A Concise Systematic Literature Review for Cement Manufacturing Decarbonization Options in South Africa

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Abstract

Literature reviews are important systematic ways of gathering relevant information on subject of interest. The emissions of carbon dioxide as one of the greenhouse gases during cement manufacturing impacts the environment through change in climate which results in temperature rises. Globally, the cement industry is under pressure to implement practical measures for reduction of carbon dioxide emissions and achieving reduced emissions by 2030 and carbon emission neutrality by 2050. This means that mitigation measures need to be developed for reduction of carbon dioxide emissions for every ton of cement produced. The manufacturing strategies available includes decarbonization of heat (for kiln burning), decarbonization through Supplementary Cementitious Materials, limestone calcined clay cement (LC^3) production and carbon capture storage and utilization. The implementation of this strategies can be bring about strategic value by assisting in generating a framework for cement manufacturing with reduced carbon dioxide emissions and for long term, reducing unemployment rate. These strategies can be implemented within South African industry having noted that majority of cement manufacturers with integrated plants needs innovative ways of reducing emissions.

Keywords
Gases, emissions, climate, neutrality and framework.

1. Introduction

Globally, climate change is an ongoing concern as contributed by industrial activities such as in the manufacturing of cement, steel and electricity from coal. This is because change in climate result with high ambient temperatures which ultimately leads to alterations of rain patterns, high rates of evaporation and droughts. The cement industry contributes to change in climate through the release of flue gases that constitute oxides of Sulphur, Nitrogen and mostly, carbon during limestone calcination process in a kiln.

This means that as the production output of cement increases, the amount of CO_2 emitted per ton ton of cement also increases based on its ratio.

The industrial sector contributes a considerable share of emissions of greenhouse gases globally as noted between 1990 to 2014 as the emission increased by seventy per cent on average or 2.2 per annum on average (de Pee et al. 2018). Furthermore, the global production of cement was projected to grow by five times more than the levels in year 1990 which is about 5 billion tones worldwide. When 1 ton of cement is produced, it emits approximately 0.89 tons of CO_2 per ton of the cementitious material. The cement sector contributes approximately 5% of man-made emissions of carbon dioxide globally, meanwhile the in South Africa it contributes less than 1% in terms of the SA National Inventory gazetted (Association of Cementitious Material Producer 2011).

The emissions within the cement manufacturing process are contributed as 50% due to production of clinker (limestone calcination in kiln), 40% due to usage of electricity and 10% due to transportation (Association of Cementitious Material Producer 2011).

The cement market in South African is concentrated with 71% of production capacity supplied to market by six major producers outlined on Table 1.

Table 1. South Africa's largest cement companies with their installed capacity as of 2014

Cement producer	**Integrated capacity (Mt/annum)**
Pretoria Portland Cement (PPC)	4.75
NPC-Cimpor	3.15
Sephaku Cement	2.50
AfriSam	2.05
Lafarge Africa	2.00
Mamba Cement	1.00
Other	6.25
Total	21.70

Source: Arp et al. (2018)

Generally, demand for cement is cyclical and dependent on the growth of economy and likewise, South Africa's cement market is strongly linked to the performance of macroeconomics and economic cycle (Arp et al. 2018). Paris Agreement commitment target indicates that the cement sector globally must reduce the emissions of greenhouse gas to about 1.7Gt by year 2050. That is, 0.4Gt reduction from the emission levels of 2.1Gt released in year 2010 (International Energy Agency (IEA) 2014). There is more work required for the reduction of CO_2 due to annual greenhouse gas emissions from the production of cement maximized by 27% which was from 3.3MtCO_2e to 4.2MtCO_2e between year 2000 and 2010. This signify that mitigation potential yearly requires to be 1.26MtCO_2e for the purpose of resulting with 12% emission reduction from the whole sector. The mitigation potential is anticipated to reach high level of 3.65MtCO_2e by year 2030 and to over 15MtCO_2e by year 2050 (Department of Environmental Affairs (DEA) 2014). Furthermore, emission intensity for most cement in South Africa is between 400kg/t and 625kg/t (Olivier 2016). There is indeed a room for improvement to reach global average emissions intensity which was about 368kg/t during year 2010 (Republic of South Africa 2014; Andrew 2019).

Scrivener (2014) further indicated on Figure 1 cement demand in countries that are developing which has forecasted to increase relative to other developed countries such as India and China until year 2050.

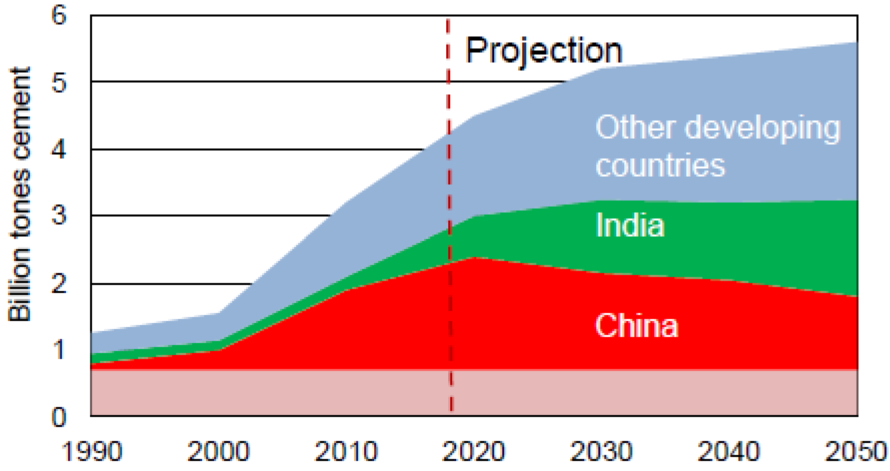


Figure 1. Cement production forecast until year 2050
Source: Scrivener (2014)

The huge cement production has impact on aspect of environment, social and economics (Klemm et al.2019). As the demand increases, the emission of carbon dioxide will continue to increase and cement industry needs to find innovative strategies to reduce the emissions.

Majority of integrated cement plants in South Africa have been operating for more than 50 years, using similar type of plant design thus with minimal innovation on equipment or reengineering on factories.

Meanwhile on the other side, the new market entrants in the cement industry has the modern cement plants with energy efficiencies that are higher and the scope of reducing the emissions of carbon dioxide by further improvements of efficiencies is small (Barker et al. 2009) Sustainable Development Goal (SDG) 12 and 13 calls for responsible consumption and production, and climate action respectively (Marwala 2022). The industry is focusing on net zero carbon dioxide emission by the year 2050 in order to alleviate the pressure the emissions have on climate change. The global temperature increase is targeted to be prevented from rising by 2 °C, which then ideally limits the average temperature increase to 1.5 °C. These then push the industry in general to reduce the global GHG emission by 80 to 95 per cent during the year 2050 in comparison to emission levels of 1990 (de Pee et al. 2018). The results of change in climate affects the activities of economy and causes threat in humanity.

The economic status of South Africa is under pressure post COVID-19 pandemic with unemployment rate.
Statistics South Africa (2022) indicated that rate of unemployment in South Africa is 35.3% during the fourth quarter of 2021 and eradication of poverty, reduction of inequality, economic growth by 5.4% on average and reduction of by 6% on rate of unemployment by year 2030 is the target in South Africa. To attain these goals, Education, Training, and Innovation are critical factors to be considered (Statistics SA 2014). The implementation of the decarbonization strategies within the cement manufacturing industry will assist in job creation based on the projects that can be rolled out and this can assist in reduction of level of unemployment caused by COVID- 19 pandemic.

1.1 Objectives

The objective of the study was to identify applicable manufacturing strategies within South Africa's cement industry aimed at reduction of carbon dioxide emissions through systematic literature review.

2. Methodology

The following method of contacting the concise literature review of the manufacturing strategies within cement industry was followed to gather data relevant to the topic at hand as outlined by Figure 2.

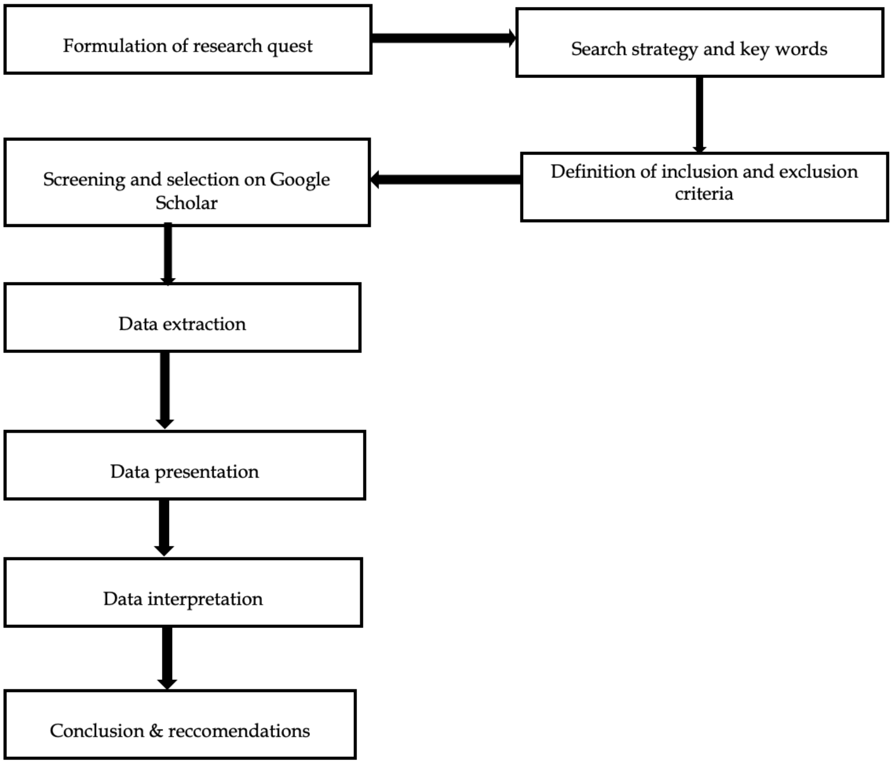


Figure 2. Literature review procedure

3. Concise literature review results

There are various strategies that can be employed in a cement manufacturing plant for the purpose of reducing CO_2 emissions. These strategies include decarbonization of heat (For kiln burning), Decarbonization through SCMs and CO_2 capture storage and utilization.

3.1. Decarbonization of heat (For kiln burning)

3.1.1. Utilization of fuels

Heat generation for kiln firing is sourced from combustion of fuels such as residue oil and solvents, wood that is contaminated and process waste from wood, used tyres and rubber waste, plastic waste, domestic waste, and sludge from sewage (Zieri and Ismail 2018). The combustion of fossil fuels and limestone calcination emits CO_2 which is defined as the emission that is direct to environment. Examples of emissions of CO_2 that are indirect result from transportation of raw materials and generation of consumption of electricity due to electrical motors and facilities. Thus 90% of CO_2 emissions are direct and 10% is indirect emissions (Mikulčić 2013).

In addition to calcination of limestone which is the major raw material in cement raw meal, magnesium carbonate ($MgCO_3$) is also another material that undergoes calcination reaction at kiln temperatures above 900℃ and directly emits CO_2 (Gao et al. 2015). The following chemical reaction equation further defines this heating process:
$MgCO_{3\,(s)} \rightarrow MgO_{(s)} + CO_2\uparrow_{(g)}$

Empirical and comparative studies have been conducted for valuable sources on calculation of production of cement and its associated emissions of CO_2. The IPCC method indicates factor of emission which is 510 kg CO_2 /ton clinker which is a method based on $CaCO_3$ calcination excluding MgO emissions.

CSI clinker-based method entails process emission on a carbonate mineral-based technique and technique of clinker composition with CSI clinker-based method being the same as the IPCC method. Another method is CBMA method which provides CO_2 calculations for producers who has alternative raw materials and alternative fuels in their operations. The clinker composition with respect to CaO and MgO is the factors that base the CBMA method instead of utilization of carbonate content in raw material (Gao et al. 2015).

The burning of fuel during calcination in the kiln results with additional CO_2 being emitted. Operating way, fuel used and carbon content ratio influences the emissions of CO_2 (Gao et al. 2015). The consumption of fuel, lower heating values (LHV) and the correspondent CO_2 factors of emission are used as an approach for the calculation of CO_2 from the common fuels used in the cement industry (Ke et al. 2012). By making use of $CaCO_3$ as a source of CaO and MgO and their material ratio for the raw meal design, CO_2 content in the raw meal can be calculated by using the following equation (Gao et al. 2015):

$$Ra_{CO2} = \Sigma(Rca_i \times r_i \times \frac{44}{56} + Rmg_i \times r_i \times \frac{44}{56})\ (i = 1,2,3\ldots)$$

Where Ra_{CO2} stands for raw meal's CO_2 content in %; Rcai, Rmgi represents the content of $CaCO_3$ and $MgCO_3$ in the raw material I in % ; r_i represents raw material i proportions in the raw meal in % ; the 44/56, 44/40 represents the content of CO_2 in the $CaCO_3$ and $MgCO_3$; the i = 1,2,3… represents the species of carbonate material.

Plastic waste is an alternative raw material with low carbon content, potential to reduce emissions of carbon by 1 ton per ton of replacement of coal feed to kiln system. Plastic waste has also good calorific value in range of 29 to 40 MJ/kg. However, higher chlorine content is experienced which can affect kiln system operation (Zieri and Ismail 2018). Replacements of fossil fuels with tyres possess a potential of 9% carbon emission reduction. However, care should be taken such that amount of fossil fuel reduction should be kept at maximum of 30% as higher replacement than this level has a potential risk of higher zinc content in the kiln and alters the cement chemistry (Chatziara et al. 2014). Other risk associated with high percentage usage of tyres as fuel feed to kilns include high costs due to manual handling, however, to offset this, shredding mechanism can be employed which might incur costs of setup (Kaddatz et al. 2103), but certainly the Return on Investment (RIO) outweighs the CO_2 emission costs.

3.1.2. Decarbonization of heat through reduction of thermal losses

During cement manufacturing, air leakages can occur resulting with heat loses from the calciner and kiln shell. A loss of about 20% from the kiln system can result with release of 8% CO_2 to the environment. Proper monitoring and maintenance of the kiln system have to be taken into account as preventative measures (Emad et al. 2013).

Waste heat recovery system (WHRSG) is one of the potential alterations that can be implemented in a cement factory in order to recover heat from flue gases and hot air streams from fuel combustions thus producing steam for electricity generation. This can save up to 10% energy and reduction of CO_2 emissions. Furthermore, combination of WHRSG and secondary kiln shell can assist in reduction of 5.30 MW of thermal energy and 14.10% of harmful gases losses (Emad et al. 2013).

A simple Rakine cycle which comprise of steam generator, turbine, condenser, and pump can be explored through implementation in a cement factory for electricity generation (Hejrati et al. 2016). Figure 3 shows the cement production line and combination of heat and power (CHP).

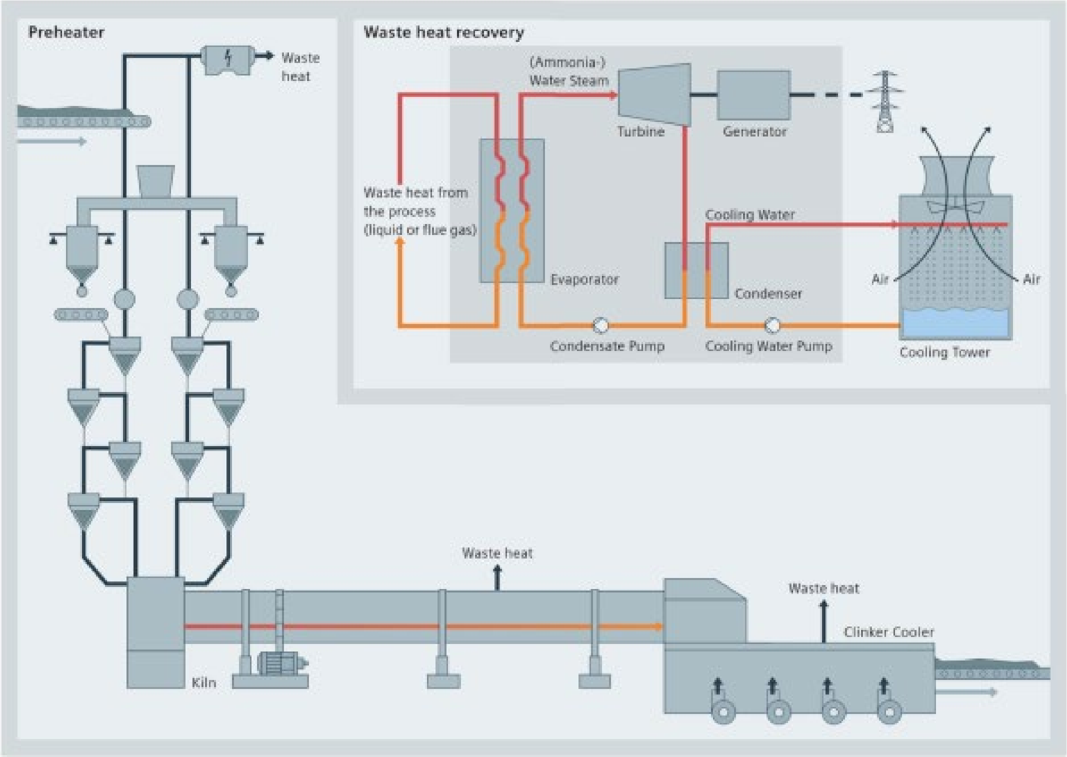


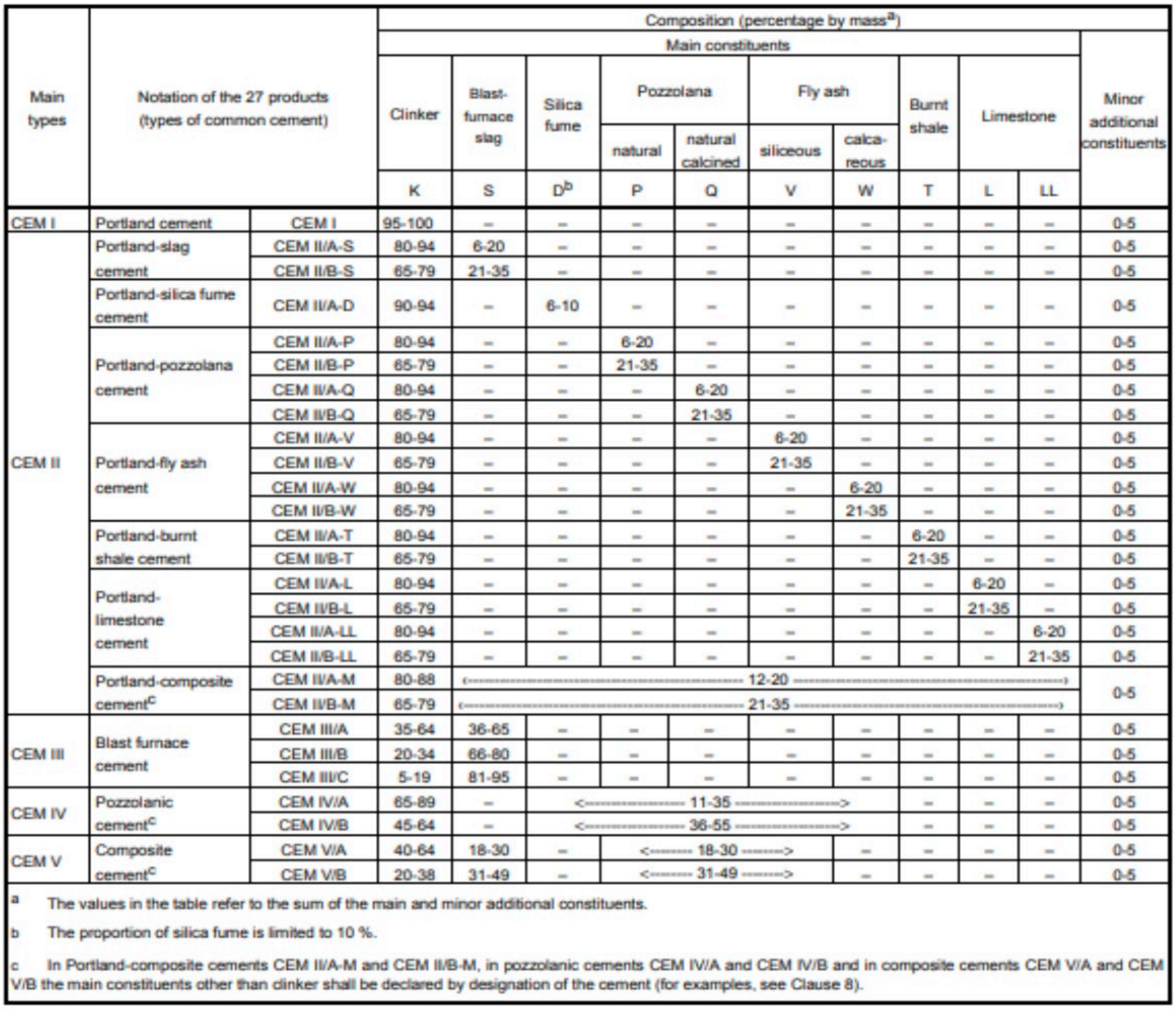
Figure 3. Production line for cement and combination of heat and power (CHP) cycle
Source: Hejrati et al. (2016)

3.1.3. Decarbonization through supplementary cementitious materials

Supplementary Cementitious Materials (SCMs) are used mostly for the purpose of improvement in Portland cement based materials and reduction of impact on environment sustainably (Miller 2018; Lothenbach et al. 2011). These materials include both pozzolans and hydraulic materials such as coal fly ash, ground granulated blast furnace slag (GGBS), silica fume and shale (Klemm et al. 2019).

Although customer expectations have grown in the past, with demand for more durable, low labour and service intensive materials at a price that is competitive, the use SCMs in manufacturing blended cement also offer this competitive edge. However, sustainability on availability of the SCMs, for example, coal fly is recovered from coal combustion product is of a concern (Klemm et al. 2019).

Thus utilization of SCMs is another cement manufacturing strategy for CO_2 emission reduction (Dhas et al. 2021). This is due to different class of cement can be made through using less amount of clinker and substituting with SCMs as guided by the South African National Standards (SANS) 50197-1 for composition, specifications and conformity as shown on Figure 4 which outlines the 27 products in the common cements family.



Main types	Notation of the 27 products (types of common cement)		Composition (percentage by mass^{a})										
			Main constituents										Minor additional constituents
			Clinker	Blast-furnace slag	Silica fume	Pozzolana		Fly ash		Burnt shale	Limestone		
						natural	natural calcined	siliceous	calcareous				
			K	S	D^{b}	P	Q	V	W	T	L	LL	
CEM I	Portland cement	CEM I	95-100	–	–	–	–	–	–	–	–	–	0-5
CEM II	Portland-slag cement	CEM II/A-S	80-94	6-20	–	–	–	–	–	–	–	–	0-5
		CEM II/B-S	65-79	21-35	–	–	–	–	–	–	–	–	0-5
	Portland-silica fume cement	CEM II/A-D	90-94	–	6-10	–	–	–	–	–	–	–	0-5
	Portland-pozzolana cement	CEM II/A-P	80-94	–	–	6-20	–	–	–	–	–	–	0-5
		CEM II/B-P	65-79	–	–	21-35	–	–	–	–	–	–	0-5
		CEM II/A-Q	80-94	–	–	–	6-20	–	–	–	–	–	0-5
		CEM II/B-Q	65-79	–	–	–	21-35	–	–	–	–	–	0-5
	Portland-fly ash cement	CEM II/A-V	80-94	–	–	–	–	6-20	–	–	–	–	0-5
		CEM II/B-V	65-79	–	–	–	–	21-35	–	–	–	–	0-5
		CEM II/A-W	80-94	–	–	–	–	–	6-20	–	–	–	0-5
		CEM II/B-W	65-79	–	–	–	–	–	21-35	–	–	–	0-5
	Portland-burnt shale cement	CEM II/A-T	80-94	–	–	–	–	–	–	6-20	–	–	0-5
		CEM II/B-T	65-79	–	–	–	–	–	–	21-35	–	–	0-5
	Portland-limestone cement	CEM II/A-L	80-94	–	–	–	–	–	–	–	6-20	–	0-5
		CEM II/B-L	65-79	–	–	–	–	–	–	–	21-35	–	0-5
		CEM II/A-LL	80-94	–	–	–	–	–	–	–	–	6-20	0-5
		CEM II/B-LL	65-79	–	–	–	–	–	–	–	–	21-35	0-5
	Portland-composite cement^{c}	CEM II/A-M	80-88	<—— 12-20 ——>									0-5
		CEM II/B-M	65-79	<—— 21-35 ——>									
CEM III	Blast furnace cement	CEM III/A	35-64	36-65	–	–	–	–	–	–	–	–	0-5
		CEM III/B	20-34	66-80	–	–	–	–	–	–	–	–	0-5
		CEM III/C	5-19	81-95	–	–	–	–	–	–	–	–	0-5
CEM IV	Pozzolanic cement^{c}	CEM IV/A	65-89	–	<—— 11-35 ——>					–	–	–	0-5
		CEM IV/B	45-64	–	<—— 36-55 ——>					–	–	–	0-5
CEM V	Composite cement^{c}	CEM V/A	40-64	18-30	–	<—— 18-30 ——>			–	–	–	–	0-5
		CEM V/B	20-38	31-49	–	<—— 31-49 ——>			–	–	–	–	0-5

[a] The values in the table refer to the sum of the main and minor additional constituents.

[b] The proportion of silica fume is limited to 10 %.

[c] In Portland-composite cements CEM II/A-M and CEM II/B-M, in pozzolanic cements CEM IV/A and CEM IV/B and in composite cements CEM V/A and CEM V/B the main constituents other than clinker shall be declared by designation of the cement (for examples, see Clause 8).

Figure 4. The 27 products in the family of common cements

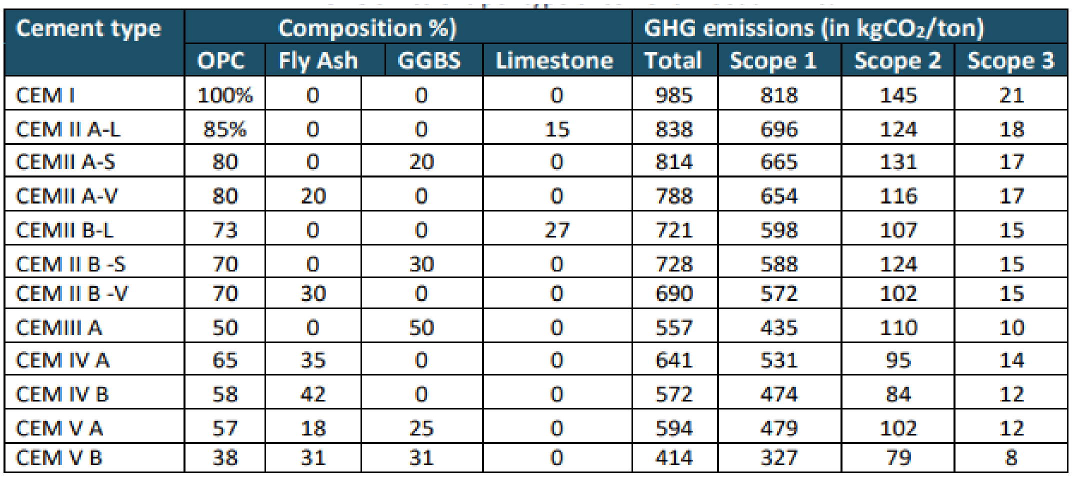
Source: South African National Standards (2013)

There is potential reduction of about 3.7 GJ and 0.83 tones of CO_2 through the deployment of SCMs as an alternative raw material for cement manufacturing (Dhas et al. 2021).

For example, the manufacturing of Ordinary Portland Cement (CEM I) contains > 90% clinker content and the remaining being gypsum. By making use of SCM,s clinker reduction can be up to a ratio of clinker to cement of 50% without varying the properties of cement being produced. In this way, the cement that has low clinker to cement ratio yields less emissions of CO_2 when manufactured as the CO_2 footprint of the SCMs as clinker substitute is low or even zero (Dhas et al. 2021).

Clinker factor reduction through utilization of SCMs also offers environmental benefit which is double impact as the materials are not occupying spaces such at landfills, but they are used in manufacturing cement (Millera et al. 2018).

Figure 5 indicates the Greenhouse gas emissions per cement type in South Africa due to the use of SCMs as reported by InEnergy (2010).



Cement type	Composition %)				GHG emissions (in kgCO_2/ton)			
	OPC	Fly Ash	GGBS	Limestone	Total	Scope 1	Scope 2	Scope 3
CEM I	100%	0	0	0	985	818	145	21
CEM II A-L	85%	0	0	15	838	696	124	18
CEMII A-S	80	0	20	0	814	665	131	17
CEMII A-V	80	20	0	0	788	654	116	17
CEMII B-L	73	0	0	27	721	598	107	15
CEM II B -S	70	0	30	0	728	588	124	15
CEM II B -V	70	30	0	0	690	572	102	15
CEMIII A	50	0	50	0	557	435	110	10
CEM IV A	65	35	0	0	641	531	95	14
CEM IV B	58	42	0	0	572	474	84	12
CEM V A	57	18	25	0	594	479	102	12
CEM V B	38	31	31	0	414	327	79	8

Figure 5. Greenhouse gas emissions per cement type in South Africa

Source: InEnergy (2010)

3.1.4. CO_2 capture storage

The CO_2 produced during clinker production can be captured and stored for commercial purposes such as in other industrial processes (Benhelal et al. 2021). Pre-combustion process, post-combustion process and oxyfuel combustion are the available technologies for carbon capture. The application of oxy-fuel firing and post-combustion are the attractive technologies in the cement plants to also implement. Post-combustion involves the separation and capturing of CO_2 as it is being emitted through the exhaust gases of the process of combustion by absorbing it in a solvent (Energy Transition Commission 2018). The absorption technology of CO_2 is chemical reaction based where the CO_2 reacts with the chemical solvent, where in most cases, the mode of separation applied is by amine from a natural gas purification process (Benhelal et al. 2021).

Meanwhile, oxyfuel combustion process involves the burning of fuel by using oxygen rather than air, the results is a stream of CO_2 that is purer which is easier to capture. The full development of Oxyfuel carbon capture and storage has efficiency of 95% CO_2 (Energy Transition Commission 2018).

However, the post combustion technology is categorized further into chemical absorption, calcium looping, physical adsorption-fuel combustion, and direct separation (Benhelal et al. 2021; Dhas et al. 2021). Calcium looping technology is also one of the reliable methods which involves the reaction of CO_2 with CaO thereby producing $CaCO_3$ at 650 °C in a reactor. Regeneration of the solid sorbent is achieved through the decomposition of $CaCO_3$ in a second reactor which is operated about 900°C. The calcium-based sorbent section can be used for clinker production (Bosoaga et al. 2009).

Gusca et al. (2010) modelled the calculation of capture, compression and pumping costs, transportation cost and calculation of injection and storage costs by making use of the following equations:
Calculation of capture, compression & pumping costs:

$C_e = f(C_{capexf}{}^{,I}O\&M,f^{,CFR,PF,FCF,P,h,C}k)$

Where C_e is the electricity cost, Euro/kWh; $I_{O\&M,v}$ is the variable O&M costs, Euro; $C_{capex,f}$ is fixed ; investment costs, Euro; CRF is the capital recovery factor; FCF is the factor for fuel conversion, kJ/kWh; PF is the factor of energy plant power , %; P is the installed capacity, MW; h is the operation hours, h; Ck is the fuel price, Euro/kJ.
Calculation of transport costs:

$C_{(TR)} = \frac{MIN\ \text{vMAX(Ctr1,Ctr2,Ctr3,Ctr4,Ctr4,Ctr5,Ctr5)}}{10^6}$

Where $C_{(TR)}$ is the CO_2 transport cost, million Euro/year; MIN ∨ MAX – range of minimal or maximal cost values for the CO2 transport; Ctr1 – the CO_2 transport cost acc. to McCollum model Euro/year
Calculation of injection and storage costs:

$$C_{(st)} = \frac{MIN \vee \mathrm{MAX(Cst1,Cst2)}}{10^6}$$

Where $C_{(st)}$ is the injection and storage costs, million Euro/year; MIN ∨ MAX is the range of minimal or maximal cost values for the CO_2 injection and storage; Cst.1 – the CO_2 injection and storage costs acc. to McCollum model, Euro/year McCoy (2008), Euro/year.

Dhas et al. (2021) further summarized the decarbonization options for the cement industry as outlined on Figure 6.

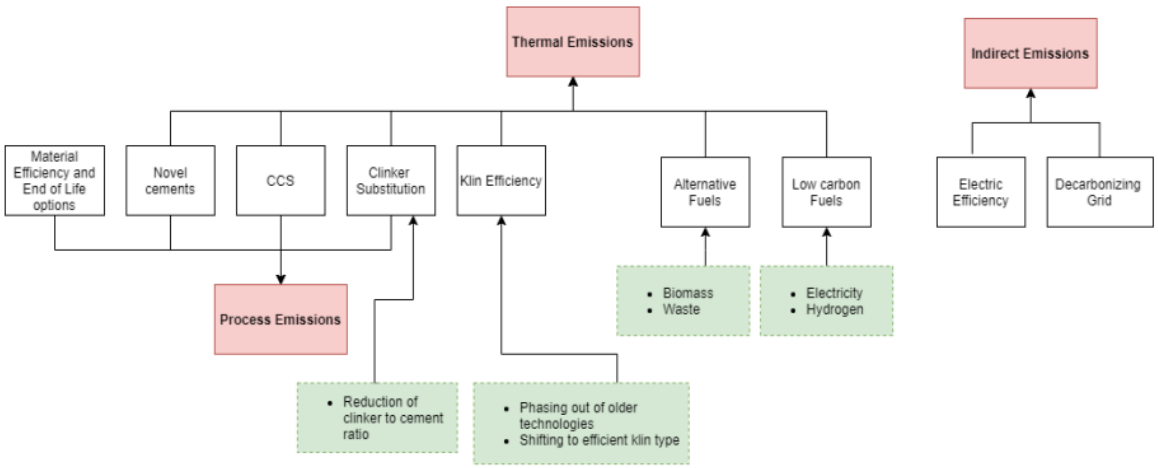


Figure 6. Options for decarbonization for the cement industry

Source: Dhas et al. (2021)

From the year 2025, the plan is to support the activities around Carbon Capture and Storage (CCS) in South Africa and to inform the implementation of commercial CCS deployment (over 1,000,000tCO_2/year) (Beck et al. 2013).

3.1.4. Limestone calcined clay cement (LC^3)

Limestone calcined clay cement is one of the cementitious binders with a potential of reduced CO_2 emission as less clinker is utilized and it is a ternary system of cements that are blended. There has been establishments as a function of utilization of Portland cement, calcined clay, and limestone. This cement type can also be manufactured by using low quality-overburden materials that are usually considered as waste from the traditional cement production such as low-grade clay and limestone constituting highly in dolomite. Furthermore, the temperature of clinkerization is taking place at half the temperature requirement in the kiln operation of traditional clinker. The limestone is then not calcined, thus not contributing to CO_2 emissions. The addition of extra alumina through calcined clay and its reaction with calcium carbonate from limestone enhances further reactivity to form alumina phases (Antoni et al. 2012).

If the ratio is kept at 2:1 for calcined clay/limestone , this can futher substitute clinker utillization by 15% in the case of blended cements which has a limit of 35% on pozzolan, which ultimately further contributes to addition of a total clinker substituation of 50%. The reactivity of this cement type at early ages is much better than that of traditional pozzolanic cements due to the rigorous reaction of alumina phase particularly in the first 7 days (Díaz et al. 2017).

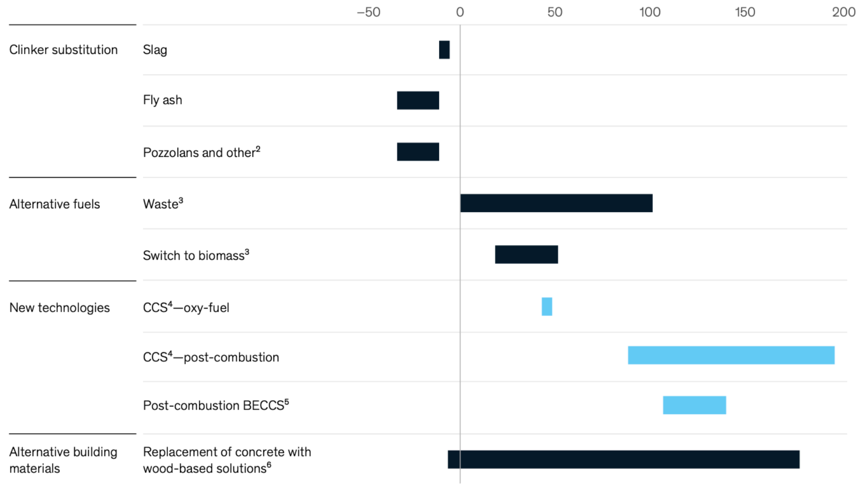
Clay calcination requires temperatures of around 700°C to 850°C which is half the calcination temperature requirement of limestone for production of clinker (Scrivener, 2014; Alujas et al. 2015; Fernandez 2011). Stationery and flash calcination are the two technological options for clay calcination (Díaz et al. 2017). The calcination through stationary option occurs in a rotary calciner, similar to the kilns for clinker production with wet process kiln that is old and refurbished to be a clay calciner (Initiative 2009). Flash calcination process occurs in a flash calciner and the feed should be dried and ground to a fine powder. The temperature requirement from hot gas stream is around 800°C to 900°C and less residence time requirement. Furthermore, this option allows for cycles of heat recovery implementation which assist in high efficiency potential with rate of power consumption of 2211MJ/t of metakaolin flash (Nicolas 2011).

Furthermore, the two technologies contribute differently with respect to CO_2 emissions to environment and this is directly related to efficiencies of energies on each technology. Table 2 indicates the calculations around consumption of energy during calcination of clay and the associated CO_2 thereof (Vizcaíno-Andrés et al. 2015).

Table 2. Energy consumption and carbon dioxide emission as a function of clay calcination technologies

Technology	**Energy (MJ)**	**Emissions (kgCO₂)**
Kiln (Industrial Trial)	4234	393
Refurbished kiln	3088	249
Flash calciner	2734	196

Cement decarbonization requires investments at large scale in technologies in which both emissions from fuel and other process related activities can be reduced. Furthermore, technologies such as carbon capture, utilization & storage and carbon cured concrete can require up to 10 years , thus for such examples of technologies needs urgent investment as early as possible to help in alleviating the pressure (Czigler et al. 2020). Figure 7 highlights the estimated abatement cost curves of various investments at large scales for reduction of CO_2 as a function of assumptions on future costs, prices of CO_2 and abatement volumes (Czigler et al. 2020).



[1] Globally assumed cost, can vary locally.
[2] Limestone, kaolin, and other.
[3] Depending on availability, quality of material, and cost to dispose.
[4] Carbon capture and storage.
[5] Bioenergy with carbon capture and storage.
[6] Includes abatement coming from displacement from steel.

Figure 7. The range of abatement cost of decarbonization options in cement industry, $/t$CO_2$

Source: Czigler et al. (2020)

4. Discussion of findings and results

The outcome of the literature indicated that there are available manufacturing strategies that can be deployed within the South African industry for decarbonization which included and not limited to decarbonization of heat used for firing of kiln, decarbonization through utilization of supplementary cementitious materials and capture and storage.

The utilization of alternative fuels for reduction of carbon dioxide can only assist to a certain extend in manufacturing cement due to their potential of affecting the chemistry of the cement being manufactured, thus this is the limitation potential of alternative fuels.

Reduction of carbon dioxide through heat reduction of thermal losses on flue gases also assist in reducing the amount emissions of the greenhouse instantly to the environment, however after enough heat is being recovered from the flue gases are being emitted to environment. Reduction of carbon dioxide through usage of supplementary cementitious materials in accordance with SANS 50197-1 2013 also assist in reducing carbon dioxide as clinker usage is less and is utilized for production of final cement product by making use of ground granulated blast furnace slag and coal fly ash in most South African manufacturers. Also, Limestone Calcined Clay Cement (LC^3) production has a potential of less clinker utilization though use of calcined clay which required heat that is about 50% of the heat required for clinker production and this subsequently reduces carbon dioxide being emitted. Carbon capture, storage and utilization seems to be a promising option; however, it requires hectares of land for underground storage. For long term, this option can result in employment opportunities when implemented which can help to reduce the unemployment rate in South Africa.

5. Conclusion

The use of alternative fuels has a potential of reducing waste from other industries that are intended to be send to landfills, for instance, hydrocarbon sludge and tyres that have reached end of use, while heat recovery from flue gas assist in reducing heat losses and emission directly to the environment and meanwhile the utilization of SMCs can assist with clinker factor reduction to a certain extend thereby reducing use of clinker which subsequently reduces amount of clinker production which is associated with carbon dioxide emissions.

Carbon capture, storage and utilization also requires hectares of land and other carbon dioxide conversion technologies to various useful forms. Most Portland cement manufacturers that have integrated plants are situated in North-West province of South Africa where land is limited, making it challenging to adopt this option.

6. Recommendations

Combination of these strategies within a cement plant can generate a framework which can be teste to reduce carbon dioxide emissions during cement production and subsequently converted into a patented model.

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