressed by a commercial partner.
- A downwards arrow indicates that while some pilot or laboratory-scale evaluation has occurred, current research is at a lower scale than previously.

Task 1 – Post-combustion

ECHNOLOGY		TRL AT PREVIOUS REVIEW	CURRENT TRL	CURRENT DEVELOPMENT TRAJECTORY	PREDICTED DECREASE STANDARD TEC
.iquid absorbents	Aqueous amine	6–9	6–9	→	Low
	Amino acid and other mixed salts	–	6	↑	Low
	Ionic liquids	1	4	↓	–
	Encapsulated absorbents	1	2–3	→	–
	Water-lean absorbents	–	5	↑	Medium
	Precipitating	4–5	4–6	→	Medium
	Liquid–liquid separating	4	4–5	↑	Low
	Catalysts	1	6	↑	Medium
Membranes	Polymeric membranes	6	6	↑	Low
	Membrane contactors	–	5–6	→	Medium
	Hybrid processes	6	6	↑	Medium
Solid sorbents	Pressure-swing adsorption (PSA) and temperature-PSA	3	6	→	Medium
	Temperature swing adsorption	1	6	↑	Medium
	Ca looping	6	6	→	Medium
Cooling and liquefaction		3	5	→	Medium
Electrochemical separation		1	4	↑	High
Algae-based capture		1	4	↓	–
Direct air capture		–	5	→	–

The highest evolution in the power sector is observed in post-combustion technologies.

Aqueous amine solutions for chemical absorption are still leading the CO_2 capture technologies but others show significant evolution since 2014

Task 1 – Oxyfuel

ECHNOLOGY	TRL AT PREVIOUS REVIEW	CURRENT TRL	CURRENT DEVELOPMENT TRAJECTORY	PREDICTED LCOE D C.F. STANDARD TEC
ressurised oxyfuel combustion	–	5	→	Medium
Dxyfuel gas turbines	2–5	2–5	↑	Low
ligh-temperature air-separation membranes	4–7	4–7	→	Low
Chemical-looping combustion	2	4–5	→	Medium

It is expected some development on oxyfuel turbines
If ECRA project is funded, it will mean reaching TRL 7 for the industrial sector
Allam Cycle

Task 1- Pre-combustion

ECHNOLOGY	TRL AT PREVIOUS REVIEW	CURRENT TRL	CURRENT DEVELOPMENT TRAJECTORY	PREDICTED LCOE D C.F. STANDARD TEC
H_2 separation membranes	5	5–6	→	Low
CO_2 separation membranes	5	5–6	→	Low
olid sorbents	–	5	→	Low
hemical liquid absorbents	–	5	→	Low
orption-enhanced water–gas shift	5	4–6	→	Medium
lathrates	–	4	→	Low

There has not been much development in this area
New physical solvents could emerge

Techno-economic method: The devil is in the details!

- IEAGHG Techno-economic criteria (support slides)
- Techno-economic scenarios (support slides)

Task 3 - Cost assessment-Gas Fired power plants

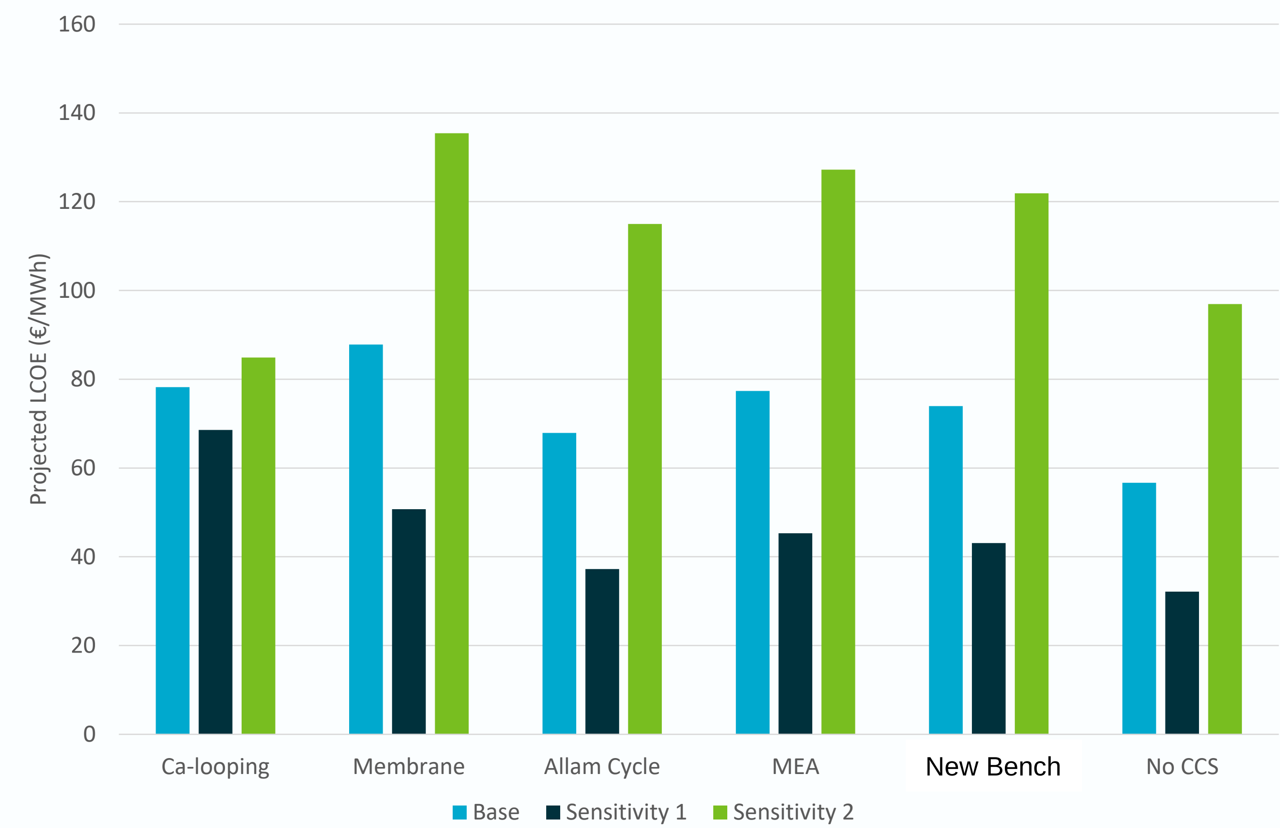
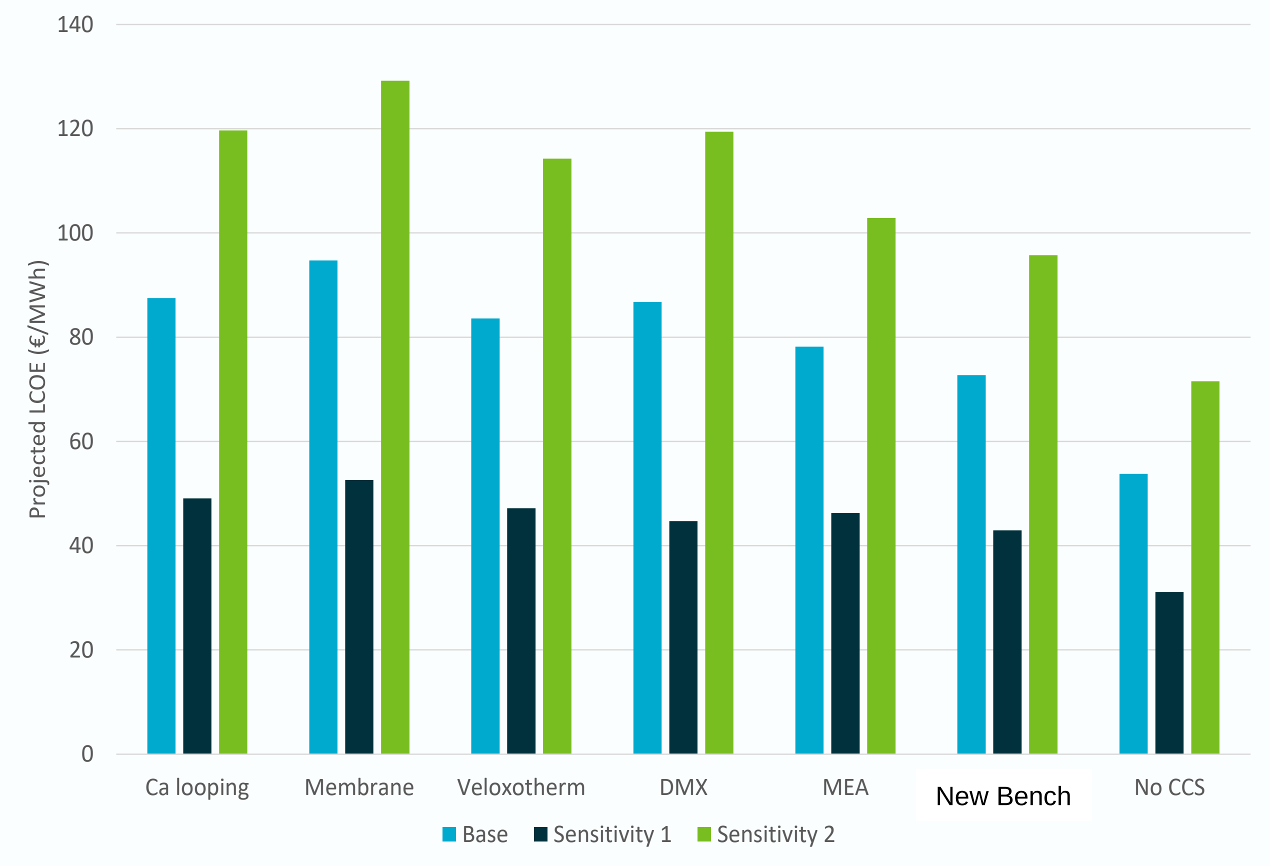


Figure 1 **Comparison of levelised cost of electricity (LCOE) of gas-fired technologies**
CCS = carbon capture and storage; MEA = monoethanolamine; PZ/AMP = piperazine/amino-methyl-propanol

Allam cycle shows the lowest cost (base case), perhaps there is a good potential for the new benchmark

BUT, sensitivity analysis shows that specific economic conditions could change that.

Task 3 - Coal fired power plants



Lowest cost showed by the new benchmark solution (chemical absorption)

BUT under specific conditons, others such as MEA, Veloxotherm, DMX or Ca-looping can be just slightly more expensive (perhaps under the limitations of this assessment)

Figure 2 Comparison of levelised cost of electricity (LCOE) of coal-fired technologies
CCS = carbon capture and storage; DMX = proprietary process developed at French Petroleum Institute Energies Nouvelles; MEA = monoethanolamine; PZ/AMP = piperazine/amino-methyl-propanol

Conclusions

- CO_2 capture technologies are advancing. However, the next generation will be probably still based on traditional chemical absorption due to its maturity (low risk). New technologies will take some time to reach the development status of chemical absorption but they are still on the loop

Conclusions

- The techno-economic assessment is still limited due to different TRLs. Other factors different than costs must be taken into account
- **Deployment: More large-demonstrations are needed**

This report will be available for the IEAGHG members soon

Ask me for more information!

monica.garcia@ieaghg.org

Supporting slides

IEAGHG Techno-economic criteria

Total plant cost (TPC)	
Installed costs	Equipment costs + material costs + labour costs
Engineering contractor's fees	10% of installed costs
Project contingency	10% of (installed costs + engineering contractor's fee)
Process contingency (only for carbon capture and storage)	16% of (installed costs + engineering contractor's fee)
Total capital requirement	
Owners costs and fees	7% of TPC
Spare parts	0.5% of TPC
Start-up costs	
Maintenance, operating and support labour costs	3 months
Maintenance materials	1 month
Chemicals, consumables and waste disposal costs	1 month
Fuel cost	25% of 1 month
Modifications	2% of TPC
Construction time	
Pulverised coal and natural gas plants	3 years
Capital expenditure schedule	
Pulverised coal and natural gas plants	20%/45%/35% of TPC, year 1–3
Capacity factor	
All except year 1	85% (7446 h)
Year 1	50% (4380 h)
Discount rate	
Plant construction and operation	8%
Operating life	
Base case	25 years
Fuel prices	
Coal	2.5 €/GJ
Natural gas	5.0 €/GJ
Fixed operating costs	
Maintenance costs	
PC plant	1.5% of TPC/year
NGCC	2.2% of TPC/year
Maintenance materials	60% of maintenance costs
Maintenance labour	40% of maintenance costs
Operating labour cost	60 k€/person-year
Number of operators	
Pulverised coal plant	16
Pulverised coal + CO_2 capture	18
Natural gas combined-cycle plant	6

Sensitivity analysis scenarios

CRITERIA	BASE CASE	SENSITIVITY 1	SENSITIVITY 2
Coal price, €/GJ (LHV)	2.5	1	4
Natural-gas price, €/GJ (LHV)	6	3	12
Discount rate, %	8	5	10
Plant life, years	25	40	25
CO_2 transport and storage cost, €/tCO_2 stored	10	0	20