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Sunk costs

Carbon capture and storage will miss every target set for it

The IEA, the IPCC, the G8, the Australian Government, the Australian Coal Association and the Council of the European Union have set targets for carbon capture and storage. None of these targets have been met, and none of these targets are on track to be met.

Discussion paper

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Summary

Industry, government and international organisations have given CCS credibility by making predictions about its success and setting targets that give it a clear place in emissions reductions plans.

The only institutional target that CCS has met concerns the number of CCS projects launched. All targets for number of projects actually built and operating or for millions of tonnes of CO2 actually stored each year ("Mtpa") have either not been met, or are not on track to be met.

The floundering of CCS over the past decade means that we cannot rely on it to reduce emissions from electricity generation. That sector should be decarbonised through uptake of renewable energy, closure of fossil fuel power plants and increased energy efficiency.

Table 1: Institutional targets and progress/outcome

Institution	Target	Progress/Outcome
G8	20 new large-scale CCS demonstration projects launched by 2010, operating by 2020	**First target (20 launched by 2010) achieved.** **Second target (20 operating by 2020) not on track.** 12 new projects operating, not all of which meet the criteria. 17 new projects *maximum* by 2020
Australian Coal Association	Large-scale demonstration projects operating in Australia by 2015	**Failed.** No large-scale projects operating by 2015, or since. One project *maximum* by 2020.
Carbon Capture and Storage Flagships (Australia)	Both funded projects operating by 2015, later 2020.	**Initial target failed.** **Revised target not on track.** Neither project expected to be operating by 2020.
Council of the European Union	12 power projects operating in the EU by 2015	**Failed.** No power projects operating by 2015. None expected by 2020.
International Energy Agency (I)	100 large-scale CCS projects operating by 2020 (new and existing) Revised to 34 projects	**Initial target not on track.** **Revised target not on track.** 18 new and existing projects operating. 23 projects *maximum* by 2020
International Energy Agency (II)	255 Mtpa stored by CCS projects by 2020 (new and existing) Revised to 50 Mtpa by 2020	**Initial target not on track.** **Revised target not on track.** ~30 Mtpa capacity in 2017 9.3 Mtpa proven capture rate in 2017 ~38 Mtpa capacity by 2020
International Energy Agency (III)	400 Mtpa stored by large-scale CCS projects by 2025	**Not on track.** ~30 Mtpa capacity in 2017 9.3 Mtpa proven capture rate in 2017 ~45 Mtpa capacity by 2025
IPCC	2,600–4,900 Mtpa by 2020	**Not on track.** 38 Mtpa capacity projected in 2020.
CFMEU, WWF, The Climate Institute, Australian Coal Association	10,000 GWh from CCS power plants in 2020	**Not on track.** No commercial-scale CCS power plants happening or planned

Note: Mtpa stands for “million tonnes of CO2 stored per annum”.

Introduction

International organisations and carbon capture and storage (CCS) boosters have made bold predictions about the uptake and success of CCS technologies. The G8, the International Energy Agency, Australian Coal Association and the Council of the European Union have all set targets for CCS uptake.

CCS' progress towards these targets is used to justify taking money from renewables and energy efficiency projects in order to fund more CCS. Last year, the Minerals Council of Australia argued for the Clean Energy Finance Corporation to extend to funding CCS projects, partly on the grounds that the world has met the G8 target of 20 large-scale CCS projects by 2020[1] (although this is not the case; see below).

The targets that were set represent credible milestones for how CCS must advance if it is to play a key role in the fight against climate change. If it has failed to meet these targets, the technology is less developed than expected – and cannot be depended on.

[1] Minerals Council of Australia (2018) *Clean Energy Finance Corporation Amendment (Carbon Capture and Storage) Bill 2017,* p 4, https://web.archive.org/web/20180416063911/http://www.minerals.org.au/file_upload/files/annual_reports/180921_CEFC_Amendment_(CCS)_Bill_2017.pdf

Target categories and criteria

Ambitions for carbon capture and storage projects fall into two main categories, each with its own sub-categories:

- **Number of large-scale projects:** These targets specify how many large-scale projects must exist to meet the target.
    - **Launched:** Count of projects "launched" or otherwise progressed (but not necessarily complete)
    - **Completed:** Count of projects operational
- **Capture and storage volume:** These targets specify how many Mtpa of CO2 should be captured and stored to meet the target.
    - **Potential capture:** Total potential for capture ("capacity") in a year
    - **Actual capture:** Total actually captured in a year
    - **Proven capture:** Total "proven" to be captured (meeting strict standards around reporting, reliability and safety) in a year

Some targets fall into both categories, for example the IEA 2009 Roadmap's target of 100 large-scale projects capturing 255 Mtpa between them.

The particular criteria set for the target will determine whether projects, capacity and storage count towards the target. For example, the definition of "large-scale" differs across projects, as does what level of verification is required for storage to be "proven".

There is also a temptation to blur the lines, for example counting storage capacity as "actually captured", even if the project's potential is not fully utilised, or to count "launched" projects towards the completed projects target. However, this is not appropriate. If the target is completed projects or CO2 actually captured, that is what progress must be measured against.

LARGE-SCALE PROJECTS

A number of targets reference the number of "large-scale" projects launched or operational (completed). The main criteria are:

- What counts as a large-scale project
- Whether existing completed projects count towards the target

Large-scale

The definition of large-scale has changed over the years, even within organisations.

The Global CCS Institute worked with the G8 to set the particular criteria required for its targets. They initially used a threshold of 1 Mtpa captured as the measure of "large-scale" or "commercial-scale". By the time the G8 criteria were settled, the threshold for non-coal projects had been lowered to "in the order of" 0.5 Mtpa captured (coal projects remained at "in the order of" 1 Mtpa captured).[2]

The Global CCS Institute further revised its criteria to capturing "not less than 80 per cent" of 1 Mtpa for coal-fired power stations (i.e., 0.8 Mtpa captured and stored) and capturing "not less than 80 per cent" of 0.5 Mtpa for other projects (i.e., 0.4 Mpta captured and stored), which is the threshold adopted by the IEA.[3]

Existing completed projects

A key detail is whether a project that pre-dates the target counts towards it. In other words, is it a target for X *new* projects by a certain year, or just a target for X *total* projects by a certain year.

Where there were no existing projects, this is a moot point. For example, since the EU had no large-scale projects to begin with, its goal of 12 power projects by 2015 is necessarily for 12 *new* projects.

On the other hand, this is a vital question for the G8 target. There are six CCS projects that pre-date the G8 target being set, five of which would probably meet the G8's definition of "large-scale". If these projects are not counted, there is no conceivable way for the G8 target to be met.

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[2] Global CCS Institute (2009) *Strategic analysis of the global status of carbon capture and storage, report 5: Synthesis report,* p 9, https://hub.globalccsinstitute.com/sites/default/files/publications/5751/report-5-synthesis-report.pdf; Global CCS Institute (2010) *The global status of CCS: 2010,* p 71, http://hub.globalccsinstitute.com/sites/default/files/publications/12776/global-status-ccs-2010.pdf; IEA and CSLF (2010) *Carbon capture and storage: Progress and next steps,* p 9-10, http://hub.globalccsinstitute.com/sites/default/files/publications/5701/iea-cslf-report-muskoka-2010-g8-summit.pdf

[3] IEA (2013) *Technology Roadmap: Carbon capture and storage, 2013 edition,* p 19, https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapCarbonCaptureandStorage.pdf; see also Global CCS Institute (2010) *The global status of CCS: 2010,* p 48, http://hub.globalccsinstitute.com/sites/default/files/publications/12776/global-status-ccs-2010.pdf

POTENTIAL AND ACTUAL CAPTURE

A number of targets involve the potential to capture and store or the actual capture and storage of a certain volume of CO2. The main criteria are:

- Whether potential, actual or proven capture is the measure
- Whether the capture from any project counts towards the total, or just that done by large-scale projects

Potential, actual or proven capture/storage

A project might have the nominal ability to capture some amount of CO2, but whether it actually captures that amount is a key question. In addition, a project's actual capture may be higher than its proven capture if it cannot satisfactorily demonstrate that its capture is secure for the long-term.

In fact, all existing targets specify that it is the actual or proven capture – and not the capture potential – that is the criteria. However, it is worth emphasising because capture potential is the data that is more readily available – and so it is tempting to use it as a proxy for actual or proven capture.

ENHANCED OIL RECOVERY ("EOR")

Whether to count EOR projects and EOR capture towards CCS development is a contentious question, for a number of reasons as provided by the Global CCS Institute:[4]

- EOR projects may also require dedicated geological storage because EOR projects do not use a constant volume of CO2 over their lifetime
- Not all regions and countries have opportunities for EOR
- Not all oil fields are suitable for EOR
- The timeframe for EOR is narrow
- Public support for taxpayer funding of EOR is limited

The G8 target does include EOR projects, despite describing EOR as a "distraction to CCS development" and saying that "the majority of the CO2 EOR experience has yielded very little information on CO2 storage, monitoring and risk assessment".[5]

[4] Global CCS Institute (2011) *Global storage resources gap analysis for policy makers, report: 2011/10,*, http://hub.globalccsinstitute.com/sites/default/files/publications/23707/2011-10-global-storage-resources-gap-analysis-policy-makers.pdf

Targets

This documents the institutional targets and projections that have been made for CCS.

IEA TARGETS

Roadmaps

2009 Roadmap:

- **100 projects capturing 255 Mtpa by 2020**
- **OECD Pacific has seven projects storing 17 Mtpa by 2020**
- **Coal makes up 37% of CCS, storing 94 Mtpa, by 2020**

2013 Roadmap:

- **34 projects capturing 50 Mtpa by 2020**

In the IEA's 2009 roadmap, the IEA proposed a "BLUE Map" scenario in which CCS reduced carbon emissions by 9.5 Gt CO2 in 2050, or 19% of the total. This would require 100 projects by 2020, storing 255 Mtpa.[6]

In 2011, the IEA confirmed:

> Some 100 projects globally are still required by 2020 if we are to set CCS technologies on the right pathway to delivery.[7]

However, in 2013 the Roadmap was re-published and the IEA cut its ambition from 100 CCS projects to "upwards of 30", not including the four that were operational in 2013,[8]

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[5] Global CCS Institute (2009) *Strategic analysis of the global status of carbon capture and storage, report 5: Synthesis report,* p 25-26, https://hub.globalccsinstitute.com/sites/default/files/publications/5751/report-5-synthesis-report.pdf; Global CCS Institute (2011) *Global storage resources gap analysis for policy makers, report: 2011/10,* http://hub.globalccsinstitute.com/sites/default/files/publications/23707/2011-10-global-storage-resources-gap-analysis-policy-makers.pdf

[6] IEA (2009) *Technology roadmap: Carbon capture and storage,* p 6, 14–22, https://www.iea.org/publications/freepublications/publication/CCSRoadmap2009.pdf

[7] Lipponen, Burnard, Beck, Gale and Pegler (2011) *The IEA CCS Technology Roadmap: One Year On,* p 5755, https://www.sciencedirect.com/science/article/pii/S1876610211008502

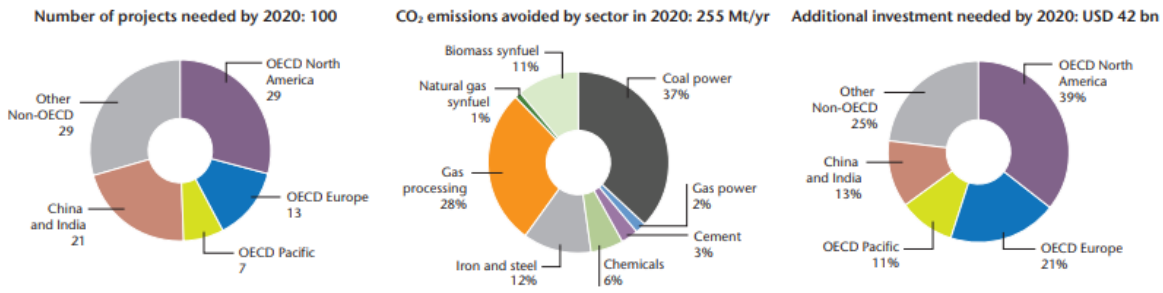
capturing around 50 Mt CO2 p.a.[9] The explanation given was practical – too few projects were in the advanced stages of planning and the revised goal was "set in this context" – rather than based on what was required for fossil fuel technology to remain viable in a carbon-constrained world.[10]

The IEA's 2009 Roadmap broke down the number of projects and emissions avoided needed by region and sector.[11] See Figure 1.

Although we do not have the resources to track the performance of each of these regions and industries, we have analysed the coal industry and the OECD Pacific region (Australia, Japan, New Zealand and South Korea)[12] as areas of particular interest.

The 2013 Roadmap did not update region- and industry-specific targets for CCS, for example for the OECD Pacific or for the coal industry.

Figure 1: 2009 Roadmap's breakdown of projects and Mtpa



[8] IEA (2003) *Technology Roadmap: Carbon capture and storage, 2013 edition,* p 10, 23, 25, https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapCarbonCapturean dStorage.pdf; note they must be using somewhat different criteria to the Global CCS Institute.

[9] Lipponen, McCulloch, Keeling, Stanley, Gerghout and Berley (2016) *The politics of large-scale CCS deployment,* https://ac.els-cdn.com/S1876610217320933/1-s2.0-S1876610217320933-main.pdf?_tid=87f6e6fc-f8cd-466f-b2fc-eefdfe2c60bc&acdnat=1524462638_c2be0b12e1f13132574480cdf7541b28

[10] IEA (2003) *Technology Roadmap: Carbon capture and storage, 2013 edition,* p 23, https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapCarbonCapturean dStorage.pdf

[11] The IEA 2009 Roadmap and the IEA 2009 Roadmap foldout give different figures for the CO2 emissions avoided (299 Mtpa vs 255 Mtpa), and by extension coal's contribution. We have chosen the lower figures to be more conservative, and because the Roadmap foldout was updated more recently than the Roadmap. See IEA (2009) *Carbon capture and storage roadmap,* p 17, 20, https://www.iea.org/publications/freepublications/publication/CCSRoadmap2009.pdf; IEA (2010) *Technology roadmap – carbon capture and storage 2009: foldout,* https://webstore.iea.org/technology-roadmap-carbon-capture-and-storage-2009-foldout

[12] IEA (2009) *Carbon capture and storage roadmap,* p 14, https://www.iea.org/publications/freepublications/publication/CCSRoadmap2009.pdf

Source: IEA (2009) *Carbon capture and storage roadmap,* https://www.iea.org/publications/freepublications/publication/CCSRoadmap2009.pdf; IEA (2010) *Technology roadmap – carbon capture and storage 2009: foldout,* https://webstore.iea.org/technology-roadmap-carbon-capture-and-storage-2009-foldout

Criteria

The IEA provided criteria for projects to count as eligible towards the Roadmaps targets:

- **Large-scale:** The IEA defined the projects needed by 2020 as "large-scale",[13] later clarifying that they were using the new Global CCS Institute definition of 0.8 Mtpa captured and stored for coal-fired power stations and 0.4 Mtpa captured and stored for other projects.[14]
- **Storage:** The Mtpa target is based on storage, not storage potential.
- **New and existing:** The 2009 Roadmap target did not require new projects. The 2013 Roadmap target did require 30 new projects, but also identified that there were only four existing projects that met its criteria.
  This paper therefore sets the target at 34 new and existing projects.

2DS Target

- **Over 400 Mtpa stored in 2025**

The IEA's 2DS scenario identifies changes required for the world to have a 50% chance of limiting global warming to 2 degrees Celsius.[15]

In 2017, the IEA reviewed 26 technologies to assess how they were tracking towards "2DS". Large-scale CCS received the worse assessment of "red", significantly off-track.[16]

[13] "The roadmap's recommendation [is] of 100 large-scale projects": IEA (2009) *Carbon capture and storage roadmap,* https://www.iea.org/publications/freepublications/publication/CCSRoadmap2009.pdf; Saether (2010) *European Zero Emissions Platform: 'We are ready to go',* http://bellona.org/news/ccs/2010-10-european-zero-emissions-platform-we-are-ready-to-go

[14] IEA (2013) *Technology Roadmap: Carbon capture and storage, 2013 edition,* p 19, https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapCarbonCaptureandStorage.pdf; see also Global CCS Institute (2010) *The global status of CCS: 2010,* p 48, http://hub.globalccsinstitute.com/sites/default/files/publications/12776/global-status-ccs-2010.pdf

[15] IEA (n.d.) *Scenarios and projections,* https://www.iea.org/publications/scenariosandprojections/

[16] IEA (2017) *Tracking clean energy progress 2017,* p 6, 11, https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf

G8 TARGETS

- **20 new large-scale CCS projects launched by 2010**
- **20 new large-scale CCS projects operating by 2020**

In 2008, the G8 leaders announced:

> We strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020.[17]

The requirement for "broad deployment" was interpreted to mean that the 20 projects would be operational by 2020.[18]

Criteria

Involved parties set criteria for projects to count as eligible towards the target.[19]

- **New projects:** The projects must be "in addition to those already operating" when the target was set.[20]
- **Large-scale:** 0.5 Mtpa captured (non-coal) or 1 Mtpa captured (coal). This was a revision down from the initial metric of 1 Mtpa for all projects.[21]

[17] Global CCS Institute (2010) *The global status of CCS: 2010,* p 71, http://hub.globalccsinstitute.com/sites/default/files/publications/12776/global-status-ccs-2010.pdf; sometimes described as a G20 target, see for example: Page (2011) *Global status of CCS: 2011,* https://www.youtube.com/watch?v=DxhbLGDig_g

[18] Global CCS Institute (2009) *Strategic analysis of the global status of carbon capture and storage, report 5: Synthesis report,* p 172, https://hub.globalccsinstitute.com/sites/default/files/publications/5751/report-5-synthesis-report.pdf

[19] Global CCS Institute (2010) *The global status of CCS: 2010,* p 71, http://hub.globalccsinstitute.com/sites/default/files/publications/12776/global-status-ccs-2010.pdf; see also IEA and CSLF (2010) *Carbon capture and storage: Progress and next steps,* p 9-10, http://hub.globalccsinstitute.com/sites/default/files/publications/5701/iea-cslf-report-muskoka-2010-g8-summit.pdf

[20] IEA (2016) *20 years of carbon capture and storage,* p 10, 17, https://www.iea.org/publications/freepublications/publication/20YearsofCarbonCaptureandStorage_WEB.pdf; see also SBC Energy Institute (n.d.) *Leading the energy transition: Bringing carbon capture and storage to market,* p 7; see also World Coal Association (2018) *Fluctuating policy and political support for CCS,* https://twitter.com/WorldCoal/status/1034498402216824832

[21] Global CCS Institute (2009) *Strategic analysis of the global status of carbon capture and storage, report 5: Synthesis report,* p 9, https://hub.globalccsinstitute.com/sites/default/files/publications/5751/report-5-synthesis-report.pdf; Global CCS Institute (2010) *The global status of CCS: 2010,* p 71, http://hub.globalccsinstitute.com/sites/default/files/publications/12776/global-status-ccs-2010.pdf;

- **Storage:** The scale requirement is based on *capture,* not capacity.
- **Integrated:** The project integrates capture and storage, and transport (if applicable).
- **Proven capture:** A monitoring, measurement and verification plan must be provided.

In the Global CCS Institute's initial assessment in 2010, only one project met all seven criteria – the Gorgon Gas Project, which is still not operating. Four operating projects met six criteria (one of these, In Salah, has since closed) and five operating projects met five criteria.[22]

The Minerals Council of Australia said in 2017:

> there will be over 20 large scale CCS projects operating by 2020 including Western Australia's Gorgon Carbon Dioxide Injection Project. This meets the G8's 2008 objective of 20 such projects by 2020.[23]

This is based on a misunderstanding the G8 target, because it is counting projects that already existed when the target for new projects was set.

CCS academics Lipponen, McCulloch, Keeling, Stanley, Berghout and Berley confirm in their 2017 paper that the G8 target will be missed because at best, there will be 14 new large-scale CCS projects operating by 2020.[24] They must be using more conservative criteria than the Global CCS Institute – a count of the Global CCS Institute database of large-scale projects operating or under construction gives a slightly higher figure of 17.[25]

IEA and CSLF (2010) *Carbon capture and storage: Progress and next steps,* p 9-10, http://hub.globalccsinstitute.com/sites/default/files/publications/5701/iea-cslf-report-muskoka-2010-g8-summit.pdf

[22] Global CCS Institute (2010) *The status of CCS projects: Interim report 2010,* p 16-17, http://hub.globalccsinstitute.com/sites/default/files/publications/5686/status-ccs-projects-interim-report-2010.pdf

[23] Minerals Council of Australia (2018) *Clean Energy Finance Corporation Amendment (Carbon Capture and Storage) Bill 2017,* p 4, https://web.archive.org/web/20180416063911/http://www.minerals.org.au/file_upload/files/annual_reports/180921_CEFC_Amendment_(CCS)_Bill_2017.pdf

[24] Lipponen, McCulloch, Keeling, Stanley, Berghout and Berley (2017) *The politics of large-scale CCS deployment,* p 7583, https://ac.els-cdn.com/S1876610217320933/1-s2.0-S1876610217320933-main.pdf?_tid=d215c205-2d22-47ec-bf33-6fea38654996&acdnat=1524528931_13e1c799ed0a985fb5ef6aeb2361e1f4

[25] Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

In either case, these are best case scenarios. The true number of CCS projects that meet the G8 target by 2020 could be significantly lower, for several reasons.

- **Under construction:** The five projects "under construction" could be delayed or cancelled, as so many other CCS projects have been. The rate of failure over project lifetime is two-to-one.[26]
- **Closures:** Some of the currently operating CCS projects could close, as the In Salah project did in 2011.[27]
- **EOR projects:** Whether to include EOR projects in the count is controversial. At most five projects would meet the target by 2020 if EOR projects are excluded.
- **G8 criteria:** A project can be operating without meeting all seven G8 criteria. In 2010 (the last time this analysis appears to have been conducted), only one of the projects met all seven criteria: the Gorgon Gas Project. Half of all operating projects met fewer than six of the criteria.[28]
  One example is that the Global CCS Institute database lists two different CCS projects associated with the Alberta Carbon Trunk Line (Agrium CO2 Stream and Sturgeon Refinery CO2 Stream). However, G8 projects are meant to cover the whole process – so these two projects may be properly counted as just one.
- **Large-scale:** The Global CCS Institute's definition of "large-scale" has loosened since the G8 criteria were fixed, and now includes smaller projects. Two or three upcoming projects are below 0.5 Mtpa in capacity.[29]
  Even if a project's capacity exceeds the target, the G8 target is to *store* that much CO2. For example, Boundary Dam Power Station is listed as having a capacity of 1 Mtpa, which meets the G8 requirement for coal-fired power plants to store 1 Mtpa *only* if it operates at full capacity. In fact, over the 41

[26] Lipponen, McCulloch, Keeling, Stanley, Gerghout and Berley (2016) *The politics of large-scale CCS deployment,* https://ac.els-cdn.com/S1876610217320933/1-s2.0-S1876610217320933-main.pdf?_tid=87f6e6fc-f8cd-466f-b2fc-eefdfe2c60bc&acdnat=1524462638_c2be0b12e1f13132574480cdf7541b28

[27] MIT (n.d.) *In Salah Fact Sheet,* https://sequestration.mit.edu/tools/projects/in_salah.html

[28] Global CCS Institute (2010) *The status of CCS projects: Interim report 2010,* p 16-17, http://hub.globalccsinstitute.com/sites/default/files/publications/5686/status-ccs-projects-interim-report-2010.pdf

[29] Sinopec Qilu Petrochemical CCS and Yanchang Integrated Carbon Capture and Storage Demonstration are 0.4 Mtpa. The Alberta Carbon Trunk Line and Terrell Natural Gas Processing Plant have ranges given for their capacity, and part of the range falls below the 0.5 Mtpa target. See Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

> months between October 2014 and March 2018, Boundary Dam stored 2 million tonnes of CO2.[30] That represents less than 60% of capacity.

Unfortunately, the Global CCS Institute seems to have stopped doing detailed analysis against G8 criteria for each project. Some projects that were previously non-compliant may have become compliant (the reverse is also possible), but this analysis would have to be conducted anew for each project.

The world is not on track to meet the G8 target by 2020 because the target was for new projects, not counting the six existing ones. Of the 17 new built and under construction projects, several do not meet the G8's criteria and would not count towards the target.

Australian Coal Association Target

- **G8-style CCS projects in Australia operating by 2015**

In 2009, Ralph Hillman of the Australian Coal Association (since merged with the Minerals Council of Australia) used the G8 targets to justify his claim that Australia will "have commercial scale demonstration plants with carbon capture and storage in operation in Australia by 2015", adding:

> Well, we have the whole G8 behind [the target]. There's a G8 commitment, there's a commitment from the Commonwealth Government, there's a commitment from state governments and there's commitment from industry.[31]

As an extension of the G8 target, this target has the same criteria as the G8 target.

IPCC EMISSIONS SCENARIOS

- **2.6–4.9 Gt CO2 per annum (2,600–4,900 Mtpa) by 2020**

In 2000, the IPCC Special Report on Emissions Scenarios considered six scenarios for the world's carbon emissions, and identified the "projected potential of CO2 capture" as being between 2.6 and 4.9 Gtpa by 2020.[32]

[30] SaskPower (2018) *SaskPower Carbon Capture and Storage Surpasses Two Million Tonne Mark,* http://www.saskpower.com/about-us/media-information/saskpower-carbon-capture-and-storage-surpasses-2-million-tonne-mark/

[31] Jones (2009) *Ralph Hillman and Richard Denniss join Lateline,* http://www.abc.net.au/lateline/ralph-hillman-and-richard-denniss-join-lateline/1689002

COUNCIL OF THE EUROPEAN UNION TARGET

- **12 power projects by 2015**

The European Union aimed to:

> stimulate the construction and operation by 2015 of up to 12 demonstration plants of sustainable fossil fuel technologies in commercial power generation [in the European Union].[33]

CARBON CAPTURE AND STORAGE FLAGSHIPS TARGET

- **2–4 projects by 2015 (later 2020)**

Prime Minister Kevin Rudd's CCS Flagships program aimed to have two to four commercial-scale projects operating in Australia by 2015. Later the target was moved to 2020 and only two projects were selected for funding.[34]

PATHWAY TO ACCELERATED DEPLOYMENT OF CARBON CAPTURE AND STORAGE

- **10,000 GWh of power generation from integrated CCS technologies in 2020**
- **Commercial-scale (>300 MW) plants operating by 2020**

A pathway to accelerated deployment of carbon capture and storage was a strategy to increase the uptake of CCS in Australia proposed in April 2008 by the Australian Coal Association (which would later merge with the Minerals Council); the Construction, Forestry, Mining and Energy Union – Mining and Energy Division; The Climate Institute

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[32] Referenced in IPCC (2005) *Carbon dioxide capture and storage,* p 24, https://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf

[33] Council of the European Union (2007) *Presidencv conclusions*, p 22, http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf; see also Kapetaki and Scowcroft (2017) *Overview of Carbon Capture and Storage (CCS) Demonstration Project Business Models: Risks and Enablers on the Two Sides of the Atlantic*, https://www.sciencedirect.com/science/article/pii/S1876610217320180#bib0010

[34] Van Puyvelde (2016) *What about Carbon Capture and Storage?,* https://www.energynetworks.com.au/news/energy-insider/what-about-carbon-capture-and-storage

(the assets and intellectual property of which were bestowed on The Australia Institute) and WWF Australia.[35]

[35] The Climate Institute (2008) *A pathway to accelerated deployment of carbon capture and storage,* http://www.climateinstitute.org.au/verve/_resources/finalpolicydoc.pdf

CCS progress

What follows is an analysis of CCS progress over time, and projected into the future. It shows that CCS is not on track to meet *any* target.

LARGE-SCALE PROJECTS

New and existing CCS projects

IEA 2009 Roadmap:

- **100 projects by 2020**

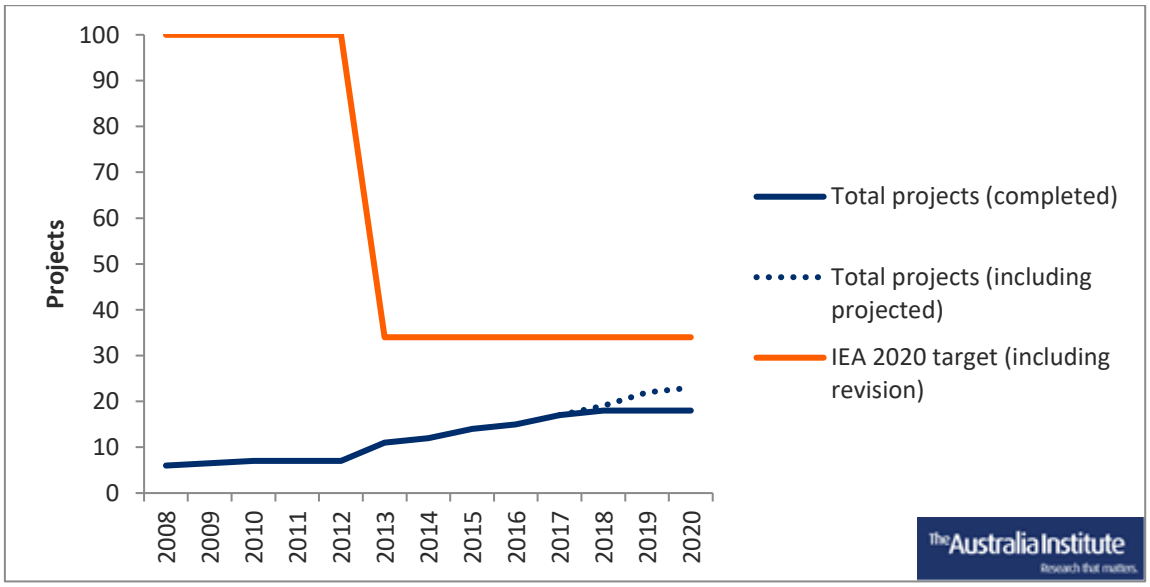
IEA 2013 Roadmap:

- **34 projects by 2020**

There are 17 CCS projects currently operating that might satisfy at least the most generous definition of "large-scale" – that is to say, that they have the capacity to store at least 0.4 Mtpa. There are a further five in the pipeline that could be complete by 2020.

This is well short of the IEA's initial target of 100 large-scale projects by 2020. It is also short of the IEA's revised target of 34 large-scale projects by 2020.

Figure 2: New and existing large-scale projects



Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects; Australia Institute calculations

New CCS projects only

G8 2008 Target:

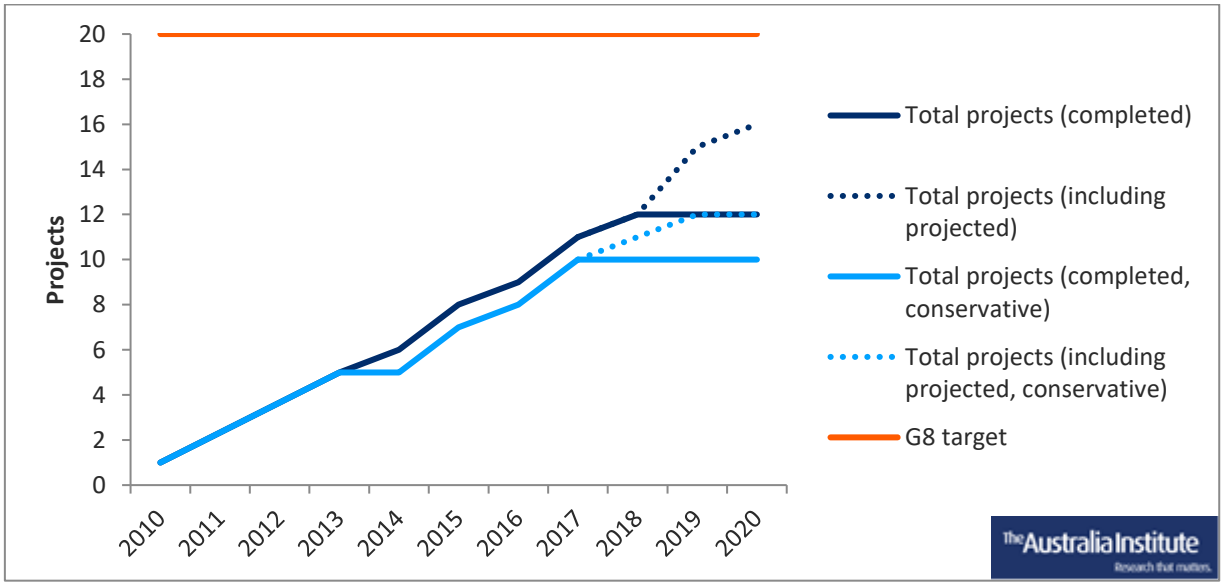
- **20 new large-scale CCS projects operating by 2020**

The IEA analysis counts the six projects completed between 1972 and 2009 that are still operational today. These projects pre-date the G8 target, which was for *new* projects. In Figure 3, we show only those projects begun after the G8 target was set.

The G8 target also used a higher threshold for "large-scale", being "in the order of" 0.5 Mtpa (non-coal projects) or 1 Mtpa (coal projects), as opposed to 0.4 Mtpa and 0.8 Mtpa respectively. The "conservative" count (excluding those projects that are or may be below 0.5/1 Mtpa) is shown in lighter blue in the figure below.

However, as the figure clearly shows, the G8 target will not be met even with the inclusion of all of these potentially ineligible projects.

Figure 3: New large-scale projects (following G8 target)



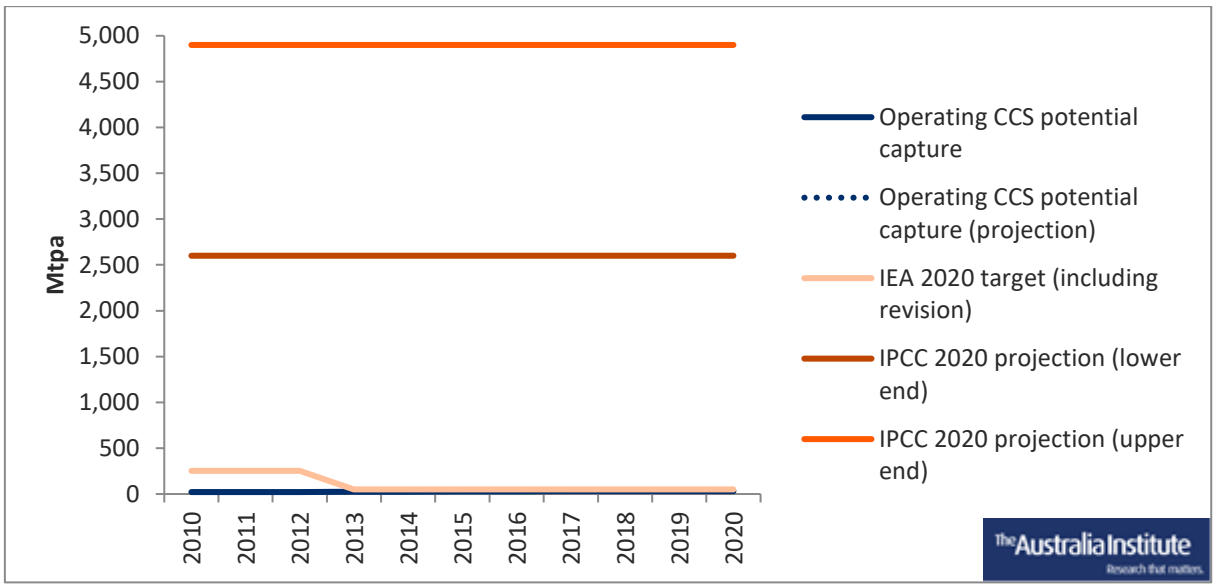
Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects; Australia Institute calculations

POTENTIAL AND CAPTURE

Potential capture by 2020

The potential capture from CCS projects in 2020 is 38.6 Mtpa. This is so far short of the IEA 2020 target of 253 Mtpa or the IPCC 2020 projection of between 2,600 and 4,900 Mtpa potential capture that the figure is not even readable. See Figure 4 for the extreme disparity between projected capture potential in 2020 and the IEA target and IPCC projection.

Figure 4: New and existing capture capacity

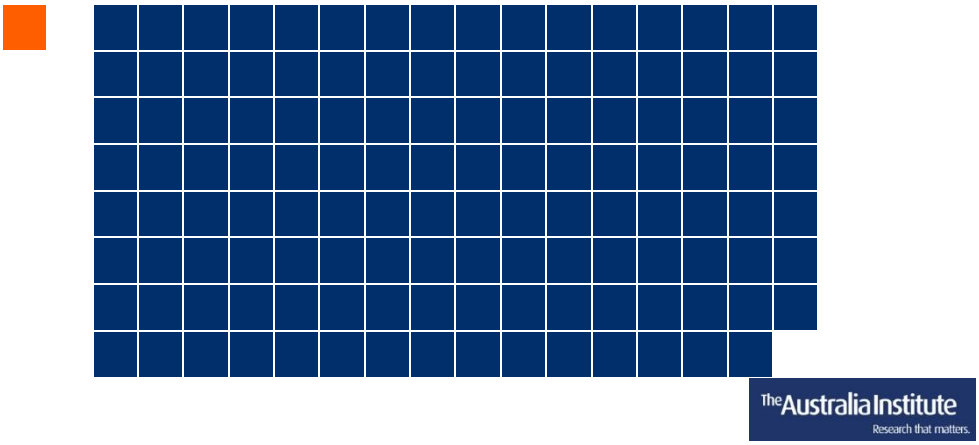


Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects; Australia Institute calculations

Note: The 2020 IEA target is set at 253 Mtpa to reflect 2 Mtpa of small-scale CCS capacity.

Another way of depicting this is in Figure 5, below, showing in orange how much CCS capture potential is expected in 2020 versus the upper range of what the IPCC projected would be needed. There will 1/127th as much as the upper range of the IPCC projections.

Figure 5: Projected capture potential (orange) vs IPCC best-case projections (navy)



Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects; Australia Institute calculations

Proven capture by 2020

IEA 2009 Roadmap:

- **Capturing 255 Mtpa by 2020**

IEA 2013 Roadmap:

- **Capturing 50 Mtpa by 2020**

IPCC 2000 Scenarios:

- **Capturing 2,600–4,900 Mtpa by 2020**

The situation is worse for CCS than the above section suggests. That is because the targets are for CO2 actually captured/stored, rather than the potential for capture/storage.

There can be a significant difference between how much CO2 a project has the potential to capture and how much it actually captures.

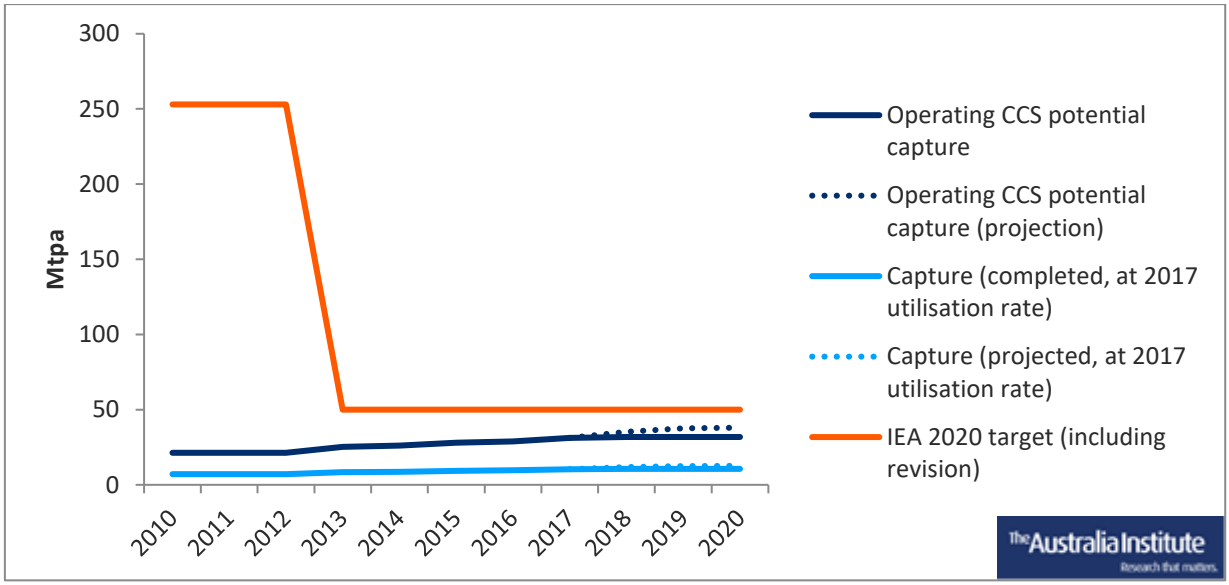
While we do not have good data on the actual capture/storage rate, we do have good data on the *proven* rate. This is more selective than the actual capture rate, because it requires monitoring to prove that the CO2 will not escape after storage.

In 2017, the world's CCS potential was about 30 Mtpa, but its proven capture was just 9.3 Mt – meaning that CCS was overall operating at less than a third of capacity.[36] Even if all projects currently under construction are completed by 2020, and they all start operating at full capacity, there will still only be 38 Mtpa captured.

Figure 6 shows the IEA 2020 target of 255 Mtpa captured compared to potential capture. It also shows what the proven capture rate would be if CCS continues to operate at less than a third of capacity (13 Mtpa).

The same problem applies to the IPCC CCS potential projections of 2,600–4,900 Mtpa, but those are so much larger than the projected capacity that including them in the figure would make the distinction impossible to make out.

Figure 6: New and existing capture capacity, including 2017 utilisation rate – out to 2020



Source: Global CCS Institute (2017) *The global status of CCS 2018,* p 18, 29, http://www.globalccsinstitute.com/sites/www.globalccsinstitute.com/files/uploads/global-status/1-0_4529_CCS_Global_Status_Book_layout-WAW_spreads.pdf; Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

Note: The initial 2020 target is set at 253 Mtpa to reflect 2 Mtpa of currently operating small-scale CCS capacity.

[36] IEA (2017) *Tracking clean energy progress 2017,* p 11, https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf

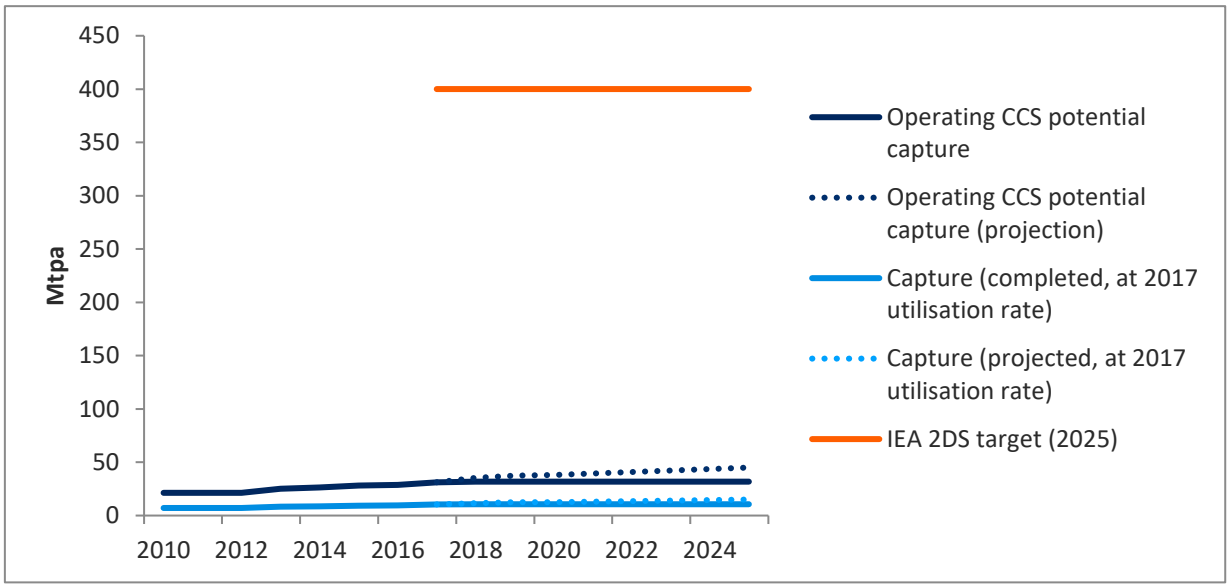
Proven capture by 2025

IEA 2017 2DS Target:

- **Over 400 Mtpa stored in 2025**

The figure below compares the IEA 2DS 2025 target of 400 Mtpa captured compared to potential capture. It also shows what the proven capture rate would be if CCS continues to operate at less than a third of capacity.

Figure 7: New and existing capture capacity, including 2017 utilisation rate – out to 2025



IEA (2017) Tracking clean energy progress 2017, p 11, https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf; Global CCS Institute (2018) Large-scale CCS facilities, http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

Note: The IEA projects 45 Mtpa capacity in 2025. This figure assumes a steady increase between 2020 and 2025 to reach that volume. In practice, it would increase in steps as projects are completed.

REGION- AND INDUSTRY-SPECIFIC PROGRESS

IEA 2009 Roadmap:

- **OECD Pacific has seven projects storing 17 Mtpa by 2020**
- **Coal makes up 37% of CCS, storing 94 Mtpa, by 2020**

Australian Coal Association 2009 Target:

- **G8-style CCS projects in Australia operating by 2015**

Council of the European Union 2007 Target:

- **12 power projects by 2015**

Carbon Capture and Storage Flagships Target:

- **2–4 projects by 2015 (later 2020)**

Australia's G8 projects

Australia did not build full-scale projects by 2015, as promised by the Australian Coal Association. The one full-scale project under construction, Gorgon Gas Project, is four years behind schedule and now expected in the first half of 2019.[37]

In 2010, the Global CCS Institute identified seven large-scale CCS projects that could meet the G8 criteria, including being operational by 2020 or earlier. It also indicated that Australia had committed to build three to five large-scale CCS projects by 2020.

Those projects were:[38]

1. **Coolimba Power Project:** A proposal to build a 400–450 MW coal-fired power plant in Western Australia, capturing 2 Mtpa. It was scheduled to be operational by 2015.
2. **Wandoan Power IGCC CCS Project:** A proposal to build a 400 MW IGCC[39] power plant in Queensland, capturing 2.5 Mtpa. It was scheduled to be operational by 2015 but was cancelled in 2013.[40]
3. **CarbonNet CCS Project:** A proposal to build a range of CO2 capture facilities in Victoria, capturing 4–10 Mtpa. It was planned to be operational between 2015 and 2019. As of November 2018, it has been moved back to an operation date

[37] Milne (2017) *Carbon hiccup for Chevron with 5 million-tonne greenhouse gas problem at Gorgon LNG plant*, https://thewest.com.au/business/oil-gas/carbon-hiccup-for-chevron-with-5-million-tonne-greenhouse-gas-problem-at-gorgon-lng-plant-ng-b88694565z

[38] Global CCS Institute (2010) *The status of CCS projects: Interim report 2010,* p 6, Appendix A, http://hub.globalccsinstitute.com/sites/default/files/publications/5686/status-ccs-projects-interim-report-2010.pdf

[39] "IGCC" refers to "integrated gasification combined cycle" technology, a form of power generation that turns coal into gas and burns the gas.

[40] Queensland Government (2018) *Projects discontinued or on hold,* https://www.statedevelopment.qld.gov.au/assessments-and-approvals/discontinued-eis-projects.html

of “2020s”, a reduced capture of 1–5 Mtpa and a capture type of “under evaluation”.[41]

4. **The Collie South West Hub Project:** A proposal to build a range of CO2 capture facilities in Western Australia, capturing 2.5–7.5 Mtpa. It was planned to be operational by 2015. As of November 2018, it has been moved back to an operation date of 2025 and a reduced capture of 2.5 Mtpa.[42]
5. **ZeroGen Commercial Scale Project:** A proposal to build a 400 MW IGCC plant in Queensland, capturing 2 Mtpa. It was planned to be operational by 2015, but it was cancelled in 2011.[43]
6. **Browse LNG Development:** A proposal to build an LNG plant in Western Australia, capturing 3 Mtpa. It was planned to be operational by 2017 but the project no longer appears as a current project in the Global CCS Institute database.[44]
7. **Gorgon Carbon Dioxide Injection Project:** A proposal to build an LNG processing plant in Western Australia, capturing 3.4 Mtpa. It was planned to be operational in 2014, but the CCS component is now only expected to be operational in 2019. Since the project began in 2016, it is estimated to have released 5.5 to 8 million tonnes of CO2 that would have been sequestered if the CCS technology were functioning.

CarbonNet and the South West Hub Project are the two CCS Flagships projects, discussed below in reference to the CCS Flagships’ target.

Australia’s CCS Flagships projects

Neither of the CCS Flagships programs were complete by the initial target date of 2015.

It is also unlikely that either CCS project will be complete by the revised target date of 2020.

In 2016, Energy Networks Australia wrote that:

[41] Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

[42] Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

[43] Queensland Government (2018) *ZeroGen Project,* https://www.statedevelopment.qld.gov.au/assessments-and-approvals/zerogen-project.html

[44] Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

> It is unclear whether [the two CCS projects] can achieve this timeframe, as progress on both projects has been slow.[45]

Since then, there has been no indication that the projects are now on track.[46]

Australia's pathway to accelerated deployment of CCS

Australia has no commercial-scale CCS at its power plants, and no plans to build any. As such, it will not meet the 10,000 GWh in 2020 target.

Coal

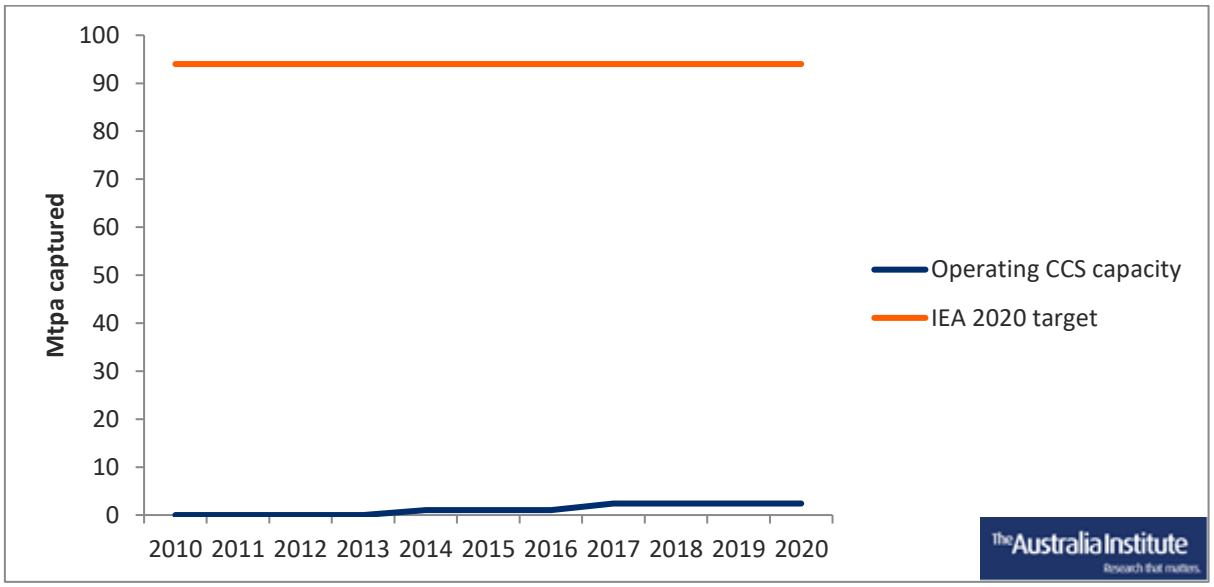
Figure 8 shows coal's performance against the initial IEA target of 94 Mtpa captured by 2020. It shows 2.4 Mtpa captured in 2020, or 3% of the target. This reflects the Boundary Dam Power Station project coming online in 2014 and the Petra Nova project operating from 2017. This estimate is optimistic because Boundary Dam is operating significantly below capacity.

There are no other projects in the pipeline that could be complete by 2020.

[45] Van Puyvelde (2016) *What about Carbon Capture and Storage?,* http://www.energynetworks.com.au/news/energy-insider/what-about-carbon-capture-and-storage#_ftn1

[46] See for example: WA Department of Industry, Innovation and Science (2015) *Carbon Capture and Storage Flagship South West Hub Project: Review report,* https://industry.gov.au/resource/LowEmissionsFossilFuelTech/Documents/CCS-western-australian-south-west-hub-project-review-report.pdf; Victoria Earth Resources (n.d.) *The CarbonNet Project,* http://earthresources.vic.gov.au/earth-resources/victorias-earth-resources/carbon-storage/the-carbonnet-project

Figure 8: Coal-with-CCS, operating and target



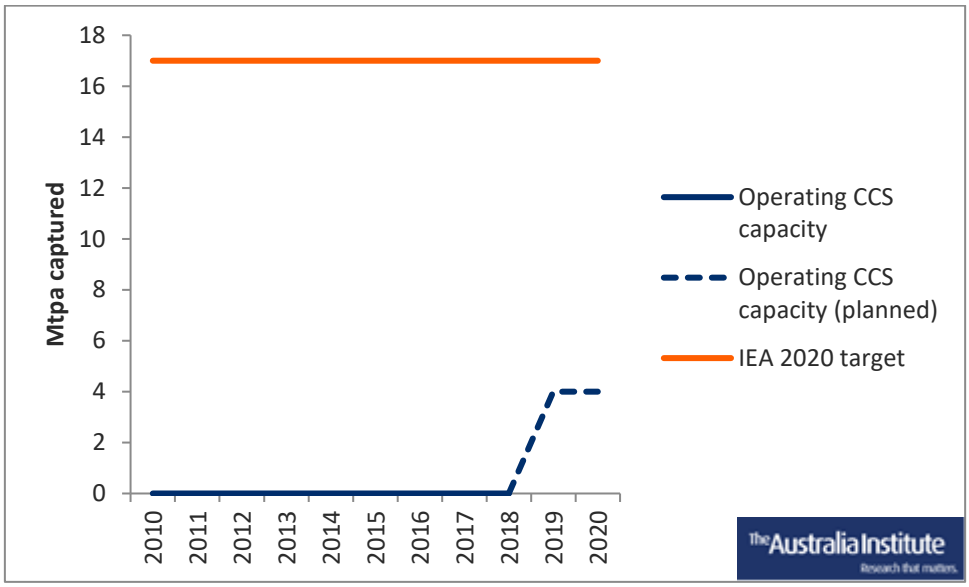
Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

OECD Pacific

Figure 9 shows the OECD Pacific's performance against the initial IEA target of 17 Mtpa captured by 2020. If the Gorgon Gas Project comes online in 2019, as is now planned (it has been delayed multiple times), then the OECD Pacific will have one project capturing 4 Mtpa, or less than a quarter of its target.

There are no other projects in the pipeline expected to be complete by 2020.

Figure 9: CCS in the OECD Pacific, operating, planned and target



Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

EU power projects

The European Union built none of its power projects by its target date of 2015, and has not built any since, despite spending "at least" EUR 587 million on at least 63 CCS projects.[47]

As of 2017:

> The two projects currently operating storage in the European Economic Area, Sleipner and Snøhvit, are located in Norway.[48]

Norway is not in the European Union.

There are not even any *plans* for such plants:

> European utilities Uniper and Engie in June [2017] announced they were walking away from a Dutch CCS project known as ROAD … ROAD is the last proposal standing for a large-scale coal or gas power CCS project in Europe. Its

[47] Teffer (2017) *After spending €587 million, EU has zero CO2 storage plants,* https://euobserver.com/investigations/139257

[48] Kapetaki and Scowcroft (2017) *Overview of Carbon Capture and Storage (CCS) Demonstration Project Business Models: Risks and Enablers on the Two Sides of the Atlantic*, https://www.sciencedirect.com/science/article/pii/S1876610217320180#bib0010

demise followed cancellation of CCS funding in Britain, ending prospects for a European commercial-scale demonstration power plant.[49]

There is still some room for industrial CCS, with a few such projects under consideration.[50]

[49] Wynn (2017) *The carbon-capture dream is dying,* http://energypost.eu/the-carbon-capture-dream-is-dying/

[50] Wynn (2017) *The carbon-capture dream is dying,* http://energypost.eu/the-carbon-capture-dream-is-dying/

Conclusion

The IPCC said in 2000 that by 2020 CCS would have the potential to capture between 2,600 and 4,900 Mtpa of CO2.

CCS will not have the potential to capture 2,600 Mtpa of CO2 by 2020.

The G8 said in 2008 that the world will need to build 20 new large-scale CCS projects by 2020 to enable the broad deployment of CCS.

The world will not build 20 new CCS projects by 2020.

The IEA said in 2009 that the world will need to build 100 large-scale CCS projects capturing 255 Mtpa by 2020 to make CCS a viable technology.

The world will not build 100 large-scale projects by 2020; it will not capture 255 Mtpa.

In 2013, the IEA revised its target to 34 large-scale projects capturing 50 Mtpa by 2020.

The world will not build 34 large-scale projects by 2020; it will not capture 50 Mtpa.

The IEA said in 2017 that CCS would have to capture 400 Mtpa by 2025 to be doing its bit to keeping global warming below 2 degrees Celsius.

CCS will not capture 400 Mtpa by 2025.

The Australian Coal Association said we would have large-scale projects by 2015.

Australia did not complete any large-scale projects by 2015.

Australia's CCS storage projects were meant to be completed by 2015, then 2020.

Our storage projects were not completed by 2015; they will not be completed by 2020.

The EU was going to demonstrate CCS viability by building 12 power projects by 2015.

The EU did not build any power projects.

Carbon capture and storage has missed every target that involved getting projects up and running, and it is on track to miss every future target. The sector has never delivered.

Appendix

PROJECTS OPERATING BEFORE G8 TARGET SET

Number counting towards G8 target: 0 (not new projects)

Number counting towards IEA target: 6

Table 2: Table of projects

Name	Operating by	Capacity (Mtpa)	Type	Notes
Terrell Natural Gas Processing Plant	1972	0.4-0.5	EOR	Possibly below G8 target of 0.5 Mtpa
Enid Fertilizer	1982	0.7	EOR	
Shute Creek Gas Processing Plant	1986	7	EOR	
Sleipner CO2 Storage	1996	1	Pure	
Great Plains Synfuels Plant and Weyburn-Midale	2000	3	EOR	
Snøhvit CO2 Storage	2008[51]	0.7	Pure	

Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

[51] Operating by March 2008, before the G8 target was set in July 2008: IEA and CSLF (2010) *Carbon capture and storage: Progress and next steps,* p 5, http://hub.globalccsinstitute.com/sites/default/files/publications/5701/iea-cslf-report-muskoka-2010-g8-summit.pdf; Leblond (2008) *Gaz de France receives first LNG from Snohvit,* https://www.ogj.com/articles/2008/03/gaz-de-france-receives-first-lng-from-snohvit.html; Van Noorden (2009) *Australia launches carbon capture institute,* https://www.nature.com/news/2009/090417/full/news.2009.372.html

NEW PROJECTS OPERATIONAL SINCE G8 TARGET SET

Number counting towards G8 target: 11 (Boundary Dam storing below target)

Number counting towards IEA target: 12 (more generous definition of "large-scale" than G8)

Table 3: Table of projects

Name	Operating by	Capacity (Mtpa)	Type	Notes
Century Plant	2010	8.4	EOR	
Air Products Steam Methane Reformer	2013	1	EOR	
Coffeyville Gasification Plant	2013	1	EOR	
Lost Cabin Gas Plant	2013	0.9	EOR	
Petrobras Santos Basin Pre-Salt Oil Field CCS	2013	1	EOR	
Boundary Dam Power Station	2014	1	EOR	Actual storage below G8 target of 1 Mtpa; coal project
Quest	2015	1	Pure	
Uthmaniyah CO2-EOR Demonstration	2015	0.8	EOR	
Abu Dhabi CCS	2016	0.8	EOR	
Illinois Industrial Carbon Capture and Storage	2017	1	Pure	
Petra Nova Carbon Capture	2017	1.4	EOR	Coal project
CNPC Jilin Oil Field CO2 EOR	2018	0.6	EOR	

Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

PROJECTS UNDER CONSTRUCTION

Number counting towards G8 target: 2–3 (if built; note that Alberta Carbon Trunk Line – Agrium actual storage may be below G8 target too, and/or may more properly count as a single project with the Alberta Carbon Trunk Line – Sturgeon Refinery for G8 purposes)

Number counting towards IEA target: 5 (if built; more generous definition of "large-scale" than G8)

Beyond 2020: There are no further projects under construction with operation dates after 2020. There are some identified as being in a more preliminary state.

Table 4: Table of projects

Name	Operating by	Capacity (Mtpa)	Type	Notes
Gorgon Gas Project	2019	3.4-4.0	Pure	Australian project
Alberta Carbon Trunk Line – Agrium	2019	0.3-0.6	EOR	Actual storage may be below G8 target of 0.5 Mtpa; both Alberta projects may count as one for G8 target
Alberta Carbon Trunk Line – Sturgeon Refinery	2019	1.2-1.4	EOR	Both Alberta projects may count as one for G8 target
Sinopec Qilu Petrochemical CCS	2019	0.4	EOR	Below G8 target of 0.5 Mtpa
Yanchang Integrated CCS Demonstration	2020	0.4	EOR	Below G8 target of 0.5 Mtpa

Source: Global CCS Institute (2018) *Large-scale CCS facilities,* http://www.globalccsinstitute.com/projects/large-scale-ccs-projects

Note: "Operating by" is the Global CCS Institute's prediction. For example, the Gorgon Gas Project is now only expected by 2019.