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Use of the by-products of post-combustion carbon capture in concrete production: Australian case study

Farid Sartipi[1*], Kanmany Jegendran[1]

[1] Institute of Construction Materials, Sydney, Australia

*Corresponding author: Farid Sartipi, Researcher, Institute of Construction Materials, Western Sydney University Kingswood campus, Building Z.1.12; NSW, 2747, Australia. E: f.sartipi@westernsydney.edu.au P: (+61) 0416731647

Abstract

Australia as one of the pioneers in the adoption of green industries, had made significant steps in zero emission programs. Post-combustion, pre-combustion, and Oxy-fuel combustion are three conventional techniques for capturing the CO_2 gas from the coal-fired power generation plants. Since almost 50% of the electricity generation is derived from the coal power plants in Australia, it is important to pinpoint the progress made in carbon capture and storage technologies throughout the last decade. This paper, firstly, reviews the advancements in the carbon capture and storage technologies in Australia by considering the pros and cons in the adoption of each of the 3 major techniques in detail. It can be of advantage for other economies in the world to adopt the presented workflow as lessons to be taken. Also, as the CO_2 storage after the capturing process is one of the challenges facing the industry, the current study, secondly, presents a new practical method to consume the captured CO_2 in construction activities specially in concrete production by promoting a new type of chemical admixture. Experimental laboratory studies show satisfying results in the utilization of the carbon capture product in concrete production. A survey had also been conducted that matches the supply and demand of recycled aggregate in the selected region showcasing the financial viability for commercializing this product.

Keywords

CO2 capture; Post-combustion Capture; Construction and demolition Waste; Chemical Admixture; Sustainable development

Introduction

For many years now, the emission of greenhouse gases had become one of the main concerns of almost any developing industry. The atmospheric concentration of the greenhouse gases is increasing due to the increase in the population of Earth and the associated human activities. Carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide are amongst the greenhouses gases that the emission of which in total is resulting in the addition of the warming of the earth's surface[1]. Report published by the international energy agency estimates the global reach of CO_2 emission to 45 gigatonnes by 2035 which solely correlates with a 5.6°C rise in the earth's temperature[2]. There are more than 100 countries that adopted the practices in the mitigation of efforts to reduce the climate change[3] where Australia is one of the leaders amongst the participants. In 2019, the Federal Government of Australia has devoted a $2 billion budget for environmental carbon footprint reduction[4]. It is known that the energy sector is one of the main sources of carbon emission all over the world. Thus, it is, first, necessary to address the efficiency of the Australian energy suppliers along the carbon capturing plans.

Following the novelty of this article, as the construction industry is also being categorized as one of the main pollutant industries globally, upon the progress of this research satisfactory results had been achieved from the laboratory test. The tests were design to evaluate the performance of a new concrete chemical admixture which is produced for the purpose of enhancing the rheology of concrete made with recycled aggregate. The so-called admixture compromises chemical absorption of CO_2 gas as part of the production process. Concrete samples had been tested under compressive machines and also slump flow test.

Review on the Australian position in green power generation

The Australian Department of the Environment and Energy stated [5] that Australia is committed to taking domestic and international action on climate change as the result of Paris agreement in Nov-Dec 2015. An ambitious target to reduce emissions by 26-28 per cent below 2005 levels by 2030 was set. By 2010, from the 30 coal-fired power plants operating in Australia, two-third of them are older than 20 years and only four employ clean coal technology [6]. CO2CRC as the authorised party facilitating the CO_2 capturing programs in Australia had stated in its 2017-18 report about the progress of 3 major projects in Australia. These projects are investigating the applicability of advanced membrane and solvent technologies on Vales Point and Latrobe Valley. The innovation of new absorbents with enhanced kinetics by ion-exchange has also been reported[7]. A summary of the Australian CCS projects is provided in table 1 below:

	Project name	State	Estimated operation date	Capture facility	Capture type	Transport type	Storage type	CO2 storage rate	Status
1	Lassie (D)	Vic	2015	-	-	Pipeline	Geological	>1 Mt.pa	Identification
2	FuturGas	SA	2017	Coal to liquid (Producing diesel and naphta / power / sulphur)	Pre-combustion	80-200 km pipeline	Geological (saline aquifer and/or depleted oil/gas field)	1.6 Mt.pa	Identification
3	ZeroGen	QL	2015	400 MW IGCC (coal) power plant	Pre-combustion	100 km pipeline	Geological (Saline aquifer)	2 Mt.pa	Evaluation
4	Browse LNG	WA	2015	LNG plant (gas processing)	NG processing	Pipeline	Geological (Saline aquifer and/or depleted oil/gas field)	3 Mt.pa	Evaluation
5	Wandoan Power (D)	QL	2015	400 MW net IGCC (coal) power plant	Pre combustion	200 km pipeline	Geological or beneficial reuse (EOR)	2.5 Mt.pa	Evaluation
6	Coolimba	WA	Not specified	2x200MW or 3x150MW coal fired CFB power plant	Post-combustion	20-80 km pipeline	Geological (depleted oil/gas field)	3 Mt.pa	Evaluation
7	Gorgon project	WA	2015	LNG plant (gas processing)	NG processing	Pipeline Geological (Saline aquifer) 3.4 Mt.pa	Geological (saline aquifer)	3.4 Mt.pa	Define

Table 1 Status of CCS projects in Australia (Source: global CCS institute, 2009)

Based on the definition made by the Global CCS Institute, a large-scale commercial CCS project is capable of storing 1Mt.pa or greater of CO_2 gas.

There are currently 22 active coal powered electricity plants in the four major states of Australia with a total maximum capacity of 24,004 MWh[8-10].

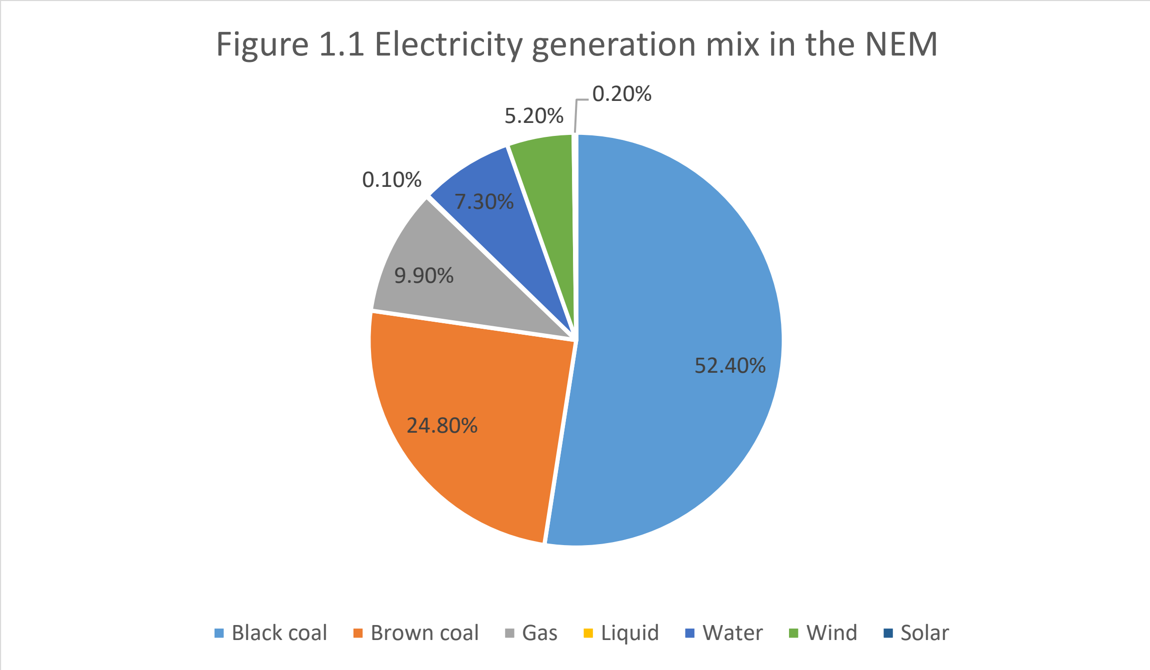
	Coal Burnt Power Station	State	Operating Company	Power Generation (MW)	Commissioned (Years)
1	Liddell	NSW	AGL Energy	2,000	1971
2	Vales Point B	NSW	owned and operated by *Sunset Power* International and trades as Delta Electricity	1,320	1978
3	Yallourn W	VIC	Energy Australia	1,480	1974
4	Gladstone	QLD	Rio Tinto, NRG Energy Inc, Southern Cross GPS Pty Ltd, Ryowa II GPS II Ltd, YKK GPS (Qld) Pty Ltd	1,680	1976
5	Gladstone QAL	QLD	–	25	–
6	Eraring	NSW	Origin Energy	2,880	1982
7	Bayswater	NSW	AGL Energy	2,640	1985
8	Tarong	QLD	Stanwell Corporation Limited (Stanwell)	1,400	1984 – 1986
9	Tarong North	QLD	Stanwell Corporation Limited (Stanwell)	443	2003
10	Loy yang A	VIC	AGL Energy	2,210	1984 – 1987
11	Loy yang B	VIC	Alinta Energy, CTFE	1,026	1993 – 1996
12	Callide B	QLD	CS Energy	700	1988

13	Callide C	QLD	CS Energy owns Calide C in a 50/50 joint venture with InterGen	**810**	2001
14	Stanwell	QLD	Stanwell Corporation Limited (Stanwell)	**1,460**	1993 – 1996
15	Mt Piper	NSW	Energy Australia	**1,400**	1993
16	Milmerran	QLD	InterGen	**851**	2002
17	Kogan Creek	QLD	CS Energy	**750**	2007
18	Collie	WA	Synergy	**340**	1999
19	Bluewaters 2	WA	Griffin Energy	**208**	2009
20	Bluewaters 1	WA	Griffin Energy	**208**	2009
21	Worsley (Alumina)	WA	BHP Billiton	**135**	2012
22	Yabulu	QLD	—	**38**	—

Table 2 List of Australia's coal burnt power stations

From the comparison of the data collected in tables above it can be concluded that only 1 out of 22 existing coal-power plants in Australia is equipped with carbon capturing techniques. The high cost associated with the transportation and storage are from the barriers.

In Australia, the National Electricity Market, NEM, and Western Australia's South-West Interconnected System, SWIS, are the largest electricity suppliers. The NEM covers Australia's eastern and south-eastern coasts compromising five states: Queensland, New South Wales (including the Australian Capital Territory), South Australia, Victoria and Tasmania [8]. Currently, coal fired power plants (both brown and black coal) makes up 78 per cent of electricity generation across the NEM. This is followed by gas, compromising for 9.9 per cent. Figures 1.1 and 1.2 depict Australia's electricity generation mix.



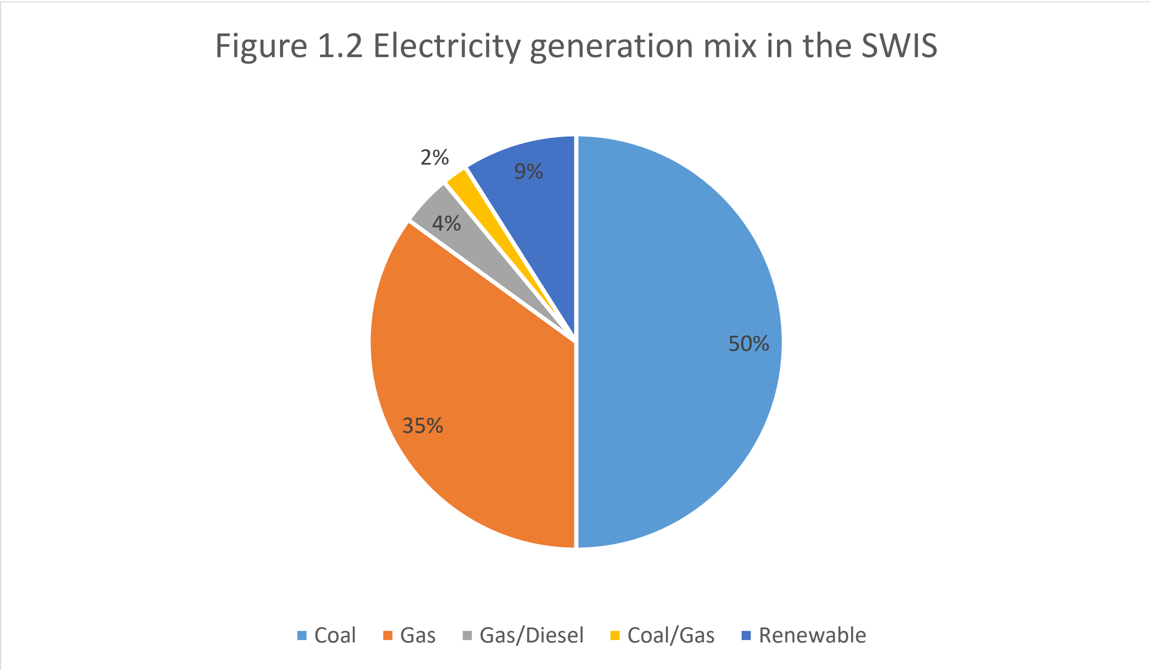


Figure 1 - Electricity generation mix in Australia

Estimates of Australia's greenhouse gas emission are produced by the Australian Department of Environment. Nearly half of all NSW emissions in 2013/2014 were from the stationary energy sector, primarily from public electricity production. Burning fossil fuels accounts for over 99% of emissions in the sector. Because of the low-cost of production and abundance of coal supplies the energy producers' tendency leans toward the use of coal powered plants. Coal combustion alone produces 51 million tonnes of emissions annually or nearly 39% of all NSW greenhouse gas emissions [11, 12]. Another studies [13, 14] show that by considering the variation in the types of coal being used in power generation, combustion technologies and operating conditions, the CO_2 emission per unit of electricity is estimated to be in the range of 0.91 to 0.98 kg/kWh. A median 600 MWh coal-fired power plant emits 500 m^3/s of flue gas containing about 15% CO_2, totalling to about 11,000 tons of CO_2 emission per day. It was reported that brown coal combustion emits relatively higher amount of CO_2 compared to black coal.

There are three options to reduce total CO_2 emission into the atmosphere, i.e., to reduce energy intensity, to reduce carbon intensity, and to enhance the sequestration of CO_2. The first option is basically promoting more efficient use of energy. The second option, hoewever, requires a switch to using non-fossil fuels such as hydrogen and renewable energy. The third and the most promising method is known to be CO_2 capture and sequestration technologies at power plants [15]. Post-combustion capture, pre-combustion capture, and oxy-combustion are three methods recognized to be effective in this area[16]. Table 3 shows a comparison of positive and negative points of each of these three methods.

	Advantages	Disadvantages
Post-combustion	• Applicable to the majority of existing coal-fired power plants • Retrofit technology option	• Low CO_2 partial pressure resulting in significantly higher performance or circulation volume requirement for high capture level.
Pre-combustion	• Synthesis gas is concentrated in CO_2 resulting in high CO_2 pressure and reduction in compression costs/loads • More technologies are available for separation	• Applicable mainly to new plants, a few gasification plants are currently in operation. • The commercial application is often costly. • Extensive supporting system required.
Oxy-combustion	• Highest concentration of CO_2 in the flue gas • Retrofit and repowering technology options	• Cooled CO_2 recycle required to maintain temperatures within limits of combustor materials • Low process efficiency caused by the heat generation

Table 3 Advantages and disadvantages of different CO2 capture approaches[16]

Post combustion carbon capturing

As the name indicates, the post combustion methods are facilitating the process of CO_2 capture from the flue gas after the fuel had been burned for energy generation purposes. A typical procedure in this process is as demonstrated in figure 2. The amine treatment of the flue gas is a widely acceptable method in the post combustion capturing method. MEA commercial absorption process constitutes of the removal of the CO_2 from the flue gas in an absorber. MEA reacts with CO_2 in the gas stream to form MEA carbamate. The CO_2-rich MEA solution is then sent to a stripper where it is reheated in order to release the CO_2. The CO_2-free MEA is recycled afterward[17].

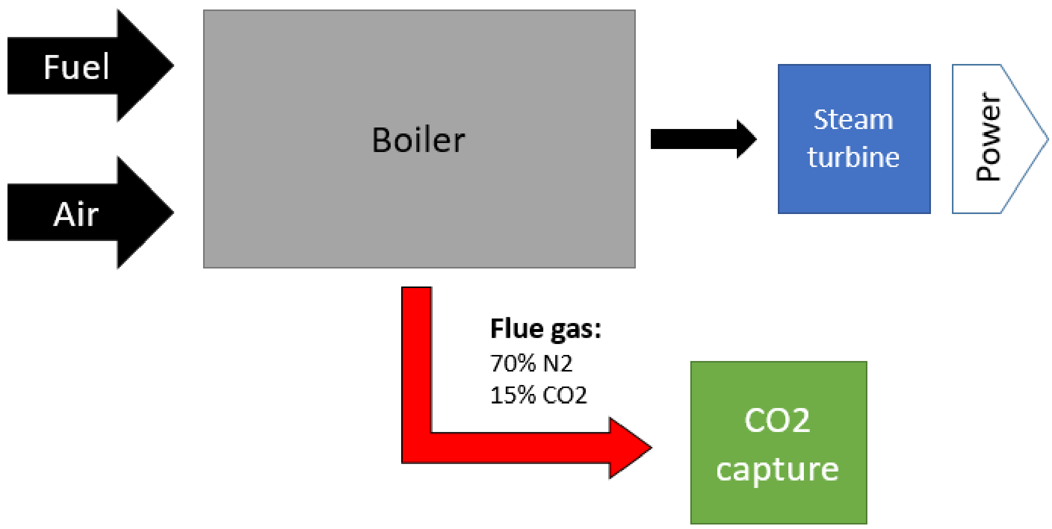


Figure 2 - Post combustion carbon capture procedure

Other solvents are also applicable for this process such as hot potassium carbonate, chilled ammonia and ionic liquids[2]. Monoethanolamine is by far the most well-known amine-based absorbent due to its high chemical reactivity and low cost of production. There are number of issues incorporated with the use of MEA in carbon capturing. High enthalpy of reaction, low absorption capacity, oxidative behaviour followed by corrosion and thermal degradation.

The solvent chemistry becomes important once it's realised that the circulation flow rate required for capturing a given amount of CO_2 by having a higher CO_2 absorption capacity. The kinetics data derived from the chemical reactions also allow the determination of the size of the absorber or desorber columns. One of the critical factors to be considered in the design process of absorber or in the selection process of the solvent is the equilibrium solubility of CO_2 in the solvent as a function of temperature and pressure shown in Figure 3. The estimation of heat energy required in the post combustion process can also be obtained from the solubility data. Henni et al. reported that the CO_2 solubility increases in amine-based solvent exposed to higher pressure[18].

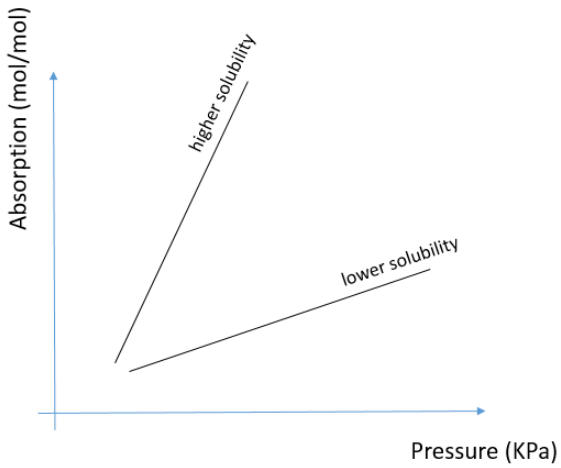


Figure 3 - Correlation of CO2 solubility in amine-based solvents with pressure

Monoethanolamine overall reaction with CO2 develops as followed in equation 1 [2]:

$$2\ MEA + CO_2 \rightarrow MEA\text{-}COO^- + MEAH^+$$

$$CO_{2(g)} + H_2O_{(l)} \leftrightarrow H_2CO_{3(l)}$$

$$MEA + CO_2 + H_2O \leftrightarrow MEA\text{-}H^+\text{-}COO^-\ (\text{zwitterion}) + H_2O$$

$$MEA\text{-}H^+\text{-}COO^-\ (\text{zwitterion}) + H_2O \leftrightarrow MEA\text{-}COO^-\ (\text{carbamate}) + H_3O^+$$

$$H_3O^+ + MEA \leftrightarrow MEAH^+ + H_2O$$

$$H_2CO_3 + H_2O \leftrightarrow HCO_3^- + H_3O^+$$

$$HCO_3^- + H_2O \leftrightarrow CO_3^{2-} + H_3O^+$$

$$MEA\text{-}COO^- + H_2O \leftrightarrow HCO_3^- + MEA$$

Equation 1 Chemical reaction of Monoethanolamine with CO2 gas.

Since the conventional amine technologies are costly, energy intensive and if implemented would result in large increase in the cost of producing electricity, it is suggested to employ the membrane systems to enhance the efficiency of the conventional MEA (Monoethanolamine) capturing technologies[12]. It has also been reported that the capture of the 90% of the CO2 in flue gas requires 30% of the power generated by the plant which adds up a cost of $40-100 for a ton of carbon dioxide. The monoethanolamine absorption would increase the cost of electricity production by 70%. [19, 20]. Another study ran by Paul Feron et al. [21] proposes a metal mediated electrochemical process to harvest the CO_2 absorption enthalpy into electric power to compensate the capture energy consumption. It was reported by the same author that *the energy output of 4.1kJ/mol CO_2 was achieved experimentally at the studied conditions, resulting in an enthalpy-to-electricity conversion efficiency of 6.4%.* Modularity and the compactness of the membrane units are from the benefits of utilizing membranes as the sequestration method. Membrane technology is a non-dispersive contacting system that the flue gas does not interact chemically with the membrane. Membrane systems brings 30 times more interfacial area than the liquid phase gas absorption methods [22]. Compared to the issues encountered with the use of liquid absorption such as corrosion and foaming, utilization of membrane technology in post combustion carbon capture, benefits the whole process by cost savings reported as 38-42%, equipment weight reduction of 34-40%, as few significant advantageous reported by Falk-Pedersen et al[23]. One of the limitation to the application of membranes is the capital and energy cost of pressure equipment. Sufficient level of pressure plays an important role in the membrane capturing process as it affects the flue gas flow rate.

Pre-combustion carbon capturing

The pre-combustion methods are chemical procedures involved in the steps before the fossil fuel combustion. These are usually chemical gasification of the input coal aiming to lower the amount of CO_2 emission after the combustion. In this process as pictured in Figure 4, coal is combined with oxygen to produce a gas made up of carbon monoxide and hydrogen (Syngas). By adding water to the syngas, CO_2 is produced and captured while the hydrogen is burned to generate power. Pre-combustion capture is potentially less expensive than post-combustion capture [15, 20].

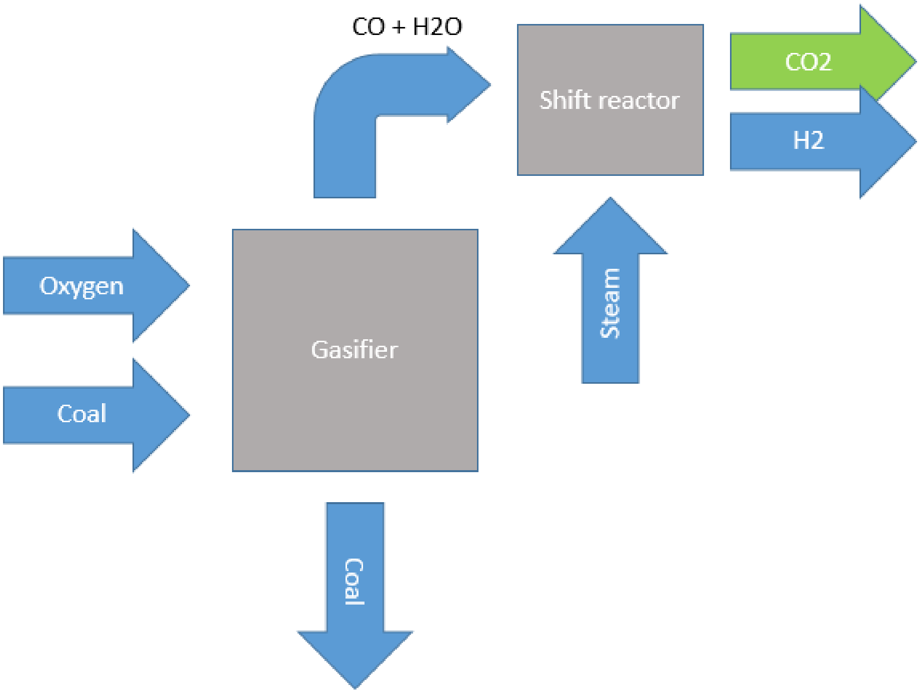


Figure 4 - Pre combustion carbon capture procedure

Scientist believe that the utilization of solid sorbents may be more efficient in some cases as compared with the efficiency of liquid phase sorbents. In the pre-combustion CO_2 capturing practices in the coal-fired power plants solid adsorbents are being used such as zeolites, activated carbon, calcium oxides, hydrotalcites, supported amines and metal-organic framework materials. Amongst the spectrum of solid molecular sieves, activated carbon (AC) and aluminosilicate zeolites show considerable adsorption capacity. It was reported by S. Garcia et al. that in lower CO_2 partial pressure, the capturing capacity of AC is lower than zeolite based sorbents. However, this ratio reverses once the partial pressure increases. It became of the interest of researchers to understand the correlation of pressure and temperature with the capturing capacity output. Experimental data revealed that the effect of temperature is negligible compared to pressure. The optimum CO_2 partial pressure is stated to be 300 kPa (Total pressure to be 1500 kPa) at the temperature of 25°C in order to obtain the maximum capturing capacity of 3.96 mol/ kg adsorbent[24]. Another study done by Trevor C Drage et al., however, shows that maximum adsorption capacity of activated carbon reached to up to 12 mol/kg in a total pressure of 4,000 kPa[25], which brings lack of consistency in the results obtained from the S Garcia's research. The inconsistency in the reported results, in fact, indicates the immaturity of the pre-combustion carbon capturing technique which makes the adoption of such technology unlikely compared to other methods. Chungsying Lu et al. in another paper compared the adsorption level of carbon nanotube, zeolite, and granular activated carbon in the same order respectively from high to low[26].

Oxyfuel-combustion carbon capturing

Such technology separates the oxygen from the air prior to combustion and produces a nearly sequestration-ready CO_2 effluent. In this case as pictured in Figure 5, the coal is burned exposed to a nearly pure oxygen and emits a high concentration of CO_2 which is almost ready for sequestration. The by-product of this process contains a high volume of H_2O which is cooled down in order to separate the CO_2 properly.

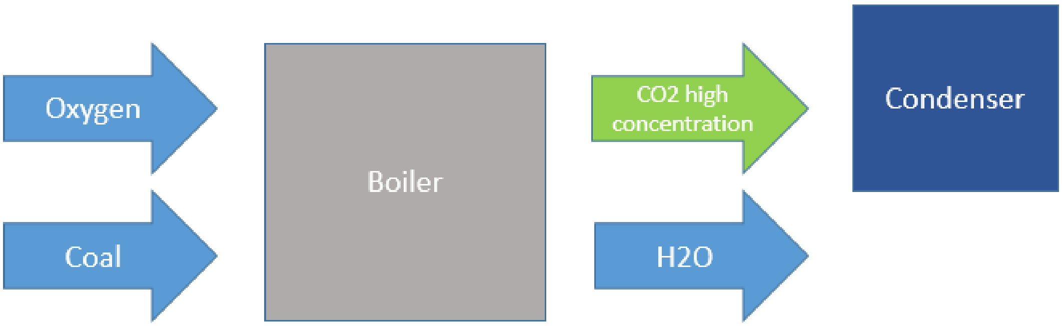


Figure 5 Oxy-fuel carbon capturing method procedure

This study aims to address the following research questions:

- What are the current coal power plants operating in NSW? What CO_2 capturing method do they utilize?
  To understand the answer to this question, governmental documents and literature exist in this field had been extensively reviewed.
- What barriers exists in the implementation of CO_2 capturing methods?
  Literature review would reveal the answer to this question.
- What are the alternatives to ease the CO_2 storage methods?
  An innovative idea of the use of the by-products of post-combustion capturing technique had been explained and tested in the laboratory.
- How does the construction industry could be a place to utilize both CO_2 capture and storage?

Laboratory experimental tests had shown a set of promising results for the use of these by-products in concrete production. Survey results also on the other hand had shown the market capacity to embrace such new approach.

Methodology

This paper, first identifies the plans and programs for CO_2 capturing and storage in Australia as a whole. Name and the status of the projects are outlined. This was done by collecting scattered data from governmental documents and scientific literature available on the public domain in order to provide an extensive report on the current status of operating coal power plants in Australia. Executive summary reports from the Australian Government Department of Environment and Energy were combined with the data published by Global CCS Institute. The review on literature in addition to previous studies on the use of recycled aggregate reveals that one of the environmental approaches in construction is the use of recycled aggregate in concrete. Combined with the CO2 capturing analogy a new chemical admixture had been produced that enhances the properties of concrete made with recycled aggregate. The results and explanation of experimental laboratory test on the applicability of a new type of concrete chemical admixture were introduced as followed. The proposed product consumes the by-product of post combustion capturing method as part of the synthesis process. Survey results obtained from the site visits to recycling plants and concrete batching plants were provided in order to match the supply and demand of recycled aggregate and market capitalization matters.

CO_2 capture from cement industry

After power generation cement is known as to be the second largest anthropogenic emission source, contributing approximately 7% of global CO_2 emissions. It is stated that the large cement manufacturers on average have a higher RoE (Return on Equity) and lower debt ratio, therefore a higher discount rate should be considered for the cost analysis compared to power plants. This is while the International Energy Agency (IEA) estimates that the global decarbonisation of cement sector costs AUD$350-840 billion. Global cement production accounts for approximately 9.6EJ of energy consumption and 1.9 Gt CO2 emissions per year [27]. Cement related CO2 emissions originate from a number of sources in the production line where 50% is associated with the process of converting limestone (CaCO3) into calcium oxide (CaO) in the midst of the formation of so called clinker. 40% of the CO2 emission in the cement production results from the combustion of fuel in the kiln and the remaining 10% roots from the transportation and electricity use in other parts of the process[28]. A study conducted in 2011 analysing the post combustion CO2 capturing from a coal power plant in Australia revealed a AUD$68/tonne cost associated with the process. This is comparable with the cost associated with the CO2 capture from a cement plant in Canada reported as AUD$49/tonne that is %27 cheaper [29].

Application of the by-products of the post-combustion methods in construction industry – CO_2 storage

One of the challenges facing the capturing technologies returns to the storage issues. In other words, the sequestration of CO_2 from the flue gas if successfully and commercially adopted via the three methods previously discussed, follows with the question "How to consume the captured CO_2 now?". Storage technologies introduce an alternative to safely consume the CO_2 in a manner that the highly pressurized gas being entrapped under the layers of the ground facilitating the oil and gas extraction processes (Use in petroleum industry). But, due to the geotechnical difficulties encountered with the implementation of this storage technique, it is unlikely to adopt such in a broader scale. Monoethanolamine is one of the widely used substances in the post-combustion technique of CO_2 capture. The experimental studies done during the terms of this research show that the by-product of such a process once had been used in concrete can enhance the mechanical properties of concrete made by recycled aggregate.

From the benefits of using such chemical admixture is the acid treatment of recycled aggregates during the mixing process. Interfacial Transitional Zone (ITZ) is known as the main factor in the low quality of recycled aggregate as the old cement mortar attached to the core degrades the overall performance of the recycled concrete [30-32]. The high recorded pH of 11 for the proposed concrete chemical admixture, in fact, facilitates the acid treatment of recycled aggregate once used. On the other side, the conventional CO_2 Concrete technology proposed by Tam et al. [33] encompasses the CO_2 molecules in a physical interlock with a low absorption rates using a pressure chamber. The current chemical admixture increases the absorption rate to up to 90% by activating the CO_2 gas chemically upon the reaction with other substances.

The other challenge that comes with the use of recycled aggregate in concrete is the high water absorption of such aggregate. This property affects the workability of concrete in a significant way which makes an environmental type of concrete as such unfavourable to the eyes of contractors [34-36]. For the commercial use of recycled aggregate as in ready-mix concrete produced at batching plants, the delivery time of the truck mixers are limited to less than 90 minutes. Lower water content available in the mix for the hydration reaction of cement means that the setting time of concrete would decreases consequently as well. This would basically mean that concrete batching plants will be having a smaller area for service affecting the number of customers and the profit margin as well. The newly proposed concrete admixture had shown a rheological enhancement on the fresh state of concrete.

The following results in table 5 were obtained during the experimental tests.

Dosage wt% of cement[1]	7days Compressive strength (MPa)	Slump table flow [37]
3%	25.6	41
5%	36	46
7%	31	52

Table 1 Properties of concrete made by the addition of the proposed chemical admixture.

In terms of the microstructure of concrete, the interface between the recycled aggregate and cement mortar plays a crucial role on the compressive strength. Also known as interfacial transition zone (ITZ), this zone corresponds to the binding and the interlocking of cement paste and aggregate. In concrete made of recycled aggregate, the ITZ is usually weak due to the attachment of the old cracked mortar on the surface of the recycled aggregate [38-40]. Several studies show that the use of low concentrated acid to maximize the adherence between recycled aggregate and the cement paste is in fact an effective method which ultimately leads to enhancement of the mechanical properties of concrete. One of these methods, for example, recycled aggregate is soaked in three different types of acid, namely, hydrochloric acid (HCl), sulfuric acid and phosphoric acid at a molarity of 0.1 M for 24 hours. In general, the treatment significantly reduces the water absorption of recycled aggregate by 7.27–12.17%. As a result, the compressive strength, flexural strength, and elastic modulus of the treated recycled aggregate are improved compared with those of untreated recycled aggregate[41-43].

Figure 6 - Footage from the effects of newly proposed chemical admixture on the fresh state properties of concrete made by recycled aggregate.

[1] Concrete chemical admixtures are usually being added to the mix with the mentioned ratios.

In accordance with data gathered from Australian natural and recycled aggregate market a ton of 10mm and 20mm recycled aggregate price is roughly $92 however the same size natural aggregates cost $192, indicating the direct effect on the final concrete product. Furthermore, considering the significant reduction in numbers of transportation cycling between the construction/demolition site and the recycling plant, it can be resulted the reduction in labour wages and fuel cost not to mention the depreciation rate of civil machineries. The same research on the supply of recycled aggregate in Sydney metropolitan showed a production capacity of 20,000 tons of recycled aggregate per month[44].

Based on our survey all of the concrete batching plants refuse to use recycled aggregate in concrete production. Variety of roots has been asked for the reason behind not using recycled aggregate in concrete including:

- Lack of experienced staff in this field
- Lack of demand for recycled concrete
- Lack of supply of recycled aggregate
- Technical barriers

The first reason comes out to be the technical difficulties of using recycled aggregate in concrete. It has been stated that the recycled concrete drops the slump extensively in less than 30 minutes. The average delivery time is 45 minutes. This time difference leads the workability of the fresh concrete to be low enough to discourage concrete distributors and concrete workers using such aggregates in concrete. The low workability of recycled concrete is due to the high porosity of recycled aggregate. Before the batch being delivered to the construction site, a considerable amount of water required for the hydration chemical reaction, absorbed by the recycled aggregate. Studies showed that a process named carbon conditioning recycled aggregate will cause the voids inside the recycled aggregate to get filled by other chemical components[33], leading to a total low porosity of recycled aggregate and, as a result, higher workability of concrete made by carbon conditioned recycled aggregate .

Having all the data gathered, the main recycled aggregate consumer across the construction industry in Sydney is the road construction sector. Still, it has been observed and stated that some construction and demolition waste recycling plants have a relatively long non-productive period throughout a year. This indicates that even though the first recycled aggregate consumer is the road construction section, the supply of recycled aggregate is much higher than the existing demand.

Taking the 240,000 tons as an annual production capacity of the metropolitan and the recommended mass portion of CO_2 agent to aggregate as 1/60, the gross annual demand of 4,000 tons of the proposed chemical additive would be resulted. Another financial benefit that the mass promotion of such product claims is the cost savings associated with the elimination of heat energy requirement for the separation of CO_2 from the rich Monoethanolamine outlet from the absorption tower. Simply explained, the CO_2 rich Monoethanolamine could be transported directly to the concrete admixture factory for the further uses.

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Conclusion

The high cost associated with the transportation of the captured CO_2, which is mainly accomplished by pipelining, low efficiency in the adsorption/absorption rate, immaturity of the industry, etc. all together increases the risk of investment in the CCS projects. In order to facilitate the issues encountered with the adoption of CCS techniques and ease the approach toward zero emission goal, this study proposed an experimented concrete chemical admixture which is useful in the enhancement of properties of concrete made of recycled aggregate. Results of the slump flow and 7 days compressive tests show a workable high performance recycled concrete. The proposed “Green concrete chemical admixture” could be seen as a solution for storage issues brought by CCS projects and also at the same time enhances the properties of recycled concrete. The barriers for a wider general use of recycled aggregate in concrete had been explained to clarify the current status of market.

References

[1] D. Pearce, "The role of carbon taxes in adjusting to global warming," *The economic journal,* vol. 101, no. 407, pp. 938-948, 1991.

[2] Z. H. Liang *et al.*, "Recent progress and new developments in post-combustion carbon-capture technology with amine based solvents," *International Journal of Greenhouse Gas Control,* vol. 40, pp. 26-54, 2015.

[3] M. Meinshausen *et al.*, "Greenhouse-gas emission targets for limiting global warming to 2 C," *Nature,* vol. 458, no. 7242, p. 1158, 2009.

[4] N. Pearson, "Morrison reboots abbott-era climate change plan," ed: 9news, 2019.
[5] "Paris agreement," Department of Environment and Energy. [Online]. Available: http://www.environment.gov.au/climate-change/government/international/paris-agreement
[6] "Clean coal," 2010. [Online]. Available: https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Browse_by_Topic/ClimateChangeold/responses/mitigation/emissions/clean
[7] "2017-18 annual report," CO2CRC, 2018. [Online]. Available: http://www.co2crc.com.au/wp-content/uploads/2018/11/CO2CRC_AR17-18_web.pdf
[8] W. Craik, "Policy Options for Australia's Electricity Supply Sector," Australian Govenment Climate Change Authority, 2016.
[9] (2014). *Australia's off-grid clean energy market research paper*.
[10] (2016). *The retirement of coal-fired power stations*.
[11] N. Government, "NSW emissions," Environment and heritage, 2019. [Online]. Available: https://climatechange.environment.nsw.gov.au/About-climate-change-in-NSW/NSW-emissions
[12] T. C. Merkel, H. Lin, X. Wei, and R. Baker, "Power plant post-combustion carbon dioxide capture: An opportunity for membranes," *Journal of membrane science,* vol. 359, no. 1-2, pp. 126-139, 2010.
[13] M. L. Mittal, C. Sharma, and R. Singh, "Estimates of emissions from coal fired thermal power plants in India," in *2012 International emission inventory conference*, 2012, pp. 13-16.
[14] F. Birol, "CO2 emissions from fuel combustion," International Energy Agency 2017.
[15] H. Yang *et al.*, "Progress in carbon dioxide separation and capture: A review," *Journal of environmental sciences,* vol. 20, no. 1, pp. 14-27, 2008.
[16] J. D. Figueroa, T. Fout, S. Plasynski, H. McIlvried, and R. D. Srivastava, "Advances in CO2 capture technology—the US Department of Energy's Carbon Sequestration Program," *International journal of greenhouse gas control,* vol. 2, no. 1, pp. 9-20, 2008.
[17] C. Stewart and M.-A. Hessami, "A study of methods of carbon dioxide capture and sequestration––the sustainability of a photosynthetic bioreactor approach," *Energy Conversion and Management,* vol. 46, no. 3, pp. 403-420, 2005.
[18] A. Henni, A. V. Rayer, K. Z. Sumon, T. Sema, R. Idem, and P. Tontiwachwuthikul, "Solubility of CO2 in reactive solvents for post-combustion CO2 capture," Future Medicine, 2013.
[19] J. M. Klara *et al.*, "Cost and performance baseline for fossil energy plants, vol. 1: Bituminous coal and natural gas to electricity final report," DOE/NETL-2007/1281, 2007.
[20] L. C. Elwell and W. S. Grant, "Technology options for capturing CO2," *Power Magazine,* vol. 150, no. 8, p. 60, 2006.
[21] K. Li *et al.*, "Reaction Enthalpy Conversion in Amine Based Post-Combustion CO 2 Capture," *Chemical Engineering Transactions,* vol. 69, pp. 139-144, 2018.
[22] A. Gabelman and S.-T. Hwang, "Hollow fiber membrane contactors," *Journal of Membrane Science,* vol. 159, no. 1-2, pp. 61-106, 1999.
[23] O. Falk-Pedersen, M. S. Grønvold, P. Nøkleby, F. Bjerve, and H. F. Svendsen, "CO2 capture with membrane contactors," *International journal of green energy,* vol. 2, no. 2, pp. 157-165, 2005.
[24] S. García, M. Gil, C. Martín, J. Pis, F. Rubiera, and C. Pevida, "Breakthrough adsorption study of a commercial activated carbon for pre-combustion CO2 capture," *Chemical Engineering Journal,* vol. 171, no. 2, pp. 549-556, 2011.
[25] T. C. Drage, J. M. Blackman, C. Pevida, and C. E. Snape, "Evaluation of activated carbon adsorbents for CO2 capture in gasification," *Energy & Fuels,* vol. 23, no. 5, pp. 2790-2796, 2009.

[26] C. Lu, H. Bai, B. Wu, F. Su, and J. F. Hwang, "Comparative study of CO2 capture by carbon nanotubes, activated carbons, and zeolites," *Energy & Fuels,* vol. 22, no. 5, pp. 3050-3056, 2008.
[27] J. Li, P. Tharakan, D. Macdonald, and X. Liang, "Technological, economic and financial prospects of carbon dioxide capture in the cement industry," *Energy Policy,* vol. 61, pp. 1377-1387, 2013.
[28] N. Mahasenan, R. Dahowski, and C. Davidson, "The role of carbon dioxide capture and storage in reducing emissions from cement plants in North America," in *Greenhouse Gas Control Technologies 7*: Elsevier, 2005, pp. 901-909.
[29] M. T. Ho, G. W. Allinson, and D. E. Wiley, "Comparison of MEA capture cost for low CO2 emissions sources in Australia," *International Journal of Greenhouse Gas Control,* vol. 5, no. 1, pp. 49-60, 2011.
[30] A. Akbarnezhad, K. C. G. Ong, M. H. Zhang, and C. T. Tam, "Acid Treatment Technique for Determining the Mortar Content of Recycled Concrete Aggregates," *Journal of Testing and Evaluation,* vol. 41, 2013.
[31] N. Otsuki, S.-i. Miyazato, and W. Yodsudjai, "Influence of recycled aggregate on interfacial transition zone, strength, chloride penetration and carbonation of concrete," *Journal of materials in civil engineering,* vol. 15, no. 5, pp. 443-451, 2003.
[32] C. S. Poon, Z. Shui, and L. Lam, "Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates," *Construction and Building Materials,* vol. 18, no. 6, pp. 461-468, 2004.
[33] V. W. Y. Tam, A. Butera, and K. N. Le, "Carbon-conditioned recycled aggregates in concrete production," *Journal of cleaner Production,* 2016.
[34] V. W. Tam, X. Gao, C. M. Tam, and C. Chan, "New approach in measuring water absorption of recycled aggregates," *Construction and Building Materials,* vol. 22, no. 3, pp. 364-369, 2008.
[35] L. Evangelista and J. de Brito, "Mechanical behaviour of concrete made with fine recycled concrete aggregates," *Cement and concrete composites,* vol. 29, no. 5, pp. 397-401, 2007.
[36] K. K. Sagoe-Crentsil, T. Brown, and A. H. Taylor, "Performance of concrete made with commercially produced coarse recycled concrete aggregate," *Cement and concrete research,* vol. 31, no. 5, pp. 707-712, 2001.
[37] V. Ducman and L. Korat, "Characterization of geopolymer fly-ash based foams obtained with the addition of Al powder or H2O2 as foaming agents," *Materials characterization,* vol. 113, pp. 207-213, 2016.
[38] S. Ismail and M. Ramli, "Engineering properties of treated recycled concrete aggregate (RCA) for structural applications," *Construction and Building Materials,* vol. 44, pp. 464-476, 2013.
[39] V. W. Y. Tam, X. F. Gaob, and C. M. Tam, "Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach," *Cement and Concrete Research,* vol. 35, 2005.
[40] M. Alexander and S. Mindess, *Aggregates in concrete*. CRC Press, 2014.
[41] A. Katz, "Treatment for the improvement of recycled aggregate," *Journal of material in civil engineering,* vol. 16, 2004.
[42] M. S. De Juan and P. A. Gutiérrez, "Study on the influence of attached mortar content on the properties of recycled concrete aggregate," *Construction and building materials,* vol. 23, no. 2, pp. 872-877, 2009.
[43] C. Shi, Y. Li, J. Zhang, W. Li, L. Chong, and Z. Xie, "Performance enhancement of recycled concrete aggregate–a review," *Journal of Cleaner Production,* vol. 112, pp. 466-472, 2016.
[44] V. Tam, F. Sartipi, and K. N.Le, "Gaps between supply and demand of recycled aggregate: Sydney metropolitan case study," presented at the CRIOCM 2018, China, Guiyang, 2018.