Topic Paper #2

AN OPEN-TECHOLOGY AND OPEN-ACCESS POST-COMBUSTION CAPTURE INITIATIVE FOR POWER PLANTS IN THE USA

On December 12, 2019, the National Petroleum Council (NPC) in approving its report, *Meeting the Dual Challenge: A Roadmap to At-Scale Development of Carbon Capture, Use, and Storage*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Supply and Demand Task Group. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of three such working documents used in the study analyses. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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An open-technology and open-access post-combustion capture initiative

for power plants in the USA

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Summary

To date, globally, several large post-combustion capture (PCC) projects to remove CO_2 from power plant flue gases, and a number of smaller ones, have been built using generally similar approaches. But, because the design, construction and operational details have largely been treated as proprietary, so far only very limited meaningful knowledge exchange has been able to take place, both from and to the projects and their developers and operators. In addition, design studies for other PCC plants that did not eventually get built have also either not been published or are heavily redacted in important areas.

An open-technology, open-access capture initiative is therefore needed to accelerate CCUS deployment and reduce the costs of CCUS by enabling improved knowledge exchange and competition within the small fleet of subsidized plants that can be built over the next 5-10 years in the USA.

Open-technology means that the physical hardware of the plant is not tied to a particular solvent, principally not contractually since experience shows there are limited technical restrictions. Open-access means that a generic solvent and process design is used, so that all details of the plant and its operation can be shared freely.

An open-technology, open-access approach is entirely feasible because the process and physical design of the capture facilities is almost identical for all of the amine-based open-access and commercially available proprietary offerings. Any differences are at the margins and all are strikingly similar amongst themselves and to the designs of the 1930's and 1940's. A wide range of amine solvents, generic and proprietary, are routinely operated in the same physical plants, for example at the National Carbon Capture Center[1] and Test Centre Mongstad[2].

The amine solvents considered generic are those readily purchased as commodities on the open market from chemical manufacturers and are usually relatively low cost. MEA (monoethanolamine) is the primary generic amine. It is widely used already in the industry and thus readily acceptable for commercially-financed projects. Tens if not hundreds of alternative solvents have been developed with the objective of lowering the energy requirements to strip CO_2 from the solvent, as compared to a relatively dilute solution of MEA in water. The overall ownership costs and long-term benefits of these proprietary solvents, and the added capital costs associated with some of them, remain opaque and impossible to confirm independently. The savings in the USA's low fuel cost environment are small compared with the potential savings associated with open competition for billion-dollar-plus facilities, which is possible when each offering is not tied to a different proprietary solvent claiming a marginal energy improvement over the generic option.

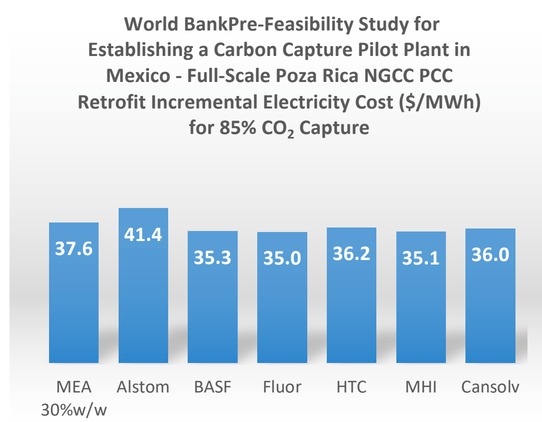
The sharing of learning from the next ten at-scale PCC plants in the USA and the subsequent fact-based competition amongst the EPC (engineering, procurement and construction) community is the most promising route to lower cost PCC in the USA. With the lower capacity factors that fossil fired power plants are experiencing, and will continue to experience, in the nation's electricity grids due to ever-increasing amounts of intermittent power from solar and wind facilities, the capital cost portion of the cost per ton of CO_2 captured will continue to increase, making solvent energy consumption increasingly less important. As an example, on NGCC plant the capital recovery portion of the cost of capture may approach 70% when realistic long term capacity factors, returns on investment and tenor of debt are considered.

[1] https://www.nationalcarboncapturecenter.com/

[2] http://www.tcmda.com/en/

1. Definitions and advantages

- 'Open-technology' means that the operators of a PCC plant are in full control of the technology used in the plant rather than purchasing a 'black box' unit. The PCC hardware can then be procured by fully competitive tendering against a common specification (as for, e.g., power plants). The specification will include a design solvent (analogous to specifying a design fuel for a power plant), but the use of improved solvents, if economic, in the future will be facilitated. Operators will also readily be able to work with a range of suppliers to modify and upgrade the PCC plant hardware when in service to use the latest technology and instrumentation as the field progresses and market requirements change.
- 'Open-access', means that a generic, non-proprietary solvent is used as the design solvent for an open-technology PCC project. This greatly facilitates procurement, since a wide range of contractors and subcontractors will be familiar with generic solvent properties and able to supply equipment at competitive prices. Restrictions associated with proprietary solvents, such as designated suppliers and non-disclosure agreements, can also be avoided. In addition, there need be no wide-reaching restrictions on knowledge transfer to and from the project, as has been the case with PCC projects and studies using proprietary solvents. The case for public support to CCUS is then strengthened.
- If any intrinsic extra net costs of using an open-access solvent arise they are expected to be modest. Licensing costs and expensive solvent makeup charges would be avoided. EPC bids for a common solvent-based capture plant would be very competitive. The use of a single, standard solvent for a project will make it possible to thoroughly verify long-term performance through pilot testing (with a matured, degraded solvent) on actual flue gases. This will facilitate competitive EPC bids from several qualified constructors with thorough process de-risking, something that would not be feasible for bids based on multiple different proprietary solvents.
- Some indication of relative costs for an open-technology, open-access PCC approach is available from a study on CCUS from NGCC plants undertaken for the World Bank[3]. Using data from a range of proprietary PCC technology vendors, minimal variation in estimated overall technical and economic performance was found between them and also only marginal advantages over the use of a first generation open-access solvent, 30% w/w MEA (monoethanolamine). This study also did not take into account any advantages that could be expected from being able to run a fully-competitive, multiple bidder, procurement process for the open-technology, open-access MEA case. The very small difference could be expected to disappear if the concentration of the generic MEA option were increased slightly. (It should be noted that no similar independent comparative study on CCUS from coal power plants has been found.)



- Other examples of open-technology PCC projects include a unit currently being built on an incinerator plant in the Netherlands with approximately 100ktCO_2/yr capacity[4], a recent feasibility study for a brown coal power plant retrofit with 8 trains of approximately 16MtCO_2/yr total capacity[5] and one of the FEED studies for a 400 MW, 1 MtCO_2/yr natural gas combined cycle plant in Norway[6].

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[3] https://www.gob.mx/sener/en/documentos/pre-feasibility-study-for-establishing-a-carbon-capture-pilot-plant-in-mexico?idiom=en

[4] https://www.co2-cato.org/publications/library1/20181204-co2-capture-and-usage-at-avr-in-duiven-liquid-co2-production-for-use-as-greenhouse-fertiliser

[5] http://www.co2crc.com.au/wp-content/uploads/2018/10/Retrofitting_Australian_Power_Station_with_PCC.pdf

[6] http://publikasjoner.nve.no/report/2007/report2007_02.pdf; https://ukccsrc.ac.uk/sites/default/files/documents/news/Karsto-FEED-Study-Report-Redacted-Updated-comp.pdf

2. The 'business case' for government support for an open-technology, open-access PCC initiative

The business case for government support for an open-technology, open-access PCC initiative is that society, electricity consumers and the bulk of USA industry will gain much greater benefits from this type of project, and especially a 'critical-mass' of multiple projects forming a linked initiative, than they can do if only the current type of 'black box' project continues to be deployed. Aspects of this are discussed further below.

- Approximately 5-10 new CO_2 post-combustion capture (PCC) projects are currently in various stages of development around the world[7] on power plants and other industries using coal, natural gas, wastes etc. at scales up to around 2 $MtCO_2$/yr per capture train. Most of these projects can be expected to progress only if they receive some form of subsidy in addition to current market measures such as enhanced carbon prices or tax incentives.
- The justification for these subsidies is that earlier deployment of even this small number of full-scale PCC units will give reduced costs and risks for subsequent rollout of the hundreds of PCC units on power, industry and biomass plants that would be required to deliver meaningful cuts in global greenhouse gas emissions. But this justification is predicated on there being effective knowledge transfer to support learning from doing and also sufficient opportunities for trying out successive improvements in operating techniques and in the range of different sub-components in PCC systems, as well as for rigorous testing of new solvents and formulations for overall cost reductions. All of this, however, has proven either impossible or extremely difficult with 'black box' PCC systems using proprietary technologies, especially given the very small number of full-scale projects to date.
- There are excellent reasons why many improvements in PCC technology should remain proprietary, and open-technology PCC plants can greatly encourage the development of a wide range of proprietary technologies.
  - All types of proprietary hardware developments can benefit from public domain data obtained through open-access PCC testing for guidance and also from access to existing open-technology PCC systems for initial testing and subsequent rapid deployment.
  - Proprietary advanced solvents, after rigorous pilot-scale testing, can also readily be used in open-technology PCC units if they are seen to confer genuine advantages. A much greater number of solvents could gain access to the market if open-technology PCC plants were deployed, and could be sourced from a much wider range of organizations than EPC contractors and very well-established solvent suppliers. It is not cost-effective to subsidize a new PCC project to test each new solvent development, not least because first-of-a-kind risks would be incurred each time. But the risks associated with using follow-on solvents in an open-technology PCC plant are much reduced once successful operation has been achieved with the initial design solvent (probably generic).
  - Even if a full-scale open-technology PCC system does not allow a totally optimized performance for a new solvent, very extensive pilot scale testing experience at sites in the International Test Center Network[8] and elsewhere confirms that reasonable results can be obtained across a wide range of solvents with limited physical plant modifications. And, much more important than marginal differences in energy requirements, open-technology PCC testing can give potential users key information on long-term solvent degradation management methods, solvent make-up requirements and atmospheric emissions.
  - Proprietary solvent formulation and management techniques can also benefit from public-domain data obtained using generic solvents in open-access PCC trials.

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[7] Possible countries/regions (in alphabetical order) include: Australia, Canada, China, Mexico, Middle East, Netherlands, Norway, South Africa, South Korea, UK, USA.

[8] https://itcn-global.org/

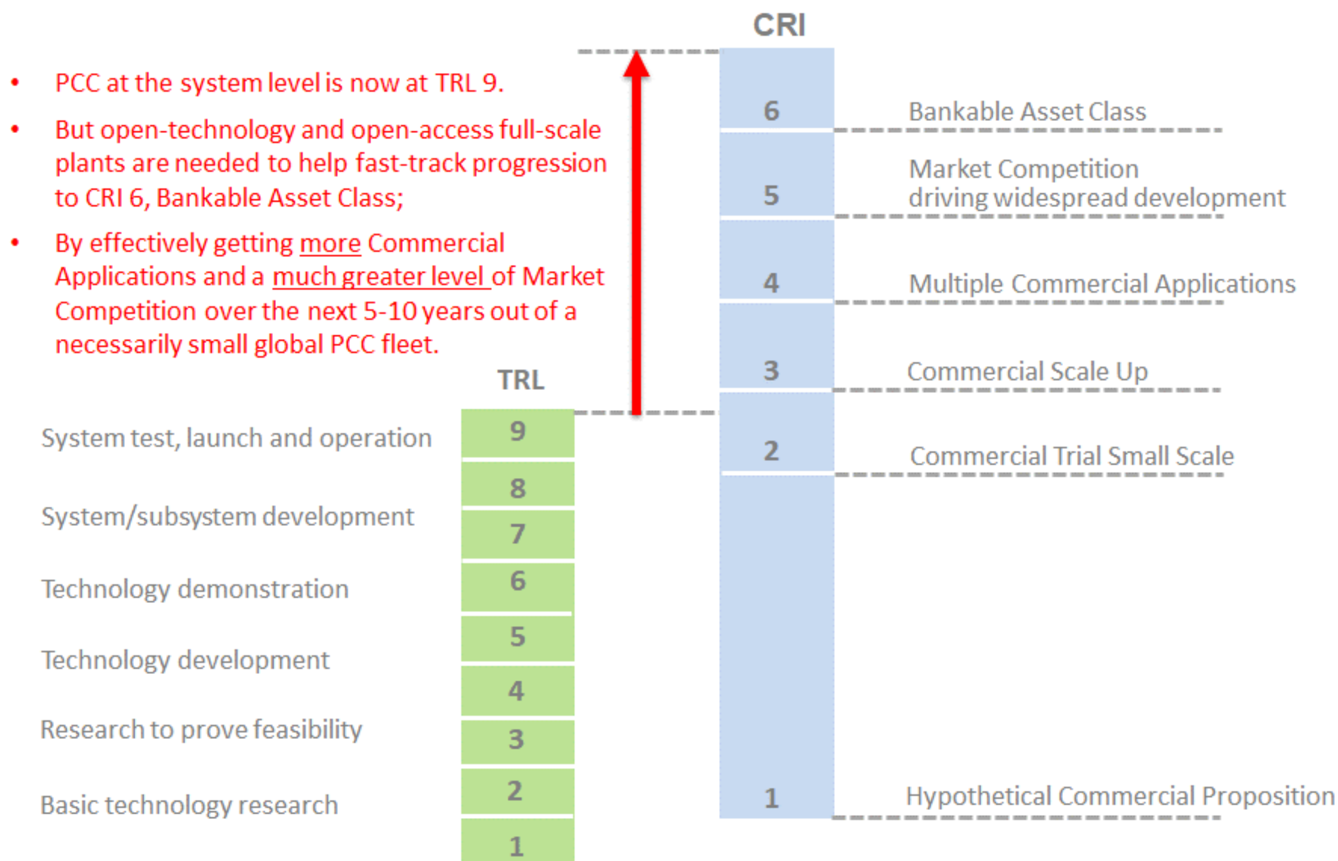
- The major part of CCUS costs is capital. Open access allows transparent, competitive EPC procurement that will lower both near term and long term capital cost elements of CCUS.

3. Delivering a global open-technology and open-access PCC program

- All participants in an open-technology and open-access PCC program will benefit if there is wider engagement. This will multiply the returns on each project's investment and subsidy.
- The availability of information from open-access PCC activities will also address frequently-raised requests from developing countries for knowledge transfer on low-carbon technologies, without 'giving away' privately-owned IP. USA leadership worldwide can be gained through transparency and openness.
- All types of PCC projects, including on coal, gas and biomass power plants, industry and incinerators, could make valuable contributions to development of the field as a whole.
- Pilot testing and research activities at all scales would also be able to make a much greater contribution if generic, open-access solvents are used in full-scale PCC projects. Open-access will enable the absolutely essential two-way exchange between research and innovation activities and full-scale operations, ensuring that researchers are aware of real requirements and that operators and designers can rapidly apply the latest knowledge to deliver cost reductions. Organizations such as the ITCN and the IEAGHG PCC conferences already work to do this as much as possible, but links with full-scale operation are currently restricted. The Mission Innovation Carbon Capture Innovation Challenge has identified Priority Research Directions C1 and C2 on PCC solvent development, delivering which is predicated on international collaboration in activities that can be demonstrated to give effective cost reductions and reduced environmental impacts in actual large-scale deployment.
- As part of concerted measures to accelerate the deployment of CCUS, governments therefore should:
  a) Identify the importance of full, open-access knowledge exchange for publicly-supported full-scale projects; and
  b) support national and international agreements and mechanisms to facilitate knowledge exchange.
- Government support will also be required for:
  a) long-term, open-access second generation solvent testing in a range of collaborating national pilot-scale facilities, based around established networks such as the ITCN; and
  b) underpinning fundamental scientific research as part of Mission Innovation (MI) initiatives.
- Projects will need to be prepared to design and procure publicly subsidized PCC plants on an open-technology and open-access basis. As noted above, if any intrinsic extra net costs of using an open-access solvent arise they are expected to be modest. Licensing costs and expensive solvent makeup charges would be avoided. EPC bids for a common solvent could be very competitive and the long-term performance of a single, standard solvent for a project could be thoroughly verified.
- As with any PCC solvent, the selected open-access solvent for a project, plus proposed long-term solvent management techniques including thermal reclaiming, will need to be tested at pilot scale on a fully representative flue gas (e.g. on the actual plant in the case of unrefined solid and liquid fuels) for 4000-8000 hours. Emissions and waste streams will be assessed rigorously in these tests, as well as the performance (capture levels, energy requirements etc.) for a representative in-service solvent rather than a fresh solvent. The test results will be part of the specification for the full scale plant design and this full extended testing will limit process uncertainty risks.
- Other aspects of PCC plant procurement can be covered by normal commercial terms for large process equipment. Appropriate contractual arrangements, test procedures and detailed specification examples

will be an important area for discussion amongst industry stakeholders that will be greatly facilitated by open-access.

- The open-technology and open-access PCC program will start with owners, contractors and technology experts from participating projects discussing detailed process configurations and operating procedures to optimize the overall effectiveness of open-technology PCC projects. This will include pilot test protocols and reporting for specification and design purposes. Some of these details will be project specific, but information exchange is still likely to be of considerable benefit to all.
- Post-combustion capture using amines is quite a unique capture technology in the CCUS field because it has demonstrably been at Technology Readiness Level (TRL) 9 for many years. What then needs to happen, is that the Commercial Readiness Index (CRI) of PCC is increased through learning-by-doing based on deployment, as illustrated in the diagram below. This will involve innovation and improvement in all of the various sub-components of PCC technology, not just in solvent formulation to minimize regeneration energy requirements.
- The open-technology and open-access PCC initiative outlined above will reach an interim conclusion when multiple full-scale OT / OA plants have been in successful operation for a number of years and a range of innovations, both open-access and proprietary, in key cost-saving sub-components have been developed and demonstrated. PCC technology will then be at Commercial Readiness Index 6, Bankable Asset Class, and ready for widespread deployment.



Based on Bruce Adderley, Jeremy Carey, Jon Gibbins, Mathieu Lucquiaud and Richard Smith, "Post-Combustion Carbon Dioxide Capture Cost Reduction to 2030 and beyond", Faraday Discussion on CCS, July 2016. http://eprints.whiterose.ac.uk/133086/