Some Studies on the Conversion of Carbon Dioxide into Useful Chemical from the Cement Industry

Dr. Kanjan Upadhyay[1] Deepak Prajapati[2]
[1]Professor [2]M. Tech Scholar
[1,2]Department of Chemical Engineering
[1,2]Ujjain Engineering College, Ujjain, M.P., India

Abstract— Global warming is one of the crucial issues of 21st century and it is the result of environmental degradation. The gradual increase of carbon dioxide due to natural and man-made activities have resulted in number of obstacles in the natural cycles of ecosystems. Carbon dioxide reduction and its conversion into other byproduct is the need of this century. Conversion of Carbon dioxide into useful product can increase the feasibility of the product. This paper aims to review the past work that has been explored to reduce the CO_2 emissions in the atmosphere and alternative methods to increase the economic value of the product formed. The main focus will be on CO_2 emissions coming from the cement industry.

Keywords: Global Warming, Cement Industry, CO_2 Conversion, CO_2 Mitigation, CCS, CCU, Climate Change

I. INTRODUCTION

Since mid of the 20th century energy and environment have been classified as the top of mankind challenges. This is due to the fact that manmade activities gradually increasing the CO_2 emissions, which is a big threat to climate change. The outcome of increase in CO_2 emissions globally is global warming. In the starting of the industrial revolution global atmosphere contained 278 ppm (Parts per million) of CO_2, and now after more than two and half centuries of CO_2 emissions, the figure is approximately 419 ppm (the latest measurement, Feb 2022). If the amount of CO_2 emissions continue at this rate, by 2060 it will have passed 560 ppm, which would be more than double the level of pre industrial times.

Burning of fossil fuels like coal, natural gas and oil contribute approximately 87% of human made CO_2 emissions, remaining is the result of deforestation and other land use changes (9%), as well as some industrial processes such as cement manufacturing (4%).

Cement is an important building construction material. For the production of concrete, it is much needed part. Concrete is the combination of Sand, crushed stone, gravel and cement. The production of Cement is directly related to the construction activities. As the worldwide need of Cement as a construction material is increasing and also the main raw material, lime stone is being readily available, cement is being produced in almost all the countries mainly in China, India and the United States.

Production process of Cement is highly energy intensive. Around 5% of total global energy consumption is estimated from the cement industry. The cement industry is major source of CO_2 emissions because of its dominant use of carbon intensive fuels such as coal and lime stone in clinker making. In Calcination process 1 Kg of $CaCO_3$ produces 440 grams of CO_2. Thus, this industry can be seen as a major contributor in the CO_2 emissions and it requires keen attention in the assessment of ways to carbon emissions reduction.

II. LITERATURE REVIEW

Cement industry emits on an average 4 billion tons of carbon each year, mostly in the form of Carbon dioxide. Many research works are in progress to mitigate the emissions of Carbon dioxide from the cement industry. The area of study includes selecting alternate raw materials, blending of cement, using some different processes, incorporating modern technologies etc. Some of the works focuses on the conversion of carbon dioxide into useful chemical also.

In the year (2021), Paolo P. et al studied synthesis of cyclic carbonate from CO_2. The outline for the study includes cycloaddition of CO_2 to epoxides. In this study, it was found that cyclic carbonates that prepared from CO_2 are sustainable alternative to toxic compounds, used in the synthesis of polymers such as polycarbonate, polyurethanes.

In the year (2020), F.N.Costa et al studied reduction in CO2 emissions during production of cement, with partial replacement of traditional raw materials by civil construction waste (CCW). The parameter of study was that traditional raw material Limestone is the main source of CO_2 emissions in clinker production, thus it was replaced with CCW. In this study, it was observed that emissions of CO_2 was reduced up to 8.1% by partially substituting the mixture of limestone-Clay, as CCW can be considered as a Calcium source in the raw mixture.

In the year (2020), S.E.Lyumibov et al studied a simple synthesis of ethylene carbonate. The parameter of the study was synthesis of ethylene carbonate from 2-chloroethanol using silica gel as a catalyst.

It was found that a simple, economic and environment friendly process using 2-chloroethanol, CO_2 as raw material and K_2CO_3 as base while silica gel act as catalyst can be utilized to produce ethylene carbonate, which is highly valuable. The process requires mild reaction conditions. The industrial applicability of this process is still under testing phase.

In the year (2020), Emad Benhelal et al studied Challenges against CO_2 abetment strategies in cement industry. The outline for the study includes studying about different strategies to mitigate CO_2 from cement plant and to identify the challenges and find out solutions for them. It was noted that the strategies were mainly divided into four groups of CCUS (carbon capture usage and storage), energy saving, utilizing ARMF (Alternative raw material and fuels) and clinker substitution. In that CCUS is one of the technologies that has great potential to mitigate CO_2 emissions from cement industry. Although, due to some technical, Financial and policy barriers it has not implemented at large scale.

In the year (2019), Qian zhu studied Developments on CO_2 utilization technologies. The outline for the study includes different kind of CO_2 conversion such as Electrochemical, Photocatalytic, Catalytic and Bioconversion. As well as it included copolymerization and mineral carbonation. It was observed that a number of catalysts have demonstrated the ability by converting CO_2 into various chemicals with high efficiency, selectivity and yield. Still a large scope of other materials needs to be investigated so as to develop technologically and economically viable process for conversion of CO_2.

In the year (2019), John Kilne et al studied CO_2 capture from cement manufacture and reuse in concrete. The outline for the study includes a technology which utilizes CO_2 in concrete so as to improve its properties. This process was used in the United States and Canada by more than 50 ready mix and concrete product sites. It was found that currently these companies are using commercial food grade CO_2 which is of high cost. Since cement industry itself produces large amount of CO_2, ways to use this CO_2 in some products needs to be investigated and employed.

In the year (2019), Atul A.Pawar et al studied about Greener synthesis of dimethyl carbonate from carbon dioxide and methanol using a tunable iconic liquid catalyst. The study involves synthesize efficient catalyst for the production of profitable fuel additives, as iconic liquid reversibly captures more CO_2 that is more efficient for mass transport of methanol at optimum reaction conditions which improve the Dimethyl carbonate yield in the process. Final results of this study showed that environment friendly iconic liquid can be used as substitute for metal oxides and as well as to minimize waste CO_2.

In the year (2019), Chaofeng Liang et al studied the utilization of CO_2 curing to enhance the properties of recycled aggregate and prepared concrete. The parameters for the study include properties of carbonated recycled aggregate (CRA), workability, mechanical properties and durability performance of concrete with CRA. It was observed that carbonation treatment of recycled aggregate absorbed a certain amount of CO_2 gas produced by cement and construction industry and also it was noted that concentration and pressure of CO_2, relative humidity and curing time all had the significant impact on the properties of CRA.

In the year (2018), Jihoon Kim et al in South Korea analyzed the process of proportioning for the production of environmentally-friendly recycled cement with the usage of inorganic construction waste.

It was found that various varieties of Portland cement can be produced by mixing inorganic construction waste, in which limestone content should be more than 85 weight%, in suitable proportion. This can be seen as an effort to make cement industry eco-friendly as well as to reduce environmental load.

In the year (2018), Esmaeil Koohestanian et al studied the process for CO2 capture from the flue gases to produce Urea and Ammonia. The parameter of the study was Oxy-fuel combustion of flue gases. In this research, it was found that if the appropriate method used for the utilization of CO2 then it will not only reduce environmental risks, but large quantity of urea can be produced by annual CO_2 removal.

In the year (2017), Sean Monkan et al studied carbon dioxide utilization as a means to improve the sustainability of ready mixed concrete. The outline for the study includes the detail analysis of effects of CO_2 utilized in the production of ready mixed concrete. The parameters of the study include mixing an optimal amount of CO_2 during batching. It was noted that when a three-way comparison was done between the reference batch, reduced binder batch and reduced binder batch with CO_2 addition, as result carbon dioxide allow for approximately 5 to 8% reduction in binder loading without compromising strength.

In the year (2017), S.R.Lingampalli et al studied recent progress in the Photocatalytic reduction of Carbon dioxide. The study involves Semiconductor based photocatalysts and Multicomponent Photocatalysts. It was observed that in the photoreduction of CO_2, CO was the prominent product which further require to be process to generate Methanol or other products.

In the year (2016), Shunjie Liu et al studied about manufacturing of polymers from carbon dioxide: Polycarbonates, Polyurethanes. The outline for the study includes process to form CO_2 based Polyurethanes, Polycarbonates and industrialization process of CO_2 polyols. It was noted that in development of di-nuclear and binary anchored catalyst system, in addition to high catalytic activities, high stereoregularity can achieved for CO_2 appoxides copolymerization. However, some of the system has a toxic metal center and also lengthy synthesis route and thus are not industrially applicable.

In the year (2016), Erdogan Alper et al studied CO_2 utilization: Development in conversion processes. The outline for the study includes processes to convert CO_2 into Urea, Methanol, Salicylic acid, Formaldehyde, Formic acid, cyclic carbonates and copolymers. On the basis of various processes, it was found that being a suitable source of carbon, CO_2 can potentially replace many oil and gases in synthesis applications and also it can replace toxic building blocks like CO and Phosgene in many commercial processes such as Methanol and Polyurethane manufacturing.

In the year (2016), Vaclav Kosie et al studied application of waste ceramic dust as replacement of cement, using experimental approaches. The outline of the study includes mechanical and durability properties of concrete blocks with addition of different dusty wastes. In this study, it was observed that compressive strength of ceramics containing plasters was up to 3 times higher as compared with the cement plaster but it was also noted that the thermal conductivity of ceramic containing plasters was also higher.

In the year (2014), Da-young oh et al studied about CO_2 emissions reduction by reuse of building material waste in the Japanese cement industry. In this study DIBMs (Demolished inorganic building material) and WCP (Waste construction powder) were used in the manufacturing of cement, resulting in various benefits such as substitution of limestone, decreasing the quantity of disposed waste and reduction in CO_2 emissions. This method can also be considered as a recycling method for the cement in the building material waste. It was noted that sharp reduction of CO_2 emissions was approximately about 0.06 million tons to 0.72 million tons from that of 29.4 million tons recorded annual CO_2 from cement production.

In the year (2014), Rosa M.et al studied about carbon capture, storage and utilization technologies. The outline for the study includes a comprehensive comparison of impacts on environment by carbon capture and storage (CCS) and carbon capture and utilization (CCU) technologies. It was noted that according to the CCS studies the global warming potential (GWP) from power plants can be reduced by 63-82%, while for CCU, the GWP varies widely depending upon the utilization.

In the year (2014), Udara S.P.R. et al studied waste heat utilization for CO_2 capture in cement industry. In this study high temperature flue gas from the cement kiln were used to produce steam in waste heat boiler. The parameter for the study includes required surface area for heat exchange, cost of installing the area and payback time of the installation. It was observed that to implement amine-based carbon capture process in the cement industry, heat integration with the cement kiln system by installing a waste heat boiler can be an economical option for the industries.

In the year (2014), Roozbeh Feiz et al studied about improvement of Carbon dioxide performance of cement industry. The study has done in two parts, the first part gives a general structured overview of the options for improvement for the cement industry and the second part of the study provides the information about the feasibility for the different categories of measures that can reduce the CO_2 emissions. It was found that a framework was developed which can be applied and facilitated strategic discussions for decision making, many different measures can be assessed on it and best one can be identified which can be applied in cement industry.

In the year (2014), Mar-Perwez et al studied CO_2 capture and utilization in cement, Iron and steel industries. The outline for the study includes a comparative study of the implementation of CCS, CCU and CCUS technology among Cement, Iron and Steel industries, it can be concluded that in future at large scale it will be feasible to retrofit Carbon capture technologies in these industries.

In the year (2014), Matteo C. Romano et al studied the calcium looping process for low carbon dioxide emission cement plants. The outline of the study includes analysis of the application of the Calcium looping process in cement plants with CO_2 capture. The result shows that the reduction in CO_2 emissions was decreased by 94% in comparison to the plant which lacks CO_2 capture.

In the year (2014), A.A. Aliabdo et al studied Re-use of waste marble dust in production of cement and concrete. The outline for the study includes properties of modified cement with marble dust and properties of concrete contained marble dust as sand replacement. In the study, it was found that the use of marble dust in concrete production gradually increases the mechanical and physical properties of concrete with the lower water/cement ratio.

In the year (2013), Yufei Wang et al studied about CO_2 reduction technologies in China's cement industry on different parameters. On analyzing these technologies, it was found that among these technologies energy efficiency improvements and use of alternative fuels will be some of the best options to reduce the emission from cement industry. Clinker substitution, which is used to reduce clinker-cement ratio and energy intensity, can result in significant cost benefit.

In the year (2013), Amin Tehari et al studied about CO_2 chemical conversion to useful products. The outline for the study includes conversion of CO_2 to carbonaceous fuels, energy constraints and catalytic reduction of CO_2. It was noted that CO_2 can be converted into wide variety of useful products such as fuels to chemical commodities and polymers, with the latest advancements in CO_2 chemical transformation has presented, with the emphasis on the energy constraints, materials and process design.

In the year (2012), F. Gabriel Acien Fernandez et al studied the conversion of CO_2 into biomass by microalgae. The outline for the study includes the efficiency of CO_2 use in microalgae culture, production of biofuels from microalgae, reduction of CO_2 emission by producing commodities. In these studies, it was observed that microalgae can't reduce the emissions of CO_2 because the produced biomass does not offer long term CO_2 storage but it can be used in the improvement of wastewater treatment processes that reduce the energy consumption and allow the reuse of nutrients contained in the waste.

In the year (2012), Emad et al studied a novel design for green and economical cement manufacturing. The outline for the study includes the introduction of a new design of pyro-processing unit in a cement industry. Due to these, the decomposition reactions that produce pure carbon dioxide were separated from other reactions. Without any fuel consumption, decomposition reaction takes place in a calciner by utilizing hot CO_2 stream as heat carrier. It was noted that by this new process 66% of CO_2 emissions can be reduced and also 2.3% energy consumption can be reduced to the already existing processes.

In the year (2012), Young Jic et al studied utilization of waste concrete powder as a substitution material for cement. The outline for the study includes waste concrete powder that was manufactured from high quality recycled aggregate, whose particles were angular similar to cement and had hydrated product attached to them. This powder was mixed with mortar and was analyzed. It was noted that it is desirable to keep WCP (waste concrete powder) replacement below 15% in mortar because higher the level of WCP used, lower the compressive strength becomes.

In the year (2011), Mauricio Naranjo et al studied about CO_2 sequestration from the cement industry. The outline for the study includes development of CO_2 capture and sequestration technologies at commercial scale in U.S. cement plant. It was found that various factors such as lack of proper CO2 capture technology also misfit of the equipment, unreliability in the CO_2 product on transportation and storage regarding the effect of impurities are need improvement to get better results from this technology.

In the year (2011), Christoph Gebald et al studied Amine-based Nano fibrillated cellulose as adsorbent for CO2 capture from air. In this study an amine-based absorbent to capture CO_2 was developed. The Parameter for the study was CO_2 adsorption and CO_2 desorption measurements. It was found that under proper condition cyclic CO_2 absorption can be observed.

In the year (2010), S. Kent Hoekman et al studied about recycling of carbon dioxide by reaction with renewably generated hydrogen to produce Methane. In this study, to determine the most effective operating conditions for the process and to examine the recycling CO_2 in combustion exhaust to methane, a series of experiments was conducted. The experiments covered testing the effects of the reactant gas mixing ratios of H_2 to CO_2, space velocity and the temperature of catalyst. It was noted that approximately 60% conversion of CO_2 can be achieved in the 300-350℃ temperature range.

In the year (2010), J. Blamey studied the calcium looping cycle for large scale CO_2 capture. The outline for the study includes reversible reaction between CaO and CO_2 for removal of CO_2 from power station exhaust and to generate pure stream of CO_2 for geological sequestration. This technology is attracting attention as it has excellent opportunity for integration with cement industry and also for its extremely cheap sorbent crushed limestone. It was found that the sorbent derived from natural limestone decreases its reactivity over a number of cycles of reaction with CO_2. Therefore, a number of different methods to either reduce the rate of decay to reactivity, increase reactivity or to reactivate the sorbent, must be employed to run the process efficiently.

In the year (2009), George A.Olah studied on chemical recycling of carbon dioxide to Methanol and Dim methyl Ether. The outline for the study includes chemical conversion to methanol and Dimethyl ether, Catalytic hydrogenative conversion of CO_2 to methanol and Electrochemical production of Methanol from CO_2 and H_2O. It was observed that the chemical recycling of carbon dioxide to Dimethyl ether and methanol provides a carbon neutral, renewable and inexhaustible source for efficient transportation fuels for strong and transporting energy.

In the year (2009), V.Nikulshina et al studied CO_2 capture from atmospheric air. The parameter of the study includes continuous removal of CO_2 from atmospheric air through Carbonation and Calcination process using concentrated solar energy as the source of high temperature process heat. It was found that the process was highly efficient for the removal of CO_2 from atmospheric air however it is not economical for large scale projects.

In the year (2009), Deborah N. et al studied Carbon dioxide sequestration in cement kiln dust through mineral carbonation. The parameter of the study includes mass change, thermal analysis and X-ray diffraction. In this study carbonation reaction were performed through the reaction of CO_2 with $Ca(OH)_2$. It was found that the reuse of Cement kiln dust for CO_2 sequestration has the potential for meeting future emission reduction goals.

In the year (2009), D.J.Barker studied use of CCS technology in cement plant. The study outlines the various factors, such as technology for CO_2 capture, its cost and its limitations that are to be assessed during the use of any CCS technology in the plant. It was found that the process of oxy combustion is considered to offer the cheapest cost solution in cement plant for capturing CO_2.

In the year (2008), The-vhe Nguyen et al studied Photoreduction of CO_2 to fuels under sunlight using optical fiber reactor. The outline for the study includes gel derived TIO_2-SIO_2 mixed oxide based photocatalysts to reduce CO_2 with H_2O to fuels under sunlight by using a solar concentrator. It was observed that an efficient photoreactor with high photoactivity catalyst is an essential step for commercial scale applications to produce renewable fuels.

In the year (2008), N.Rodriiguez et al studied process for capturing carbon dioxide from the calcinations of $CaCO_3$ used in cement manufacturing. The outline for the study includes the process that was based on the use of hot CaO particles to flow heat from a circulating fluidized bed combustor to a calciner. It was noted that with the use of this process CO_2 emission of a cement plant can be reduce around 60%.

In the year (2007), Kari Skjanes et al studied a multidisciplinary, biological approach using solar energy to capture CO_2 while producing H_2 and high value products. The outline for the study includes the methodology that capture CO_2 in photobioreactors, using microalgae to convert industrially produced CO_2 and solar energy into algae biomass by photosynthesis. It was observed that method was quite efficient but the algae required are obtained by identifying wild type strains with optimal capabilities thus making it less feasible.

In the year (2006), Chritos et al studied the use of construction and demolition wastes as raw materials in cement clinker production. The aim of this study was to investigate the use of construction and demolition wastes as substitute of raw material of Portland cement. In this study, the relativity of generated mixtures was evaluated on the basis of free lime content. The results showed that without affecting negatively the cement clinker properties, recycled aggregates enhanced the burn ability of the cement.

In the year (2003), C.A. Hendriks et al studied emission reduction of greenhouse gases from the cement industry. The outline for the study includes the detailed analysis of cement production process to identify the ways to reduce GHG emissions. It was observed that by some of the ways such as, improving energy efficiency, shifting to more energy efficient process, shifting to lower clinker/cement ratio, shifting to lower carbon fuels, emission of CO_2 can be reduced.

In the year (2002), S.Kaneco et al studied high efficiency electrochemical CO_2 to Methane conversion method using methanol with lithium supporting electrolysis. In this study, for various lithium supporting salts the electrochemical reduction of CO_2 with a Cu electrode in methanol was investigated. As methanol is widely used in industries as CO_2 adsorbent at low temperature. Thus, electrochemical reduction of CO_2 can be widely used to produce fuel, for storage of solar energy and production of intermediate material for petrochemical industry.

In the year (2002), Daniel. J.et al studied carbon sequestration utilizing industrial solid residues. The outline for the study includes reaction of CO_2 with non-carbonated minerals. It was found that the sequestration of non-carbonated materials is comparatively low with other materials, if the industries effectively process such streams, it will lead to cost effective direct aqueous carbonation technology.

In the year (2000), Nuran et al studied the use of waste ceramic tile in cement production. The parameter of the study includes pozzolanic properties of waste tile, setting time, stability, particle size, density, specific surface area and strength of cement after mixing the powder of waste ceramic tile. It was noted that waste tile can be used as pozzolan and up to 35% weight ratio waste tile can be added in cement.

III. CONCLUSIONS

From the literature it has been observed that increase in industrial activities has resulted gradual increase of CO_2 emissions in the atmosphere. The major sector where CO_2 reduction is urgently required is the cement industries. These industries are located near the raw material site's location. In general, nearly 440 grams of CO_2 emissions is observed during the calcinations of 1 kilogram of calcium carbonate. As observed from the literature, alternative methods to convert CO_2 into polymeric products, substitution of the raw material with civil construction waste, conversion of CO_2 into value added products like Ethylene Carbonate, Dimethyl carbonate, Methanol, Urea, Ammonia, Bioplastic, Biofuels and other products like this are possible. Calcium looping technology is one of the promising technologies that can reduce CO_2 emissions from the cement industry nearly by 90%. Some of the technologies are under pilot scale and some are commercialized. Techno economic feasibility is an important part that has to be considered by working in this area. Each technology has got its own limitation and benefits. The future work in this area is related to experimental work and collection of data to reduce CO_2 emissions from the Cement plant sites.

REFERENCES

[1] Ali A Aliabdo, A. E. (2014). Reuse of waste marble dust in the production of cement and concrete.
[2] Andri, N. M. (2021). Environmental impact of cement production and solution.
[3] Azin, R. (2011). Waste heat reuse in cement plant.
[4] C A Hendricks, E. W. (2003). Emission reduction of greenhouse gases from the cement industry.
[5] C.A. Hendriks, E. D. (2003). Emission reduction of Green houyse gases from the cement industry.
[6] Chaofeng liang, B. P. (2019). Utilization of CO_2 curing to enhance the properties of recycled aggregate and prepared concrete.
[7] Christoph Gebald, J. A. (2011). Amine based Nanofibrillated cellulose as Adsorbent for CO_2 capture from air.
[8] Coles, H. K. (2004). The Cement Sustainability Initiative implementing change across a global industry.
[9] D.J. Barker, S. T. (2009). CO_2 capture in the cement industry.
[10] Da-Young Oh, T. N.-j. (2014). CO_2 emission reduction by reuse of building material waste in the Japanese cement industry.
[11] Deborah N. Huntzinger, J. S. (2009). Carbon dioxide sequestration in cement kiln dust through mineral carbonation.
[12] Emad Banhelal, M. I. (2021). Challenges against CO_2 abatement strategies in cement industry.
[13] Emad Benhelal, Z. H. (2012). A novel design for green and economical cement manufacturing.
[14] Enst Worrelll, L. P. (2001). CO_2 emission from the global cement industry.
[15] Erdogan Alper, O. Y. (2016). CO_2 utilization: Developments in conversion processes.
[16] Erdogan Alper, O. Y. (2016). CO_2 Utilization: Developments in Conversion Processes.
[17] Esmaeil Koohestanian, j. S.-K. (2018). A novel process for CO_2 capture from the flue gases to produce urea and ammonia.
[18] F. Gabriel Acien Fernandez, C. G.-L. (2012). Conversion of CO_2 into biomass by microalgae: how realistic a contribution may it be to significant CO_2 removal?
[19] F.N. Costa, D. R. (2020). Reduction in CO_2 Emissions during production of cement, with partial replacement of traditional raw materials by civil construction waste (CCW). ELSEVIER.
[20] G, S. (2009). Opportunities and prospects in the chemical recycling of CO_2 to fuels.
[21] George A. Olah, A. G. (2009). Chemical recycling of carbon dioxide to methanol and dimethyl ether: from GHG to renewable, environmentally carbon neutral fuel and synthetic hydrocarbon.
[22] Howard Klee, E. C. (2004). The cement sustainability initiative.
[23] J.Bamey, E. A. (2010). The calcium looping cycle for large scale CO_2 capture.
[24] Jihoon Kim, S. T. (2018). Theoretical Study on the production of Environment Friendly Recycled Cement using inorganic Construction Wastes as secondary materials in South Korea.
[25] John Kilne, C. K. (2009). CO_2 capture from cement manufacture and reuse in concrete.
[26] Kari Skjanes, P. L. (2007). A multidisciplinary biological approach using solar energy to capture CO_2 while producing H2 and high value product.
[27] Keith, D. W. (2009). Why capture CO_2 from the atmosphere.
[28] Keith, D. W. (2009). Why capture CO_2 from the atmosphere.
[29] M. Sachneider, M. r. (2011). Sustainable cement production present and future.
[30] Mark- Perez -Fortes, J. A. (2014). CO_2 capture and utilization in Cement and iron and steel industries.
[31] Matteo C. Romano, M. S. (2014). The Calcium looping process for low CO_2 emission cement plants.
[32] Mauricio Naranjo, D. T. (2011). CO_2 capture and sequestration in the cement industry.
[33] N. Rodriiguez, M. (2008). Process for capturing CO_2 arising from the calcination of the caco3 used in cement manufacture.
[34] Najafabadi, A. T. (2013). CO_2 chemical conversion to useful chemical products.
[35] Najafabadi, A. T. (2013). CO_2 Chemical conversion to useful products: An engineering insight to the latest advances towards sustainability.
[36] Nuran Ay, M. U. (2000). The use of waste ceramic tile in cement production.
[37] Pawar, A. A. (2019). Greener synthesis of dimethyl carbonate from carbon dioxide and methanol using a tunable ionic liquid catalyst. Open chem, 1252-1265.
[38] Pescarmona, P. P. (2021). Cyclic carbonate synthesised from CO_2: Applications, challenges and recent research trends.

[39] R.Rehan, M. (2005). Carbon dioxide emissions and climate change: Policy implications for the cement industry.
[40] Raw S C, C. A. (2010). Photocatalytic conversion of carbon dioxide to hydrocarbons.
[41] Roozbeh Feiz, J. A. (2014). Improving the CO_2 performance of cement, part II: framework for assessing CO_2 improvement measures in the cement industry.
[42] Rosa M, C. F. (2014). Carbon capture storage and utilization technologies: A critical analysis and comparison of their life cycle environment impacts.
[43] S. Kaneco, K. e. (2002). High efficiency electrochemical CO_2 to methane conversion method using methanol with lithium supporting electrolytes. Ind. Eng.Chem.
[44] S.Kent Hoekman, A. b. (2010). Co2 recycling by reaction with renewably generated hydrogen.
[45] Sampth, U. (2014). Waste heat utilization for CO_2 capture in cement industry.
[46] Sara P.Cueller-Berendex, B. E. (2013). Photosynthetic bio energies utilization $CO_{2:\ an}$ approach on flue gases utilization.
[47] Schneider, M. (2015). Process technology for efficient and sustainable cement production.
[48] Sean Monkman, M. M. (2017). CO_2 utilization as a means to improve the sustainability of ready mixed concrete.
[49] Sergey E. Lyubimov, A. A. (2020). A Simple synthesis of ethylene carbonate from carbon dioxide and 2-chlorothanol using silica gel as a catalyst.
[50] Shunjie Liu, X. W. (2016). Polymers from carbon dioxide: Polycarbonates, Polyurethanes.
[51] T, S. k. (2007). Transformation of carbon dioxide.
[52] The-vinh Nguyen, J. C. (2007). Photo reduction of CO_2 to fuels under sunlight using optical fiber reactor.
[53] Tsimas, C. -T. (2006). use of construction and demolition waste as raw material in cement clinker production.
[54] V.NikulGebald, A. (2009). CO_2 capture from atmospheric air via consecutive carbonation and calcination cycles in fluidized bed solar reactor.
[55] Vaclav Koci, J. M. (2016). Application of waste ceramic dust as a ready to use replacement of cement in lime - cement plasters: an environment-friendly and energy efficient solution.
[56] Young Jic Kim, Y. W. (2012). Utilization of waste concrete powder as a substitution material for cement.
[57] Yufei Wang, S. H. (2013). Integrated assessment of CO_2 reduction technologies in China's cement industry.
[58] Zhu, Q. (2019). Developments on CO_2 utiilization technologies.

